The Impact of Social Expectations towards Robots on Human-Robot Interactions

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Abstract

This work is presented in defence of the thesis that it is possible to measure the social expectations and perceptions that humans have of robots in an explicit and succinct manner, and these measures are related to how humans interact with, and evaluate, these robots.

There are many ways of understanding how humans may respond to, or reason about, robots as social actors, but the approach that was adopted within this body of work was one which focused on interaction-specific expectations, rather than expectations regarding the true nature of the robot. These expectations were investigated using a questionnaire-based tool, the University of Hertfordshire Social Roles Questionnaire, which was developed as part of the work presented in this thesis and tested on a sample of 400 visitors to an exhibition in the Science Gallery in Dublin. This study suggested that responses to this questionnaire loaded on two main dimensions, one which related to the degree of social equality the participants expected the interactions with the robots to have, and the other was related to the degree of control they expected to exert upon the robots within the interaction. A single item, related to pet-like interactions, loaded on both and was considered a separate, third dimension.

This questionnaire was deployed as part of a proxemics study, which found that the degree to which participants accepted particular proxemic

behaviours was correlated with initial social expectations of the robot. If participants expected the robot to be more of a social equal, then the participants preferred the robot to approach from the front, while participants who viewed the robot more as a tool preferred it to approach from a less obtrusive angle.

The questionnaire was also deployed in two long-term studies. In the first study, which involved one interaction a week over a period of two months, participant social expectations of the robots prior to the beginning of the study, not only impacted how participants evaluated open-ended interactions with the robots throughout the two-month period, but also how they collaborated with the robots in task-oriented interactions as well. In the second study, participants interacted with the robots twice a week over a period of 6 weeks. This study replicated the findings of the previous study, in that initial expectations impacted evaluations of interactions throughout the long-term study. In addition, this study used the questionnaire to measure post-interaction perceptions of the robots in terms of social expectations. The results from these suggest that while initial social expectations of robots impact how participants evaluate the robots in terms of interactional outcomes, social perceptions of robots are more closely related to the social/affective experience of the interaction.

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Chapter 1

Introduction

1.1 What are robots? - Where do they come from?

To start with these questions might seem flippant, trivial, or strange, considering the topic of this thesis, and the background of the likely reader. If one is to ask an undergraduate fresh out of an exam in an introductory course on AI & Robotics, the answer might have been taken from Mataric (2007) and answer that it is a *...is an autonomous system which exists in the physical world, can sense its environment, and can act on it to achieve some goals* (ibid, p.2). This might be qualified with a historical overview of robots as programmable machines capable of performing sequences of tasks, and of current advances in teleoperation, if the student is particularly forthcoming. Despite this textbook answer, however, the answer is not as clear-cut. In the BBC2 popular science show James May's Big Ideas (Walker and Paterson, 2008), the presenter travels the globe in a search for the robot promised him in the science fiction of his childhood. While he comes across many different robots, it is clear that, to the presenter, at least, a robot is a humanoid machine. This suggests that, to many, the definition of robot would be a *'human-like machine'*, while this is not necessarily as correct, it is very much in line with many of the cultural ideas of robots that Kaplan (2004) raises. This suggests that a thesis that examines perceptions of robots, requires a certain flexibility in its definition of what a robot is. In fact, I will go so far as to suggest that that a strict definition of the term 'robot' is beyond this thesis, and I will half-jokingly misquote Gombrich (1995) comment on art and say that... 'There is no such thing as *robots*. There are only *roboticists*' (qv. Ibid p 15). Throughout this thesis, the term 'robot' will be used loosely to describe what engineers, scientists, journalists, science fiction writers and the general public call robots. If someone calls something a robot, I am happy to consider it one, at least until someone else can provide a compelling argument as to why it is not.

With that out of the way, I would like to move on to answer the second part of the question, which is about the origin of these robots. As I have already nailed my colours to my mast by defining robots as anything described as a robot, I don't think it is unreasonable to consider the origin of word 'robot' as well as the robots themselves.

The word 'robot' famously comes from the Karel Čapek play 'Rossum's Universal Robots' (Čapek et al., 1923), a play that explores class relations in 1920s central Europe. This suggests that robots, or at least, our initial conception of them, come from fiction. In Čapek's work, the initial tension lies between the great utility of using the robots as appliances, and the possible need to be treating them as social equals. The failure to resolve this tension is what leads to the ultimate downfall of humanity, as the robots rise up to destroy those who have enslaved them. The final resolution in the play comes with the last human endowing the final robots with full human value. This 'robot uprising' is a theme that is continued in many fictional narratives that have been created about robots (Syrdal et al., 2011b), and are often caused by humans not acknowledging their social obligations to their robotic servants, instead seeing them only as machines that can act as tools [1].

A reaction to this approach to fictional robots can be found in the work of Isaac Asimov. Asimov (1968) proposes a technological solution to this tension. Rather than raising robots up to the level of their human creators, humans could prevent the possible dangers presented by these complex machines by asserting their control over them. Asimov's three laws of robotics are the most well-known instruments of control from this branch of fiction.

While all technologies are, to some extent, fictions before their realisation, technological developments of the machines that became known as robots were particularly influenced by the works of Science Fiction that preceded them. George Monsun, one of the creators of Unimate, the first industrial robot, explicitly refers to the Isaac Asimov's books about robots as an important inspiration for the development of this system (Ballard et al., 2012).

The tension that is in the foreground in both Čapek and Asimov, still exists in social robotics today. These tensions between the human and the mechanical, equality and control, and between revolution and reaction, still exist in the narratives surrounding depiction of robots today and how we feel about autonomous technologies in our daily lives, and how we expect to interact with them.

The work presented in this thesis stems from an interest in exploring these tensions, and seeing how these high-level concepts may be relevant to the interactions that I have seen between humans and robots in the studies

[1] As examples of this consider the success of the movie franchise *Terminator*, *Matrix* and *I, Robot*, as well as the hugely popular TV-series *Battlestar Galactica*.

that I have done.

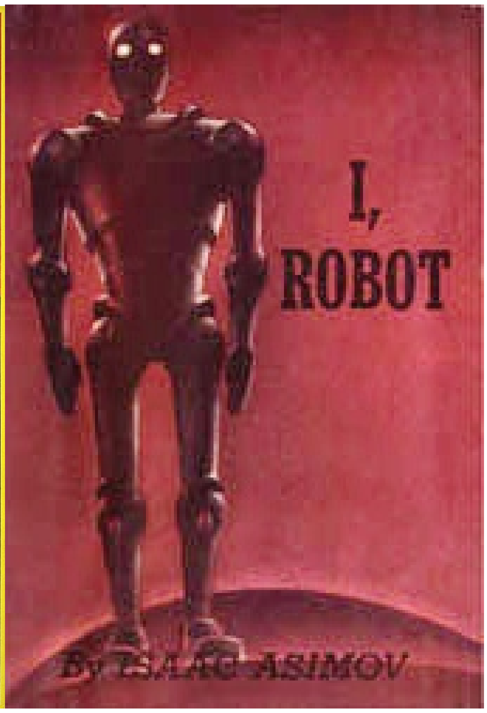
1.2 Human-Robot Interaction - A Moving Target

The commonsensical view of what a robot is, or should be, that you may encounter when discussing robots with colleagues, students or the general public, is often cemented. Despite this, any research into human responses to, and interactions with robots are, essentially, studies of moving targets. The first results I published in defense of this thesis were published in 2006, and needless to say, developments in technology relevant for human-robot interaction have been dramatic in the intervening years. These developments have been constantly instantiated in robots, both research prototypes as well as products intended for public use. These robots span a wide range of possible uses, appearances and capabilities, and sometimes one wonders if they have anything in common, except for the word 'robot' being used to describe them. In addition, while new robots have appeared, others have stopped being produced, meaning that research conducted on them can no longer be directly applied to them. The response of a researcher in the field, as Dautenhahn (2007a) argues, needs to be one of reasoned pragmatism, focusing on the requirements and constraints of the specific research project that they are working on. Robots are artificial, they are by their very nature created for a reason, and the case could be made that research into human interactions with robots should have ensuring that these robots are better able to fulfill their purpose as their main, and possibly only, focus.

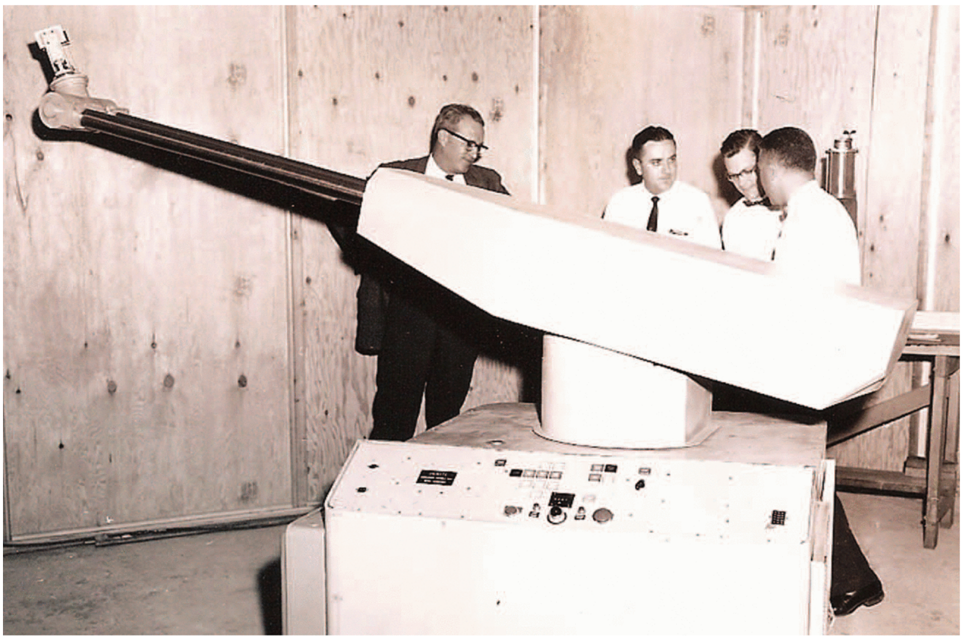
Despite this, there is a need to allow for research involving different platforms and interactions to be related to one another. In order to do this, it is necessary to adopt approaches that allow for generalisations across different research projects. There are many ways to address this. One way

Figure 1.1: Revolution, Reaction and Realisation.

(a) RUR Poster, New York 1939



(b) I, Robot, Front Cover



(c) Unimate

is through the standardisation of methodology across interaction contexts (Bethel and Murphy, 2010). While another is to develop standardised measures of responses to specific robotic platforms that can then be used to compare robots to one another (Bartneck et al., 2009b; Ho and MacDorman, 2010)[2]. The work presented in this thesis can be considered to be part of this tradition, where the aim is to investigate facets of human-robot interactions that are independent of specific interactions and platforms. In particular, my aim is to investigate whether or not social expectations and perceptions of robots are related to how participants interact with robots, and subsequently evaluate their interactions with them.

1.3 Thesis

Building on some of these general issues in human-robot interactions, and acknowledging the tension between the imagined equal partner and the imagined controlled servant, that is seen in the narratives surrounding the creation of autonomous technologies, my interest lies in how exploring this issue can be used to understand human interactions with robots across different contexts and platforms.

The thesis that this work seeks to advance is as follows: *It is possible to measure the social expectations and perceptions that humans have of robots in an explicit and succinct manner, and these measures are related to how humans interact with, and evaluate, these robots.*

To advance this thesis, it became necessary to create a questionnaire measure for such perceptions and expectations, which could easily be deployed in studies involving human-robot interactions. Examining relationships between this measure and other aspects of the interactions would then

[2] These and other considerations will be discussed in greater detail in Chapter 2

allow for the assessment of the impact of such social perceptions and expectations.

1.3.1 Research Questions — Social Expectations of Robots

In its widest sense, when I use the term *'Social Expectations'*, I refer to the phenomenon described by writers in several fields in which humans respond to non-human entities or artefacts in a manner similar to how they would respond to a human being in a similar situation. It has been described variously as an anthropomorphic fallacy in ethology (Mitchell et al., 1997), the 'Media Equation' by Reeves and Nass (1996), a 'reversed' dehumanisation process by Eyssel et al. (2010), the outcome of active mental models by Kiesler and Goetz (2002), or a sophisticated process of joint pretense (Clark, 1999). I will discuss these approaches in more detail in Chapter 2, but I will note here that while they differ in terms of the processes and mechanisms they posit as the cause of these responses, they do agree that these responses are *measurable* and are impacted by both the behaviour and appearance of the entity/artefact in question, thus allowing a researcher to quantify the degree of social expectations and relate it to its antecedents as well as its behavioural outcomes.

Research Question 1 — Measuring Social Expectations

To some extent, the measurement of social expectations are tied to the theoretical approach of the researchers attempting the measurement. For example, Eyssel et al. (2010)'s 'psychological anthropomorphism' applies the psychological processes that is proposed for understanding intergroup relations in human (where out-group individuals are seen as less humans), and applies them to robots. Thus, measures arising from this approach measures to what extent a robot belongs to the in-group of humanity. Reeves and Nass (1996) posit the response as almost completely non-voluntary and as such the measures used depend on specific experimental paradigms intended to show particular responses. Kiesler and Goetz (2002)'s mental model approach assume that these responses are explicitable, i.e. they can be made conscious, and as such use direct questions about beliefs about the robot as their measures.

There are, of course, other measures that take into account social expectations, but are not wedded to a specific theoretical approach. Bartneck et al. (2009b)'s Godspeed Questionnaire, was explicitly divorced from such theories and relied primarily on empirical findings regarding responses to its constituent parts. In light of its comparable popularity (Weiss and Bartneck, 2015), this approach seemed to have suited the more pragmatic field of human-robot interaction.

This pragmatic approach is also one that will be taken in the work described in this thesis. While informed by the theoretical discussions on what the processes and mechanisms of social responses to robots arrive from and entail, it is not an attempt at resolving this discussion. Rather, my interest lies in an easy and reliable measure of social responses that can be applied to a wide range of platforms and contexts that can be related to one another. This *does* mean that the measurements from certain approaches are not applicable. As I will discuss in Chapter 2, the Media Equation body of work relies on specific paradigms and as such cannot be used, the joint pretense approach Clark (1999) is deeply rooted in verbal interaction, which limits its usefulness for non-verbal interactions, and the dehumanisation approach relies strongly on inferences as to the 'true nature' of the robot made by the participant.

While a detailed discussion and description of my considerations in the development of such a questionnaire-based measure will follow in Chapter 3, I will briefly outline my approach to address this issue. The approach taken is one of reasoned pragmatism where I aim to measure social expectations in a manner that is not only meaningful in terms of it being a valid measure, but can also be used to explain and possibly predict interactional outcomes in human-robot interactions. This also entails that it should be brief enough to be used in different situations without being too intrusive.

The work detailed in this thesis attempts to sidestep the questions raised by the different approaches outlined above by focusing on the expectations a human interactant would have of an interaction of a robot rather than the nature the of robot itself. While this may be a subtle distinction, it allows for a focus on practical, empirical outcomes within HRI studies that prototype interactions with future and emergent technologies. I will also consider whether or not social expectations can be be measured as a unidimensional construct, or if it is multidimensional. Will a robot inhabit a general anthropomorphic social role in an interaction, or can it be one of a set of specific roles? If a human interactant has a strong anthropomorphic social expectation from a given robot, does it matter if the robot is considered to be a butler or a surgeon?

These particular questions will be addressed primarily in Chapter 3.

Research Question 2 — Relating Measures of Social Expectations to Interactional Outcomes

As one of my stated aims for measuring social expectations is that they should be able to explain interactional outcomes, an important part of the work described in this thesis is to apply the measures developed to HRI studies. This work is part of the wider work at the University of Hertfordshire Robot House (Duque et al., 2013), which focuses on the future development of domestic companion robots (Dautenhahn, 2004). Within this general topic, the role of social expectations were explored in the following types of interactions:

1. Proxemics
2. Task-Collaboration
3. Open-ended Interactions

Proxemics is a topic of some importance in the field of HRI (Greenberg et al., 2011). The main difference between robots and other appliances in human-centred environments is their ability move autonomously in the same space as humans. This means that exploring what behaviour is expected of robots in different situations is quite pertinent (Huttenrauch and Severinson Eklundh, 2002). For humans, social relations are considered to be important in terms of how we move, both in terms of relative distances (Hall and Hall, 1969), as well as in terms of relative facing (Kendon, 1990). This makes proxemics an important phenomenon to relate a measure of social expectations to. The relationship between my measures of social expectations and proxemics will be addressed in Chapter 4, in a set of studies on human-robot proxemics in domestic environments.

Task-Collaboration is another issue in which social expectations is likely to play a role. Fiore et al. (2011) suggest that understanding social relations and perceptions between the human and robot interactant is an important research issue facing research on human-robot teams. Chapter 5 describes my attempts at relating participant social expectations of a robot to the outcomes of two human-robot collaborative tasks.

Open-ended Interactions and the evaluations of these are important when studying companion robots. Dautenhahn (2007b) argues that a companion robot needs to not only be able to perform useful tasks, but to do them in a *socially acceptable manner*. It is not unreasonable to expect that how a person expects a companion robot to behave has social origin. While certain aspects of such interactions such as task-collaboration and proxemics can be studied separately, it is also necessary to consider possible interactions with a companion robot in a more holistic manner. In Chapter 5 and Chapter 6, I will examine how social expectations of robots impacted how participants evaluate robot behaviour within open-ended interactions with a companion robot.

1.4 Context of the Work

The work described in this thesis has been conducted as part of the The majority of this work has been conducted within three EU projects:

- Cogniron — The Cognitive Robot Companion
- LIREC — LIving with Robots and intEractive Companions.
- ACCOMPANY — ACceptable COMPanions for AgeiNg Years

The majority of the work presented in this thesis was conducted within Cogniron and LIREC, with some exploratory work having been conducted within ACCOMPANY.

Cogniron

The goal of the Cogniron project was to ‘ *...to study the perceptual, representational, reasoning and learning capabilities of embodied robots in human centred environments. The project develops methods and technologies for the construction of such cognitive robots, able to evolve and grow their capacities in close interaction with humans in an open-ended fashion....*’[3]. The work from this project described in this thesis focus on the use of human personality traits as a means of measuring social expectations of robots as well as the initial use of proxemics as a test-bed for the role of social expectations of robots.

LIREC

The LIREC[4] project aimed to develop digital companions that would be capable of long-term relationships with humans. The work from LIREC described in this thesis is primarily from work surrounding the University of Hertfordshire's Home Robot Companion showcase scenario and focused on social role expectations and how these interact with proxemic preferences. In addition, the work in the UH Showcase also involved long-term studies of Human-Robot Interaction, which were used to explore how measures may of social expectations interacted with preferences and evaluations of robot behaviours over time.

ACCOMPANY

The ACCOMPANY[5] project was a more application focused project which aimed to develop technologies that would be of use for older people care. The

[3] http://www.cogniron.org/final/Home.php
[4] http://lirec.eu/project
[5] http://rehabilitationrobotics.net/cms2/node/6

work from ACCOMPANY presented in this thesis involved are exploratory and examine how participants' social role expectations impacted their attitudes to the robots and their tasks within this domain.

1.4.1 Publications related to this thesis and The Role of The Researcher

Human-Robot Interaction is a highly multidisciplinary field, and because of this, none of the research described in this thesis would be possible to perform by a single researcher, working on their own. Because of this, there is a need to go through the list of publications that are

Secondary Analysis Work

These publications are secondary analyses, in which I worked on results from experiments performed by other researchers in the research lab. These experiments were aimed at creating baselines for appropriate robot behaviour and design, while my secondary analysis was aimed at investigating underlying variables that might explain particular results or allow for more general conclusions beyond the immediate context of the given experiment.

> Syrdal, D. S., Dautenhahn, K., Woods, S., Walters, M. L., and Koay, K. L. (2006). 'Doing the right thing wrong' - Personality and tolerance to uncomfortable robot approaches. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 183–188. IEEE

This was a secondary analysis of an early proxemics study, which related human personality to evaluations of the less socially appropriate proxemic behaviour. While this analysis built on earlier result, the theoretical approach, analysis and conclusions were conducted independently.

Walters, M. L., Syrdal, D. S., Dautenhahn, K., Te Boekhorst, R., and Koay, K. L. (2008). Avoiding the uncanny valley: robot appearance, personality and consistency of behavior in an attention-seeking home scenario for a robot companion. *Autonomous Robots*, 24(2):159–178

The above publication was a collaboration with Dr. Michael Walters, whose doctoral research focused on the design space of social robots, and who had developed a set of robot appearances in order to study human reactions to them. My contribution to this paper was an analysis of human responses to the video made by Dr. Walters and other members of the ASRG, focussing on the explanatory power of individual differences in the human participants when assessing their preferences in terms of degree of anthropomorphism in robot design, and on how participants perceived the robot in terms of anthropomorphic personality traits.

Collaborative Empirical Work

These publications detail work in which I have collaborated with other members of the ASRG, and those of our EU partners in terms of planning, running and analysing human-robot interaction studies. Due to the overarching requirements of the projects that they have been conducted within, aspects of them were sometimes beyond my control, however, the focus on individual differences, and measurements of the robots in terms of social perceptions and expectations were introduced due to my interest. In the running of these studies, I would be responsible for briefing participants, developing and deploying questionnaires and interview schedules, as well as the subsequent statistical or qualitative analysis of results.

Syrdal, D. S., Dautenhahn, K., Walters, M. L., and Koay, K. L. (2008a). Sharing spaces with robots in a home scenario—Anthropomorphic attributions and their effect on proxemic expectations and evaluations in a live HRI trial. In *Proc. AAAI Fall 2008 Symposium: AI in Eldercare: New Solutions to Old Problems*, pages 7–9

This study was similar to Syrdal et al. (2006) in that the general interest was to establish further baselines for proxemic preferences in HRI. My personal work focused on individual differences and anthropomorphic perceptions of the robot, and their relation to proxemics.

Syrdal, D. S., Dautenhahn, K., Koay, K. L., Walters, M. L., and Otero, N. (2010a). Exploring human mental models of robots through explicitation interviews. In *Proceedings of the 19th IEEE International Symposium in Robot and Human Interactive Communication (RO-MAN 2010)*, pages 638–645. IEEE

The purpose of the study from which this publication was taken was to develop a questionnaire for which to explore similarities between perceptions of domestic robots and pets. For this purpose, two videos were developed by researchers at UH and one of our EU partners. This publication, however, details a more in-depth exploration of how the participants' individual experiences formed the basis for their evaluation of the robot, based on a secondary analysis that was performed by me.

Koay, K. L., Syrdal, D. S., Ashgari-Oskoei, M., Walters, M. L., and Dautenhahn, K. (2014). Social roles and baseline proxemic preferences for a domestic service robot. *International Journal of Social Robotics*, 6(4):469–488

This publication details two studies. The first is a survey-based study which was conducted in conjunction with an art installation in the Science Gallery in Dublin. While I was not involved the art installation itself, I designed an implemented the questionnaire on a computer terminal for visitors to use. The second part is a proxemic study which was conducted with Dr. Kheng Lee Koay and Dr. Mohammadreza Ashgari-Oskoei. In this study, I was part of the team designing the overall study, and handled all the measurements that were taken from the participants. I was also responsible for the analysis of results presented in the above paper, and the research question centered around the social expectations were based on my particular research interest. In addition, I handled the final collation and editing of the paper itself.

> Syrdal, D. S., Dautenhahn, K., Koay, K. L., and Ho, W. C. (2014). Views from within a narrative: Evaluating long-term human–robot interaction in a naturalistic environment using open-ended scenarios. *Cognitive Computation*, 6(4):741–759
>
> Syrdal, D. S., Dautenhahn, K., Koay, K. L., and Ho, W. C. (2015). Integrating Constrained Experiments in Long-term Human-Robot Interaction using Task-and Scenario-based Prototyping. *The Information Society*, 31(3)

The work leading to these two publications exemplifies the multidisciplinary nature of human-robot interaction beautifully. The planning, preparation, execution and analysis of this study, was set of iterative processes in which human-centric and technological concerns where addressed in repeated discussions and implementations. While the initial approach was suggested by me, the final methodology and scope of the study was arrived at by the entire LIREC team at UH. Within the studies, my particular role was to design and deploy questionnaires and interview schedules, as well as to analyse responses to these.

> Syrdal, D. S., Dautenhahn, K., Koay, K. L., Walters, M. L., and Ho, W. C. (2013a). Sharing spaces, sharing lives–the impact of robot mobility on user perception of a home companion robot. In *Proceedings of the 5th International Conference on Social Robotics, ICSR 2013, 27-29 October 2013, Bristol, 8239 LNAI*, pages 321–330. Springer

The above paper only reports on a fraction of the work that was performed in this particular study, which is described in greater detail in Chapter 6. This study involved a sophistication of the approach to the previous study, and my colleague and supervisor Dr. Kheng Lee Koay deserves most of the credit for the methodological improvements that were achieved, although the full implementation in a coherent study was a team effort. In terms of study design, my particular interest was in how to measure social perceptions of the robots across the study. As before, I handled the questionnaires and analysis.

1.5 Structure of The Thesis

This thesis will have 6 chapters (in addition to this brief introduction):

- **Chapter 2 — Related Literature** will take a look at how other researchers have addressed the social aspects of robots and attempt to justify the approach taken in this thesis.
- **Chapter 3 — Measuring Social Expectations** will describe two

questionnaire-based approaches used to measure social expectations of robots, one based on existing questionnaires intended for the measurement of human, and another one developed as part of this PhD work. It will also describe empirical studies aiming to explore correlations of responses to these measures in an attempt to gauge the validity of these approaches.

- **Chapter 4 — Proxemics** describe a set of empirical studies aimed at exploring how social expectations impact proxemic preferences in Human-Robot Interactions.

- **Chapter 5 — Initial Social Expectations and Long-term Interactions** describe an empirical study in which the relationship in which prior social expectations were related to evaluations of robot behaviour within both constrained task-based interactions as well as, more open-ended interactions appropriate for a home robot companion.

- **Chapter 6 — Changing Social Expectations in Long-term Interactions** describe an empirical study where both prior social expectations were related to evaluations of robot behaviour within a long-term, open-ended interaction with a robot home companion, and how these were related to changes in perceptions of robots in terms of social expectations.

- **Chapter 7 — Summary and Conclusions** contains a brief summary of the main findings of the preceding chapters, and discuss the results as a whole.

Chapter 2

Related Literature

Chapter Overview

2.1 Human – Robot Interaction

As mentioned in last chapter, the work described in this thesis is situated within the field of Human-Robot Interaction (HRI). Murphy et al. (2010) defines human-robot interaction as a field focused on the '*..design, understanding and evaluation of robotic systems which involve human and robots interacting through communication.*'(ibid, p.85). It is a field in which field trials of Unmanned Search and Rescue Vehicles (Goodrich et al., 2009; Murphy, 2004) are discussed alongside operations of of semi-autonomous, adaptive wheel-chairs, (Andonova, 2006; Carlson and Demiris, 2012) and emotional relationships with pet-like robots (Friedman et al., 2003; Turkle et al., 2006). In addition, interactions between human and robots is examined from a wide range of perspectives, including Psychology (Bartneck et al., 2009b; Powers et al., 2003), Sociology (Weiss et al., 2010), Anthropology (Mutlu and Forlizzi, 2008) Linguistics (Fischer et al., 2011; Skubic et al., 2004), Design (Fernaeus et al., 2010) and Engineering (Parlitz et al., 2008). This research uses a wide range of methodologies, including, but not limited to constrained experiments (Salem et al., 2013), prototype evaluations (Bartneck and Hu, 2004; Syrdal et al., 2014), surveys (Nomura et al., 2012; Sung et al., 2008), and ethnography (Fernaeus et al., 2010; Mutlu and Forlizzi, 2008).

This diversity makes HRI a dynamic, multidisciplinary field that is able to explore the use of robots in a variety of settings from many different angles. It also makes it a field in which a researcher is exposed to the insights and contributions of a multitude of research traditions. This meeting of disciplines is possibly one of the most exciting parts of working in this field. However, this diversity in terms of topics, methodologies and perspectives can sometimes make it difficult to relate studies from one research group to those of others. In addition, robotic research platforms are often unique, expensive, customised and reliant on very specific sets of expertise in their operation, which means that each platform may only be used by a few research groups, which serves only to aggravate this issue (Dautenhahn, 2007a).

2.1.1 Addressing Diversity

These difficulties of generalisability and replicability are continuously being addressed in the field. To address the issue of replicability Bennett and Sabanovic (2013) suggest that the creation of inexpensive, standardised replicable robot platforms for testing of specific HRI topics is a way of allowing researchers to examine general effects in HRI across different research groups without needing to take into account platform-specific effects. Sets of tools and libraries like ROS (Robot Operating System) (Quigley et al.,

2009) allow for sharing of software across different research groups, which allows for sharing of code for specific robot behaviours . In addition, relatively inexpensive research platforms like the NAO robot[1] as well as the use of off-the-shelf consumer electronics like the Pleo[2] and AIBO[3] robots also allow researchers across different groups to directly compare results. However, as large swathes of the field of HRI is in support of the development and application of a given specific robot platform, and for this, platform specific effects may be far more important than general ones.

Bethel and Murphy (2010) suggests that this variability is also caused by differences in approaches to research methodologies, and that lack of rigour in the design, execution, analysis and reporting of HRI research may be responsible for findings that cannot be replicated. This can be mitigated by rigorous adherence to research methodologies from other human sciences, and by adopting best-practice approaches from, in particular, experimental psychology. While it is difficult to argue against rigorous methodology, it is important to note that this approach can be quite reductionist. Studies using this approach have and will yield interesting and valid findings, but it also requires a degree of control which may not always be suitable for studies intended to be holistic evaluations of robot applications in naturalistic environments.

In addition, there has also been a movement towards the adoption of common metrics and measurements in the field. One example of this, is the creation of Human-Robot specific standardised scales such as the Negative Attitudes towards Robots Scale (NARS) (Nomura et al., 2006), and the Godspeed Questionnaire (Bartneck et al. (2009b)), however, these are

[1]Produced by Aldebaran Robotics
[2]Pleo is produced by the Innovo Labs Corporation
[3]AIBO was produced by the Sony Corporation

intended to measure specific aspects of an interaction, and so by their very nature will only address the specific questions that the developers of the questionnaire had an interest in, and as Ho and MacDorman (2010) points out in regard to the Godspeed questionnaire, may also reflect the prejudice of the field of the instruments' creator. This may limit the applicability of these instruments to members of other disciplines as they relate to concepts and constructs relevant only to the creator's specific discipline[4]. This suggests that even though measurements may be valid on its own terms, they lack applicability across subfields in HRI, in particular when it comes to measuring practical outcomes. This suggests that metrics need to focus on higher-level concepts that can apply across specific interactions and robots, and that these need to be relatively focused on interactional outcomes.

The approach used in this thesis to understand and explain human behaviour in human-robot interaction is focused on the user, and focuses on the *expectations* that the user has of an interaction with a robot. It seeks to explore how these expectations can be measured before, during and after interactions, how they may impact an interaction, how they change because of the interaction, and how they influence how users evaluate the interactions in hindsight.

2.2 Expectations in HRI

Any technological artefact is designed with a set of expectations regarding how future users of the technology will use it. These expectations may be based on different considerations, it may suffer a breakdown if certain expectations are not met (Diesel in a petrol engine, empty cells in a spreadsheet

[4]In fact, Bartneck et al. (2009b) (p.72) highlights this particular problem when discussing Kiesler and Goetz (2002) as they allude to the 'vagueness' of discipline-specific language in this particular paper

leading to divide-by-zero errors, QWERTY-keyboards preventing damage to the typewriter, etc.), or the designers may have studied the work flow that the technology is being inserted into so their expectations are based on their perceptions of existing user behaviours, which leads them to try to fit the use of the technologies into existing expectations for the task in which the technology is used. However as the example in figure 2.1 highlights, this is not always as straightforward as one would hope.

Norman (1999) refers to these expectations as *constraints*, i.e. features of the task and the artefact that constrain the behaviour of the user into behaviours that will allow the artefact to perform its functions. These constraints can be physical (i.e. the system does not allow the user behaviours outside of this constraint) as well as cultural (i.e. the system relies on existing cultural norms to guide the user to an appropriate behaviour). Norman (2002) point out the danger of misinterpreting, or being imprecise with cultural constraints. From this point of view, the problem shown in figure 2.1, is one of misinterpreting cultural constraints (by not being specific as to *which* culture one adopted the constraints from) and having a physical constraint that prevents the user from rectifying one's mistakes. What should be noted here is that while physical constraints are purely a matter of design and product-testing, cultural constraints are an empirical matter. In order to gain insight into what cultural constraints are for a given artefact in a given interaction with a given user-group, one must examine this empirically (Norman, 1999, p. 41), through prototyping, surveys, observations or experiments.

In Human-Robot Interaction, in particular in the subfields which deal with interactions with autonomous robots, there is a tendency, explicitly or not, to use cultural constraints from social human-human interactions in order to promote interactions with created artefacts and inform the design of social robots. Fong et al. (2003) argue that robots being socially interactive can be used in different application domains which require social/human-like interaction capabilities, such as persuasive technologies, guide-robots, conversational partners, etc., and highlight a set of challenges that need to be met in order for social robots to be able to perform such tasks. Bartneck and Forlizzi (2004) echo this view, suggesting that robots should '*mimic human social norms, and... provide a consistent set of behaviour*'. Złotowski et al. (2015) notes the benefits of adopting human-like behaviours, interaction modalities and appearances in social robots, but also concedes that such efforts are not necessarily straightforward.

The problem when implementing such a suggestion is, however, two-pronged: There is the technical problem (Fong et al., 2003, section 2):*How does one implement and robustly mimic human behaviour?* There is, however, an equally important problem: *What are the human social norms in the given situation?* As noted by Norman (2002), social situation operate with narrow and specific cultural constraints. There are small margins between appropriate and inappropriate social behaviour, and in the case of artefacts designed to look human-like, the margins are also small for appearance as well. The 'Uncanny Valley' effect (Mori, 1970) is an oft-cited example of the consequences of straying slightly outside the margins of human appearance. Moore (2012) suggest that this is caused by perceptual tension at category boundaries, which in turn would lead to similar phenomena in interactions which rely on narrow cultural constraints. In terms of robot appearance, Dautenhahn (2002) goes as far as suggesting that human-like elements, not just in terms of physical appearance, but also communication modalities (like text-to-speech), should be avoided unless the system is capable of interaction modalities that closely matches that of natural human interactions.

Bartneck et al. (2009a), however, suggest that the challenge can be met with a rigorous approach to both studying the human qualities that one want to create, and when implementing them on a robotic platform.

In order to do this, however, we need to be able to investigate how human interactants perceive, interact with, and evaluate robots in terms of anthropomorphic expectations.

The next section will give a brief outline of the main relevant strands of research in Human-Machine Interaction that try to address this, tying notions of anthropomorphism in with research in HCI/HRI.

2.3 Social Expectations, Anthropomorphism and the Social Robot

I defined the concept of social Social Expectations very loosely in section 1.3.1, in order to disentangle it from the more loaded term of *Anthropomorphism.* However based on the work discussed in section 2.2, the concept of anthropomorphism remains a crucial related concept, and clearly, much of the thought and research surrounding this concept is relevant to the work in this thesis.

2.3.1 Introducing Anthropomorphism

Anthropomorphism, or the assignment of human characteristics to a non-human object/entity, is a major theme in human-robot interaction. Prior to its inclusion in studies of human–machine interactions, this phenomenon was primarily an issue in the field of ethology, where the assignment of human-

Figure 2.1: Example: The Dreaded coffee machines in UH

The coffee machines that are being used by Food Hertfordshire which operates the canteens across the University of Hertfordshire provide an excellent example, when there is a mismatch between the assumed behaviour that the designer of a technology has, and the expectations arising from the process which the technology is intended to be situated in.

Normally, when one is considering buying a hot beverage, the first thing one decide on is which drink one would like. Then there are often a host of other decisions, such as the size of the drink, whether or not one would like some milk or sugar in it, etc. If you were to create sequential diagram of someone's decision making process, it would likely look like this:

Drink? → What Drink? → How Big?

However, this is *not* the way that the designers of the interface of these coffee-machines want the user's decision-making process to work. The way that the interface is designed, the user needs to first specify the size of the drink and whether or not they want cream or sugar, *before* they decide what drink they want.

Drink? → How big? → What Drink?

This mismatch has caused some problems. In the first few weeks after they had been installed, one could usually find a small sea of large cups with a small amount of coffee in them, left behind by people who had been caught out by this issue, and Food Hertfordshire decided to remedy this by *explicitly* telling the user what they should be doing, countering their prior expectations.

This conflict between expectations by the system, and the expectations of prospective users, is likely caused by the designers relying on professional staff in cafés, where all the information is provided to the server *before* the operation starts and the first decision made in *their* work flow is to pick up a cup of a given size.

This small mismatch in work flows between the different user-groups lead to wasted cups and the need to put explicit instructions on the machines.

like motives and cognition to animals sometimes occur when describing or explaining animal behaviour. While this phenomenon can be viewed as a fallacy which obscures the underlying processes from which the behaviour emerges (Davis, 1997), it can also be viewed as a useful heuristic when describing and discussing behaviours in terms that are easily understood by a wider audience (Asquith, 1997). While anthropomorphism is a less controversial topic in the field of HRI, a similar tension does exist to a certain degree here as well.

2.3.2 Ethology

Ethology, the study of animal behaviours, is (prior to HRI, at least) the field where concerns and thoughts about anthropomorphism are the most pertinent.

As a field, ethology has had conflicted approaches to anthropomorphism. Mitchell (1997), points out that in the literature related to the concept, there are at least two subtypes of anthropomorphism that are discussed, sometimes without the author of the relevant work explicitly stating what definition they are working from. The most commonly referenced is that of '*inaccurate anthropomorphism*', which is incorrectly describing non-human entities as if they had human characteristics. This stance on anthropomorphism is commonly used in order to guard against the tendency of researchers into animal behaviour to rely on human-like explanations for their observations.

Davis (1997), argues that the tendency to interpret animal behaviours that are similar to human behaviours as arising from human-like cognitive processes can be dangerous for two reasons. The first reason is that by relying on processes that (likely) do not exist, we may make predictions about future behaviours that are unlikely to be true. The second reason is that by assuming that a specific behaviour relies on human-like cognitive processes, we are misinterpreting the behaviour, itself. An example used is that while pigeons, rats, and humans all navigate mazes, and at first glance seem to approach them in a similar manner, more detailed examination of their behaviour will reveal subtle differences in their behaviour which suggests profound differences in the processes that give rise to them. These differences and our insight into their antecedents may go unnoticed if we had relied on erroneous anthropomorphic descriptions of the behaviours in the first place.

Asquith (1997) concedes the danger of misinterpreting the given behaviours that *appear* similar to those that appear in humans. However, here the similarities between humans and non-human animals are highlighted. Asquith notes that while, for instance, a given commonsensical anthropomorphic interpretation of a primate facial expression may be wrong, this does *not* mean that primate are incapable of experiencing emotions in a similar manner to humans. This means that anthropomorphism may be the correct stance to adopt in some cases. In addition, when discussing the behaviour of non-human animals in the scientific community and when engaging the general public, anthropomorphic metaphors are often easy to grasp, and are more often than not sufficient to allow for a discussion on the animal behaviour in question.

This ease of using anthropomorphic language and metaphor to discuss and reason about non-human entities is part of the second subtype of anthropomorphism, which Mitchell (1997) describe as *subjective anthropomorphism*, which is'*. . . the attribution of mental states or other psychological characteristics to animals*', regardless of it being accurate or not (ibid, p.408).

As noted by Asquith (1997), this allows for ease of communication regarding complex behaviours. However, the anthropologist Guthrie (1997), when defining *Anthropomorphism*, while using the subjective anthropomorphism definition, goes on on to state that the origin of the term is to describe this attribution when it is a fallacy. Guthrie goes on to point out that this fallacy is universal across human cultures, suggesting that it is a fundamental feature of how humans make sense of the world, expanding the notion of anthropomorphism out from purely attribution of human traits in animals to a '*Global Anthropomorphism*', suggesting that humans have a predisposition to attribute human characteristics not only to animals but to all objects and events in their environment.

These three perspectives from ethology summarise many of the risks and benefits of anthropomorphism in human-robot interaction. Guthrie's (1997) universal anthropomorphism suggest that anthropomorphic attributions are easily evoked by robots with minimal human-like characteristics, and Asquith (1997) suggest that these attributions can be reliably used to communicate (from the designer's point of view) information relevant to the interaction. However, a natural tendency to rely on anthropomorphic cues may lead the human interactant to attribute robot behaviour to an anthropomorphic cause, which in turns leads to an inappropriate response to the robot's behaviour. The example described in figure 2.2 shows how similar anthropomorphic attributions may lead to different behaviours, and to different outcomes. The same overall attribution ('The robot is confused'), may lead to different anthropomorphic strategies to remedy a situation being employed, and these strategies may not be equivalent. Thus, anthropomorphism, and its effects, needs to be studied quite extensively in Human-Robot

Interaction, which cannot automatically adopt the stances that the different schools of thought in ethology have arrived at. For one, robots are created artefacts rather than naturally occurring phenomena, which means that its creators can vary the degree to which a robot will evoke anthropomorphism in the on-looker, as well as the degree to which anthropomorphic responses are appropriate. In addition, as Turkle (1997) observes, the features that humans use to differentiate humans from animals, are not the same as those used to differentiate humans from computational artefacts. As such, HRI requires its own approach to anthropomorphism.

2.4 Anthropomorphism in Human-Robot Interaction

Anthropomorphism is a common theme in Human-Robot Interaction research, in particular as the concept of robots are in the, popular psyche at least, bound up with human-like machines (Kaplan, 2004), however, the topic has been addressed from a variety of viewpoints.

2.4.1 Computer As Social Actor (CASA) — The Media Equation

Any work conducted in the field of social interactions with computational artefacts would be at remiss to not consider the work of Reeves and Nass (1996). This approach, often described as *Computer As Social Actor* (CASA), considers both the possibility and implications of computers (and other technological artefacts) being social actors within a given interaction (Nass et al., 1993). CASA theorists observe that people will often respond to the behaviour of computer in a way that is analogous to the way that they would

Figure 2.2: The 'Confused' robot

In the study reported in Syrdal et al. (2014), participants would interact with a modified UH Sunflower robot in a domestic living room. As this was a human-centered space, navigation was sometimes difficult for the robot. If a robot's path was perceived to be blocked, the robot would reassess the space by spinning slowly in a circle, in order to build up a map of its immediate environment, so that a new path from its position to its end goal could be planned. Most participants would describe this behaviour as indicative of 'confusion' on the part of the robot, and as such it gave the participants an indication that the robot would be delayed in its performance of its task.
In addition, some participants would also respond to the 'spinning behaviour' as if it was an affective signal, as if the robot's 'confusion' was analogous to how a human being might feel if it was uncertain about which direction to take. As such a behaviour would be quite a strong signal in human-human interactions, these participants acted to alleviate the perceived 'stress' of the robot.
One response would be to give the robot 'space', by moving away from the robot. This particular behaviour would often benefit the robot, as more often than not, the way that the participant had positioned themselves made navigation difficult.
Another response, however, was to engage in a different strategy to similar to that one would use to encourage a confused and nervous human or animal. The participant would either lean in or move closer to the robot to verbally encourage the robot, or in some cases, get up and move around in the proximity of the robot while doing so. This behaviour, while intended to benefit the robot, made it less likely that the robot would find a prompt path to its goal as the participant would then change the immediate area around the robot, and in some cases constrict its available space for safe navigation further.

respond to another human in a similar interaction, even with minimal cues that would suggest any sociability on the part of the computer. The possibilities that arose from this phenomena are, of course, intriguing. When creating software and machines of varying complexities, it allows for the guiding of the human user through high-level social cues, leveraging what we already know about how humans interact with one another. However, just the presence of such a phenomenon was not enough, and subsequent work by the same group outlines an approach to examine this phenomenon in an experimental manner (Nass et al., 1994). This approach would start with a given interaction and then suggest drawing on existing knowledge about how humans may respond in certain interactions. When one replaces one of the interactants with a computational artefact, one can then examine and quantify to what extent the human behaviours observed could be explained by what they would be expected to do in an interaction with another human being that acted in the same way. This approach would allow for the gradual understanding of the importance of the CASA approach for specific interactions and what particular computer behaviours and characteristics were important for eliciting social behaviours. This paper also presented five experiments suggesting the impact of the CASA phenomenon across different contexts. One of these experiments also saw that participant would respond in accordance with the stereotypes associated with the human gender that the computer would present. This would suggest that not only did computers elicit social responses, but that they could also *inherit specific social qualities of specific types of human beings*[5] which means that the designers of technologies can leverage our existing knowledge of

[5]Evidence for this 'inheritance' of characteristics can for instance be found in Eyssel and Loughnan (2013), which suggest that participants apply their racial prejudice to racially typed humanoid robots.

human-human interactions in order to encourage users to interact with the technology in a specific way (Siegel et al., 2009).

This approach was expanded upon in a series of empirical examinations, and also presented in greater detail in a later book, *The Media Equation* (Reeves and Nass, 1996). This book summarised the empirical studies building on the CASA stance, but also extended the notion of computers being social actors to all media. In addition this approach also stated a coherent theoretical framework to explain and predict these approaches. This framework posited the inherent "laziness" of human cognition as an underlying cause for this, and that this would lead humans to apply a set of heuristics originally developed for social situations with other human beings as a means of assessing and responding to computational artefacts. This framework suggested that these applications did not rely on conscious beliefs regarding the actual nature of the artefact encountered, but rather that they would spring into place unconsciously and automatically.

This process applies a set of heuristics, which are described by Tversky and Kahneman (1974) as pre-set principles that reduce complex perceptual and decision making tasks into simpler judgemental operations. The manner in which these principles impact human perception and decision making is not easily available to the individual, but over time, experiences of instances where they have been misapplied may lead to individuals consciously correcting for some of the biases that they cause. While much empirical research has focused on the mistakes and errors that such heuristics may cause, it should also be noted that they are overall beneficial. Arkes (1991) argues that while relying on heuristics may lead to erroneous judgements in some cases, they might still be useful.

This echoes the discussion regarding anthropomorphism in the field of ethology, Guthrie (1997) even goes as far as suggesting that anthropomorphic attribution has become a heuristic due to the benefits of getting it right outweighing the costs of doing it incorrectly.

However, some criticism of this assumed automaticity has been raised, in particular from researchers applying the *Mental Model* framework to understand anthropomorphism in how users interact with robots. For instance, even though some of our behaviours may appear to be congruent with attribution of human traits to the robot, they do not necessarily reflect an underlying belief about the nature and worth of the robot (Bartneck et al., 2005). However, this does not change the contribution that this approach have given to the field in terms of empirical results. The work of Reeves and Nass (1996), demonstrated that human behaviour with a wide range of technological artefacts could be understood and described in terms of their analogues in social human behaviours. However, this response is not likely to be purely a function of the appearance or behaviour of the technology in question. For instance, the results presented by Shen et al. (2011) suggests that *beliefs* about a robot may actually influence behaviours that seem automatic. This study examined motor interference from performing a movement in front a robot, and found that motor interference was more pronounced if the participant *believed the robot to be a social entity.* This suggest that conscious beliefs regarding the nature of a robot may impact anthropomorphic responses, not just in terms of conscious reasoning, but even at an unconscious level. One way of examining these beliefs are through the mental model approach.

2.4.2 Mental Models

The term *mental model* was first coined by Craik (1943), and suggests that individuals reason about objects and events in their environment by running 'simulations' in their mind. These models, which in Craik's original work can be considered a type of folk physics, differ from heuristics in that their components can be brought into conscious thought. Craik defined them not as mere simplifications of phenomena but as pragmatic, ad-hoc, and goal-driven. What is important, in Craik's view, is that the relations between the different parts of the model share those characteristics of their external counterparts that allow for an accurate prediction of the behaviour of the system, only in those aspects that it was used to consider. In other words, the purpose of these mental models is not to make a statement about a systems true nature, but to allow the individual to make informed decisions as to how to interact with a given system within a given situation. It follows from this that the individual's mental model of a particular system or process will change as the individual encounters the system in different situations and interacts with different aspects of it. While our conception of what a mental model is, and how it can best be described and examined has changed over the years (Johnson-Laird, 2004), the conscious availability of these models remain one of their important features across different theoretical understandings of mental models.

Using Social Mental Models to Understand Human-Machine Interactions

Understanding social aspects of human-machine interactions as the product of mental models, is interesting because, unlike the pre- and unconscious heuristics posited by the Media Equation approach, the underlying mechanisms are available to examine using interviews and questionnaires. They can also be influenced through descriptions and dialogue. This approach, based on conscious thoughts accessible through language, allows for the description of how individuals perceive and respond to different computational artefacts, which in turn allows for the creation of standardised measurements in a manner similar as to those created for the measurement of human traits (John et al., 1988)[6]. Such measurements can be used for a variety of purposes, they can be used to explain human responses within human-machine experiments (Andonova, 2006; Syrdal et al., 2008a; Tapus et al., 2008), scales to differentiate between different computational artefacts along different dimensions or to compare robots to humans (Woods et al., 2005) or animals (Syrdal et al., 2010b).

The fact that mental models can be made explicit and examined through interviews and questionnaires means that one can study not only the outcome of these mental models, but may also study how they change over time. Some studies, such as Powers et al. (2003) and Walters et al. (2008) (discussed in more detail in chapter 3), have examined these models as originating from interpretations of external cues in the appearance of the robots. Others have investigated how these models may change over time. For instance, Fischer and Lohse (2007), suggested that human mental models of robots, while formed quickly, are not easily changed after their formation. Broadbent et al. (2011) found that participants have strong negative responses to robots who do not match their users' mental models of what they should be like. In light of this, Phillips et al. (2011) propose that the design and deployment of robots intended for human interaction need to consider the mental models that they elicit in their users, in particular

[6]As pioneered by Kiesler and Goetz (2002) even used human personality trait descriptors to describe robot personalities

in terms of perceived anthropomorphism. This is echoed by Ososky et al. (2013a) who also point out that anthropomorphic mental models of robots tend to be a feature of naive users of these robots.

Thus, the mental model approach is a rich source of insight into the relationship between anthropomorphism and other aspects of human-robot interactions. However, this approach to the above papers, posit that the behaviour of the human partner in an HRI scenario is based on a belief about the nature of the robot itself.

2.4.3 'Psychological' anthropomorphism

Of the approaches in this section, 'Psychological' anthropomorphism, as introduced into HRI by Eyssel et al. (2010) is possibly the most recent to the field. It draws on social psychological research regarding how members of different social groups view members of other groups. This work builds on the work of Haslam et al. (2005) who introduced a questionnaire-based instrument through which they assessed the degree to which certain traits were seen as intrinsically human nature (i.e. possessing them was an *essential* part of being human) and traits that differentiated humans from non-human animals (i.e. *unique* human traits). The traits that were seen as essential traits of human nature were traits such as ability to exhibit emotions, warmth, desire etc. The traits which differentiated humans from other animals were those related to reasoning and the ability to understand and adhere to rules. This two-dimensional approach to anthropomorphism, mirrors and confirms Turkle (1997) observations of the two separate sets of traits that people use to differentiate between humans and machines and between humans and animals. These constructs were then used, to investigate a process they refer to as *dehumanisation*, the process through which one denies humanness to members of an out-groups. This can be done by denying the intrinsically human traits to members of a lower social class, thus making them more 'animalistic', seen in perceptions of asylum seekers or refugees (Haslam and Pedersen, 2007; Saminaden et al., 2010) or by denying differentiating traits to member of other groups (as commonly seen in stereotypes of people of Chinese or Japanese descent in North America), making them more 'robotic' (Castano et al., 2009).

In human-robot interaction, this approach to human-human perceptions is turned on its head, and anthropomorphism is framed as a type of '*reverse dehumanisation*'. Eyssel et al. (2010) operationalised this process as the degree to which the participants would allow for a robot to have traits seen as essentially human (and shared with animals), and concluded that a high degree of anthropomorphism was associated with a more pleasant interaction. Later work using this approach also argued that the way that participants anthropmorphised robots rely on cues and processes that are congruent with what one would expect in human-human interactions, with regards to gender (Eyssel and Hegel, 2012) as well as ethnicity (Eyssel and Kuchenbrandt, 2012), race (Eyssel and Loughnan, 2013), and the emotional state of the on-looker (Eyssel and Kuchenbrandt, 2011; Eyssel and Reich, 2013).

This approach, when applied to HRI has, however, had as its main focus an attempt to understanding anthropomorphism and dehumanisation through robots, rather than on how to best design robots and interactions (Eyssel and Kuchenbrandt, 2011). While it certainly has allowed for a more detailed and rigorous measurement of how participants evaluate robots, and interact with them, in terms of their anthropomorphic experience, it relies on the participants making an ontological claim about the anthropomorphic nature of the robot, when faced with the researcher's question. It is also not clear to what extent such anthropomorphism would have on the limited range of interactions one would have with robots. For instance, contemporary discourse regarding slaves of African descent in the southern United States clearly suggests a large degree of dehumanisation in how white slave-owners viewed them. This still didn't prevent them from being used extensively, over a long period of time, in tasks similar to those posited for a domestic service robot (Stampp, 1971). In Britain, discourse regarding working class people also have strong elements of dehumanisation (Jones, 2012), but those engaged in it will still happily interact with the (dehumanised) working class in interactions that are instrumental in nature, at the shop till, with the cleaner, with security guards etc. However, the success of such interactions may not be related to a high degree of anthropomorphism, at all. In fact, a high degree of anthropomorphism may even have a negative impact on them.

Some experiments in HRI support this notion, Bartneck and Hu (2008) make the case that even when interactions may seem as interactions with a living analogue of the robot, *'there are situations in which this social illusion shatters and we consider them to be only machines'* (ibid, p.416). The two examples used in support of this are experiments in which a human participant is in a position to hurt or destroy a robot it is interacting with. In one of these examples, the participants are happy to destroy the robots *regardless of the success of the previous interaction.* This suggests that psychological anthropomorphism may not be as strongly related to the quality of the interaction as is suggested by Eyssel et al. (2010), and that when examining social expectations of robots, a valid approach may also be to examine the interaction itself, and consider how users react when faced with a technology that may be interacted with in a social manner. The 'Performed Belief' approach next, is an example of such an approach.

2.4.4 Performed Belief

Another way to understand the social aspects of interactions between humans and machines is as play, or *Performed Beliefs* (Jacobsson, 2009). This approach stresses the importance of play-like behaviour in social interactions. While the Media Equation suggests an automaticity in the way we respond to technologies and the Mental Models approach suggests that they are based on reasoning and predictions about the nature of the objects in the interactions, this approach is rooted in the interactions themselves, and suggests that there is a strong element of play in the way that humans interact with technological artefacts. This play-behaviour can be completely arbitrary, and does not have to be rooted in a systemic understanding of the technology in question, latching on to different features of the technologies. A participant may (as seen in Syrdal et al. (2014)), decide that the movements of a robot is like a toddler, and proceed to encourage it in a sing-song voice, and then in the next minute inquire as to how the system prioritises tasks in order to work around a perceived bug in how it responds to a particular event.

Clark's notion of *joint pretense* (Clark, 1999) highlights the communicative aspect of this general approach, either to other humans in the interaction, or to oneself, as its defining feature. By 'pretending' that the robot is like a human in some aspects, the user taps into a set of possible behaviours that may be useful, and can then set about experimenting with the usefulness of each behaviour from this repertoire. While this behaviour is similar to that one would see in the sort of mental model approach suggested in Kiesler and Goetz (2002), the anthropomorphic role that the user assigns the robot in a given interaction is not an expression of the users' beliefs about the true nature of the robot. Rather, the user only adopts the perceived interactional roles for the purposes of the interaction only.

This approach understands anthropomorphism in HRI, as play, and understands behaviours congruent with anthropomorphic roles within the human-robot interactions as epistemic actions (Cowley and Macdorman, 2006) that allow the user a framework for exploring the robot, and its interactional and functional capabilities without tying the user down to a specific model for understanding the robot's true nature. There is certainly some evidence that participants use anthropomorphic interactions with technologies to relieve tension and cope with stress when interactions break down (Luczak et al., 2003). This can mitigate some of the negative consequences of mistakes and encourage playful epistemia. This tendency for 'play-like' interactions has also been noted by researchers in human-machine interactions, as it can also be used to encourage a range of behaviours, strategies, and suggestions within a prototyping process when developing technologies (Seland, 2009).

As will be discussed in Chapter 5 and 6, encouraging confidence through playful interaction is a useful technique in prototyping interactions, and this has been noted in HRI. In fact, Belpaeme et al. (2013) goes as far as suggesting that children are better participants in prototyping processes because of their *willingness to engage in pretend play and anthropomorphism.* The role of different features of the technology, and the interaction context that afford different types of behaviours can be explored, described and examined vigorously through interviews, observations, questionnaires and experiments, within these playful interactions.

However, another approach to understanding the anthropomorphic nature of the relationships that arise from this even relatively playful interactions suggest that within these *relationships*, anthropomorphic beliefs arise and can be studied.

2.4.5 Authentic Relationships

> *'When we walk our way and encounter a man who comes towards us, walking his way, we know our way only, and not his; for his comes to life for us only in the encounter.*
>
> - Martin Buber, *I and Thou* (1970)

While interactions may be playful in nature, in some situations, the emergent relationship between user and robot may take on a shape that is better understood as the relationship between two human peers than that of a human playing a game on a computer. Kahn Jr et al. (2012) describe how children engage in playful interactions with a robot, but when it is the robot's turn to play, a 'technician' appears to put the robot away. When the robot complains about the unfairness of it all, the child agrees, verbally supporting the robot and may even protest or attempt to negotiate with the technician in order to let the robot 'have its go'. What might have been understood as a playful expression of performed belief seems to have formed the basis of a proto-relationship in which the children affords the robot similar privileges as themselves.

In a paper exploring what one could consider psychological anthropomorphism, Kahn Jr et al. (2007), highlight 9 benchmarks that they believe can be applied to assess whether or not the robot can be considered human-like within an interaction. While some of these, like imitation, can better be understood as expressions of the CASA stance, and some, like creativity, are features of the robots themselves, the majority of these benchmarks can only be expressed within the relationships that humans form with robots. Rather than automatic responses, considerations of the robots' true nature, or some elaborate 'game'-like pretend play, they argue that the benchmarks for human-likeness in interactions lie in *mutuality.* Drawing on the relational philosophy of Martin Buber (Buber, 1970) they argue that at its core, relationships between humans and other humans are based upon reciprocity, and that social interactions between humans and robots involve the building of relationships.

This approach to social, anthropomorphic interactions between human and robots, in which one investigate the emergent relationship, have produced some interesting findings. As discussed above, Kahn Jr et al. (2012) describe a set of experiments in which children after interacting with a robot, were not only willing to allow the robot moral standing within the interaction, but were also *prepared to argue with an adult in ensuring that the robot's moral rights were being protected.* In older adults, Turkle et al. (2006) describe how users of socially assistive robots engage in relationship building behaviors, sharing memories and caring for the robots. These relationships can also have a practical purpose. Bickmore et al. (2005) noted the emergence of relationships between human users and a virtually embodied conversational agent intended to encourage them to do more exercise. Bickmore et al. proceeded to suggest that such a relationship could be useful when persuading potential users to make healthier choices.

David Levy's *Love & Sex with Robots* (Levy, 2009), represents another approach to the relational understanding of anthropomorphism. Levy's approach sees human-robot relationships as potentially equivalent to that of human-human relationships. This equivalency is presented both as an extrapolation of empirical findings as well as a design goal. Using logic similar to that underlying Alan Turing's Imitation Game (Copeland, 2000)[7], Levy argues that it is not only possible, but likely that robots will be designed with interactional capabilities that will make the experienced relationship between human and robot almost indistinguishable from those between humans. Levy also addresses the 'Fiendish Expert' issue, which posits that no matter how cleverly one constructs an artificial agent to appear like a human, there will always be particular tells that a trained observer can use to distinguish human from non-human agents (Copeland and Proudfoot, 2009). Levy argues that the tells are not that important. Research, in particular from the *CASA* approach to anthropomorphism suggests that our anthropomorphic responses to technology are more forgiving than our conscious reasoning about the agent's true nature.

However, Turkle (2007) argues that despite an artificial companion exhibiting behaviours and responses congruent with those we would expect to see in a human relationship, the fact that the companion is *not* another human means that the relationship lacks authenticity, and this will ultimately cause a breakdown in the interaction and/or relationship. Rather than there being 'Fiendish Experts', human social expectations are so complex and encompasses such a wide variety of interactions, that the artificial agent will at some point fail to act in a 'human' way. In addition, much of human-human relationships rely on empathy and sympathy arising from shared experience. Boden (2009) raises the question of how an artificial entity can even give the semblance of a human-like response to a human emotional need:

> ...imagine I was to tell my *companion* that my child had died. What could it possibly respond with? What sort of re-

[7] Often referred to as the 'Turing test'.

> sponse would I want from a machine that is not born, has no experience of family, and is purely a set of automatic responses to what it perceives my emotional state to be at that given time. Is there any response it could give me that wouldn't be insulting to me?
>
> - Margaret Boden, (Boden, 2009)

In addition, the possibility of conflicts between the user and the robotic system may similarly cause a breakdown in the anthropomorphic understanding of the human-robot interaction. For instance, Sorell and Draper (2014) suggest that situations may occur in which the robot may seemingly act or encourage the user to act differently than the primary user would want to act, in order to safeguard the user's health and safety.

These counter-arguments, suggest that the possibility of such relationships, if possible, may not be universal, and may depend on idiosyncratic factors in the human interactant, or on specific situational circumstances. However, this does not change the underlying approach of examining what sort of relational roles that robots may adopt within interactions. In fact, Draper et al. (2014) suggest that reframing the duties of the robot in terms of anthropomorphic relations may actually resolve conflicts between a human user and a robotic system.

2.4.6 Functional Relationships

Many would argue that anthropomorphic relationships as conceived and discussed above may not be possible and indeed not even desirable. However, as noted by Suchman (2007), when a technology is inserted into any setting, it is also inserted into a complex web of relationships and interactions. Robots deployed into human-centred settings will likely take on tasks and functions previously performed and provided by humans. This transfer of duties from humans to robots have often led to robots being described using the title that one would use for a human being performing similar tasks. The Da Vinci Surgery System[8] is often described as a robot *surgeon*, various robots are described as robot *butlers*, and this extends even into functions taken up by animals in human-centred environments. Robots like the Sony AIBO and the Pleo are described as robot *pets*.

While these descriptions are not necessarily correct even in terms of the duties that the robots fulfill (The Da Vinci System is a remotely operated surgical tool, few robot butlers manage other domestic robots, etc.), they do work to frame the expectations some of their users might have as to what sort of interactions they might have with them.

The use of functional roles to describe how people interact, and envisage interactions, with robots have been used in several strands of HRI research.

Several studies have suggested that people distinguish between what sorts of functional roles they expect robots to perform.

In findings reported by Dautenhahn et al. (2005), participants were divided in terms of the functions and roles that they would want a robot to perform. When asked to what sort of role a *home robot companion* could take, the vast majority of their participants were happy with the robots taking on roles such as 'assistant' or 'machine'. Roughly half of the sample were happy with the robot taking on the role of 'servant', while less than one in five thought a robot companion could be a 'mate' or a 'friend'. This sort of split was also seen in the sorts of practical functions that the participants felt the robot could take on. There was a split between purely practical tasks like household chores, and emotional tasks such as looking after chil-

[8]http://www.davincisurgery.com/

dreni. While all participants saw practical tasks as something that robots could perform, only a very small minority were happy to accept robots for the emotional tasks.

A similar split was reported in Syrdal et al. (2011b). Here, a British sample described caring professions such as nursing, as roles that robots should *not* have. This study also suggested that this effect was less apparent in a Japanese sample. This, in turn suggests cultural differences in the sorts of expectations people may have of roles and functions of robots. The reason for this split in the British sample was seen almost as a function of these roles relying on traits that would be described by Haslam et al. (2005) as *essential* human traits.

Takayama et al. (2008) describe the findings of a survey which describe participants' views of what roles they consider appropriate for a robot. While the previously seen dichotomy between tasks that require essential human characteristic traits and those that don't is present, this survey also highlights that participants envisage that many of these tasks should be performed by humans and robots working together.

However, it is not just traits considered essentially human that may be important. While Ezer et al. (2009) acknowledge the division between interactive/social tasks and tasks that were purely practical in nature, they also suggest that how critical a task seems to the user may also impact user decisions regarding task domains. The issue of criticality is further explored by Chanseau et al. (2017) who found that their participants defined critical tasks as those in which the consequences of the robot making a mistake would be both irreversible and have large impact on the user.

These studies suggest that there are likely at least two dimensions of how people envisage the different roles for robots in terms of functional and/or task based roles. One relates to the social aspect of the robots, whether or not it is expected to interact in a social manner, and the other is a matter of control, related to the degree of autonomy bestowed upon the robot. While this may impact the task domains that participants are willing to accept robots within, it is likely that they may also influence *the manner in which a robot performs a given task.*

From task to social role

These functional roles may not just be restricted to a set of tasks. Findings reported by Fischer (Fischer, 2006; Fischer and Lohse, 2007) describe participant reasoning regarding the robot's interactional capabilities that vary around the degree of sociality (i.e. the degree to which human interactional behaviours are appropriate for interacting with the robot) and autonomy (i.e. the degree to which the robot can perform its tasks without human interference).

Ezer (2009) conducted a survey in which participant expectations of robot traits for a domestic robot were related to the expectations of the roles that the participants envisaged for it. The traits were divided into three groups, *Social-oriented*, i.e. traits related to social interactions such as 'Affectionate' and 'Expressive'; *Performance-based*, i.e. positive traits that were associated with a robot's ability to perform its tasks, such a 'Precise' or 'Efficient'; and *Non-productive* traits, which were negative traits related to a robot's ability to perform its tasks, such as 'Wasteful' and 'Chaotic'.

The robot roles suggested were both roles defined by functional roles, such as 'Servant and 'Assistant', but also more general descriptive roles were suggested such as 'Appliance', 'Pet' and 'Friend'. Ezer's analysis suggests that participants expectations of robot roles can be expressed in terms of three general categories of roles. The first category is *Human* and had items such a 'Friend'. Participants expecting their robot to have these sorts of roles, also expected robots to have more Social-oriented traits. The second sets of roles were labelled *Supportive*, and had items such as 'Servant'. This role-dimension was associated with Performance-oriented traits. The third dimension was labelled *Subordinate* and had items such as 'Toy' and 'Pet'. This dimension was correlated with the Non-productive traits.

This suggests that purely functional roles do carry a varying degree of social expectations that come in addition to the ability of the robot to perform a specific task.

Joosse et al. (2013) argue that as there is a consensus in the psychological literature that different occupations have different social expectations associated with them, the expectations that we have of the manner in which robots carry out their function may be influenced by the occupational role that the robot may occupy. They also argue that the degree to which the robot conforms to these expectations will influence how its users will evaluate it. Their findings demonstrated that not only do participants have different expectations of robots in terms of the personality traits that they expect the robot to exhibit, but that there are also individual differences between participants in terms of they evaluate robots with a given personality type in a given occupational role.

They conclude that robot's behaviours when performing a certain task need to be adapted so that the *manner in which the task is conducted* is consistent with the 'personality' that the particular user will expect such a robot to have.

While many occupations have very clearly defined stereotypes, it has been argued that what sort of occupational role the home robot companion may take is far less clearly defined Dautenhahn et al. (2005). This may lead to the role of individual differences that Ezer (2009) and others see in functional role preferences interacting with the individual differences that Joosse et al. (2013) saw in the personality expectation.

2.5 Summary

This thesis does not attempt at resolving the different approaches to anthropomorphism in human-robot interaction, but rather, it attempts to view it in a practical manner. As such it examines Anthropomorphism as a set of social behavioural expectations that are not only measurable, but will also be actionable, in that they may led to different expectations within the broader space of expectations around interactions with robot home companion.

For HRI, anthropomorphism is not purely a function of the robot, neither in terms of its appearance or simulated human behaviors. It is also not purely a function of the human interactant. It is not a pre- or unconscious response, a belief about the true nature of the robot, nor an emotional attachment to it. It is, however, a *constraint situated within the context of that particular interaction*, that allows for meaningful interaction within human-centred environments. Faced with a near-infinite amount of possible behaviors the human can engage in with the perceived tabula rasa of the novel artificial being, it allows for the management of expectations, and thus behaviour.

It cannot be a one-dimensional construct, because *just being human does not reduce the amount of possible interactions.* Is the person in my living room a burglar, a policeman, a child, a lover, a beggar or a nurse? Are they outgoing, timid, angry, violent or scared? Does their relative 'humanness' impact these interactions? Anthropomorphism is not one thing, rather it is a category of possible roles that the robot can inhabit. While I may never afford the robot the status of human, I might easily refer to it a robot-nurse, robot-guard dog or robot-butler.

The robot's true nature as a robot does not change the fact that my expectations of its behaviour are constrained by expectations 'inherited' from the roles that humans may inhabit within the situational context we find ourselves in, however. My behaviour towards the robot, and my evaluation of the robot are grounded in this inheritance.

This approach to social expectations of human-robot companions suggests that the most appropriate approach to investigating them is through the lens of the functional role approaches. This allows for investigating social expectations within practical scenarios. Both the two main approaches, personality as mediating function as proposed by Joosse et al. (2013) and the function/trait relationships of Ezer (2009) suggest that these expectations can not only be measured using self-report tools like interviews and questionnaire, but may also impact the manner in which a person will expect to interact with a robot within a given task, and impact the manner in which a participants evaluates the robots behaviour.

The next chapter, Chapter 3, will describe how both personality traits and functional traits were applied in order to measure social expectations of robots, as well as the development of a questionnaire measuring role expectations specifically for a robot companion. The following chapter will then focus on how these measures can be used to investigate how these social expectations impact expectations of robot behaviour, human behaviour in human-robot interactions and evaluation of robot behaviours.

Chapter 3

Measuring Social Perceptions

Chapter Overview

This Chapter draws on the conclusions in the preceding chapter and addresses them by attempting practical measurements of human social expectations of robots within human-robot interactions. The first set of measurement uses personality measures as suggested by Kiesler and Goetz (2002) and Joosse et al. (2013) and relies strongly on already validated measurements of personality assessments. The research presented in this chapter on this particular method of measurement is not a validation of this approach as such, but rather an exploration of its feasibility and usefulness within the human-robot interaction studies with robot companions, in particular as outlined in this and the following chapters. The other type of measurement is strongly focused on the functional role approach as suggested by Ezer (2009). This approach has seen less standardisation, and as such, the development of a questionnaire tool that can easily be included in larger-scale (i.e. studies that have a scope and purpose beyond this measurement) human-robot interaction studies was in itself a goal for the work presented here.

3.1 Social Expectations in terms of Human Personality

3.1.1 The assessment of robot personality based on appearance

As discussed in the preceding chapter, the use of personality traits when asking people to describe robots can be based on the understanding of such a description as an expression of the raters underlying mental model of the nature of the robot's anthropomorphic personality (Kiesler and Goetz, 2002). However, as previously mentioned, this particular approach can be problematic, as many studies report that participants may not believe that the underlying nature of the robot allows for it to have anything resembling a human personality. However, what is sometimes described as personality traits are sometimes shorthand for interaction expectations based on stereotypes of social roles, and in light of Joosse et al. (2013), difficult to avoid, and will be particularly helpful when designing user interfaces and behaviours of such artefacts as it allows for easy and intuitive predictions of system behaviour based on expected system personality. This argument is also presented by Duffy (2003). In the domain of HRI, when confronted with entities with unknown behaviour, such as robots, anthropomorphism might thus be used as a guide to cope with the unpredictability of the situation (Goetz et al., 2003).

The implications of such a paradigm is that robot design should endeavour to create robot appearances to which personality attributions are made that correspond to the intended behaviour of the robot (Duffy, 2003).

For this to be possible, it is necessary to explore the relationship between personality attribution and appearance in HRI situations. To be able to fully explore this relationship we will first consider how humans rate other humans in terms of personality with limited information before we investigate HRI studies. In the field of personality and social psychology, studies investigated how successfully participants rate strangers on various personality dimensions at zero acquaintance, i.e. contexts in which perceivers are given no opportunity to interact with strangers (targets of whom no prior knowledge is available to the subject (Albright et al., 1988)). These studies found that the traits Extraversion, Agreeableness and Conscientiousness seem to allow for the most successful rating of strangers, with Emotional Stability and Openness to Experience the most difficult to rate (Albright et al., 1988; Borkenau and Liebler, 1992)). This effect is exhibited even in situations where there is no interaction between participants and even when rating is done purely on the basis of emails (Gill et al., 2006). This body of research also suggests that Extraversion ratings are highly correlated with the physical attractiveness ratings of the person being rated. Of particular interest here is the Borkenau and Liebler (1992) study where participants rated strangers according to the Big Five personality traits after having only seen still photos or videos of the strangers.

If one purely extrapolates the results from Human-Human studies on personality attributions to HRI one would expect that Extraversion, Conscientiousness and Agreeableness will be the personality traits with the largest systematic variance in participant ratings due to cues arising from appearance and behaviour, i.e. that these are the traits where people's ratings will change the most according to differences in between robots. Research on the attribution of personality to robots does to some extent support this extrapolation. Kiesler and Goetz (2002) reported that participants found it easier to rate the robot on the Extraversion dimension, while finding Emotional Stability and Openness to Experience the most difficult dimensions in which to rate the robot. Note, this study, along with a previous study (Woods et al., 2005) also investigated the issue of participant projecting their personality traits unto the robot. Woods et al. (2005) found that this was not the case. This, however, is not a focus of the studies presented in this chapter which were primarily focused on the relationship between designed appearance and perceived robot personality.

3.2 Social Role Expectations based on Social Roles

However, as discussed extensively in the previous chapter, many participants may not be comfortable with assigning *human-specific* personality traits to robots. Both Kaplan (2004) and Syrdal et al. (2011b) suggest such a reticence, and there is a risk that using such measurement tools may only obtain a measure of the degree of 'anthropomorphic buy-in' that the rater is willing to commit to the robot. In other words, rather than a measure of personality in the sense of human individual differences, the personality ratings is more akin to an affordance of the possibility of having such a personality trait instead. As such, there is a risk of this particular approach only becoming a unidimensional measure of anthropomorphism rather than one that allows for more specific expectations.

While the degree of anthropomorphism may have an impact on the user, as suggested by Groom et al. (2011), there are limits to what extent a one-dimensional scale of human to non-human may be for certain interactions.

In addition, there is also another, practical, issue with using personality traits to differentiate between robots. In humans, the majority of individuals are clustered around the average on all trait dimensions (Matthews et al., 2003). When commonsensically describing a person as 'extrovert' or 'disagreeable', the implied meaning is 'more extrovert or disagreeable *than most other people*'. We use personality descriptors to denote remarkable traits (otherwise, we wouldn't need to remark upon them in the first place). In research, however, extrovert or disagreeable would be defined based on the distance of an individual's score from a population or sample mean. In essence, matching robot personality to a user personality (as in Tapus et al. (2008)) would be meaningless for a large portion of the users, as the majority would cluster quite comfortably around the mean. One could then end up with the majority of 'robots with personality ' (if defined through traits) having no discernible personality at all. This means that it is possible that personality measures would not be *discriminant*, i.e. that they might not allow the participant to distinguish between different robots and robot behaviours when using these measures.

Because of this, it may also be worthwhile to examine social expectations completely based on the roles themselves rather than the personality traits that they were based on. As discussed in the previous chapter, both Fischer (2006) and Ezer (2009) suggest that role perceptions based on function may impact the manner in which participants would interact with, and respond to robots.

3.3 Empirical Approach

The work in this section of the thesis is primarily focused on assessing the feasibility of using the two approaches, *Personality descriptors* and *Social Roles* to measuring the specific social expectations that participants have of robots in a given situation. As with all the work conducted as part of this thesis, this investigation was carried out in parallel with general human-robot interaction research conducted within the UH Adaptive Systems Research Group ensuring that the practical administration of these measures was possible in a range of studies.

3.4 Personality Measures

There were two sets of studies investigating the use of personality measures as tools for examining participant social expectations of robots within human-robot interactions. The first study was done using a video-based methodology, in which groups of participants would watch an HRI scenario, and were then asked to complete a questionnairei. Some of these questions allowed them to rate the robot in terms of personality descriptors. The second set of studies had the participants conduct an actual live interaction with a robot. While studies do suggest that it in some cases, one will get similar results when conducting video-based studies and live interactions Woods et al. (2006), both approaches were used. The video study was performed as it allowed for a larger sample size, and greater statistical power, while the live interactions were performed to see if the visceral interaction experience would have an impact on responses along these measurements.

3.4.1 Video Study

The results from this study have been reported in full in Walters et al. (2008) and Syrdal et al. (2007a). While these papers also touch upon other aspects of how people respond to robots of different appearances, the following section focuses on how participants assign human personality traits to robots:

Methodology

Participants: There were 77 participants in this study. (71 males and 6 females, 18 to 52 years of age). The mean age of the participants was 25 (SD=9) and the median age was 24. The participants were students or staff at the University of Hertfordshire from various disciplines.

Procedure: The participants were shown a video in which a robot approached a person in a home environment in order draw his attention using sound and gestures. The scenario designed for these particular trials took place in a real home (The University of Hertfordshire Robot House) to increase the believability and ecological validity of the trials. Subjects were provided with the following instructions at the outset of the trial:

> ‘To help us refine human-robot interactions,we need to know exactly what people prefer or actively dislike. This trial aims to explore some important aspects of human preferences toward different robot appearances and behaviour styles. A robot companion within the home would need to know how to attract a person’s attention for different situations, and what people’s preferences are. You will view some videotaped clips that depict a scenario where a person is busy at home, when the doorbell rings. The robot companion goes to answer the door and lets the person in, and then needs to let the person at home know that they have a visitor. The video clips will show the robot with three different appearance styles, and the ability to use different cues (e.g. lights, noises, voices) to attract your attention, in the hope of initiating an interaction with you. We would like you to watch each video clip carefully and imagine that you are the

> person interacting with the robot. We would like you to tell us about your preferences by completing the questionnaire at the end of the clips.'

The participants were shown three versions of the video clip. In each version the robot's appearance as well as gesture and sound cues were varied. The first appearance (see Figure 3.1), labeled 'mechanoid appearance' was a standard PeopleBot (ActivMedia Robotics) with a camera but no specific anthropomorphic features. In the HRI scenario it communicated, i.e. indicated its presence, using beeps and movements of its gripper. The second appearance (see Figure 3.2), labeled 'basic appearance' was modified by our research team to feature a simple mechanical head, i.e. a translucent round 'head' with two glowing lights for 'eyes' with circuitry clearly visible. It communicated using a mechanical voice and a simple arm. The third appearance (see Figure 3.3), labeled 'humanoid appearance' was modified to feature a detailed humanoid head with glowing elliptical eyes, nose and mouth, painted in silver. It communicated using a human voice and a human-like arm for gestures. Gesture and sound cues were chosen by the research team in order to match the overall robot appearance (basic, mechanical, humanoid).

Measurements: The participants' academic background, computer proficiency, prior exposure to robots, and other demographic details were assessed using questionnaires. Participant Personality was measured using the International Personality Item Pool (Goldberg, 1999) (IPIP), which measures human participants along the 'Big Five' model of personality (Matthews et al., 2003). See Table 3.1 for example items from the IPIP. Perceived robot personality was assessed using a set of 5 semantic differential scales

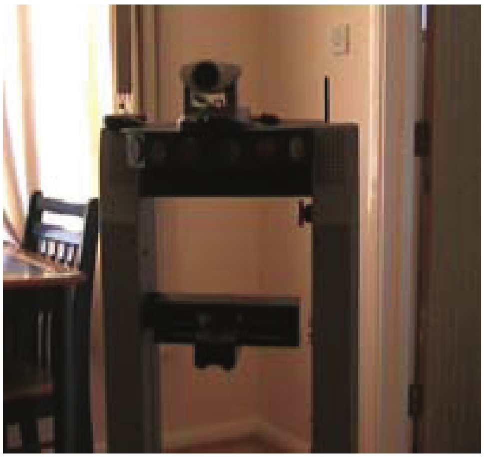


Figure 3.1: Mechanoid Appearance

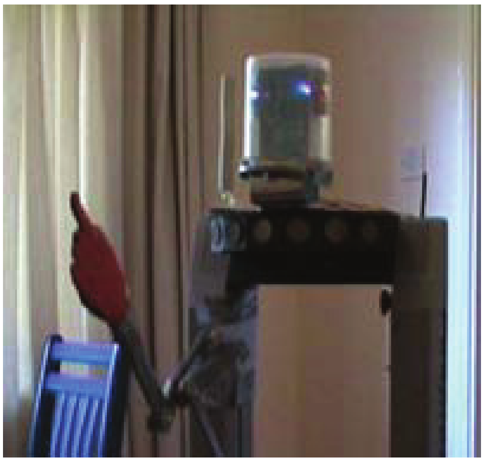


Figure 3.2: Basic Appearance

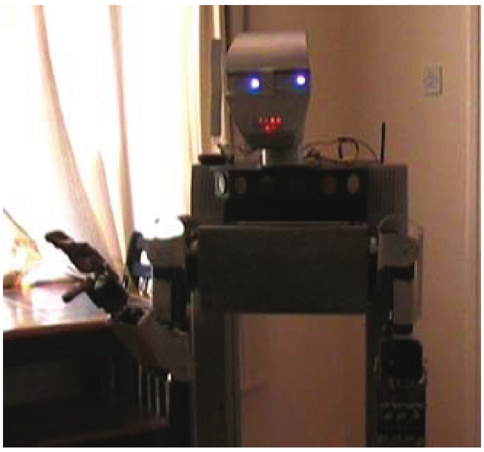


Figure 3.3: Humanoid Appearance

Table 3.1: Sample Items from the International Personality Item Pool

Personality Trait	Sample Item
Emotional Stability	I am relaxed most of the time.
	I get stressed easily.
Extraversion	I am the life of the party.
	I am quiet around strangers.
Agreeableness	I sympathise with other's feelings.
	I feel little concern for others.
Conscientiousness	I am always prepared.
	I leave my belongings around.
Intellect	I use difficult words.
	I am not interested in abstract ideas.

Table 3.2: Semantic Differential Scales for Robot Personality

Personality Trait	Item
Emotional Stability	How relaxed and content, or stressed and easily upset was the robot?
Extraversion	How extravert/introvert was the robot?
Agreeableness	How interested/disinterested in people was the robot?
Conscientiousness	How organised & committed or disorganised/uncommitted was the robot?
Intellect	how intelligent or unintelligent was the robot during its tasks?

which are described in Table 3.2 [1].

Research Aims As discussed above in section 3.1, in order for the use of personality descriptors to have any value as a measure of social expectations, they need to be *discriminant*. Assessing this discriminant validity was done by testing for significant differences between the different robot appearances along the different personality traits. However, in addition to being discriminating between different robot appearances, these differences should also be *multidimensional*, i.e. if different robot appearances are associated with different personality types, then they should have unique personality profiles. A *unidimensional* result, i.e. one in which a rating on one personality trait for a given appearance is strongly associated with its ratings on the other personality traits, suggest that the respondents are not rating personality as such, but rather some sort of anthropomorphic capability to have personality traits. These would be tested in turn through the analysis.

Results

Discrimination between Robot Appearances Mean personality ratings for each robot appearance can be found in Table 3.3 and in Figure 3.4. These suggest that the different robot appearance styles were rated differently for each of the personality traits, with the Mechanoid robot scoring the lowest. The scores, were however, not normally distributed for these ratings, so non-parametric tests were used to assess the differences between the different appearance styles. The results from a series of Friedman tests are presented in Table 3.4 and show significant differences between the different

[1] While it can be argued that Semantic Differential scale responses should be treated as ordinal data, it has been argued that, in practice, there is empirical evidence that the relationship between the different level are treated as interval analogues of the visual distances from each adjective (Heise, 1969).

appearances for all personality traits. These were further addressed by a set of Bonferroni corrected Wilcoxon Signed Rank tests. These are reported in Table 3.5 which suggests that there were significant differences between all three appearance styles across 4 of the 5 personality traits[2]. The exception was *Emotional Stability* in which participants only differentiated between the Mechanoid and the Humanoid appearance styles.

Table 3.3: Personality traits assigned to robot appearances

3.3

Robot	**Trait**	**Mean**	**SE**
Mechanoid	Extraversion	2.35	0.10
	Agreeableness	2.46	0.11
	Conscient.	3.18	0.11
	Emot. Stab.	3.22	0.10
	Intelligence	2.86	0.10
Basic	Extraversion	3.11	0.09
	Agreeableness	3.19	0.09
	Conscient.	3.42	0.08
	Emot. Stab.	3.33	0.08
	Intelligence	3.21	0.10
Humanoid	Extraversion	3.76	0.10
	Agreeableness	3.65	0.10
	Conscient.	3.74	0.08
	Emot. Stab.	3.58	0.10
	Intelligence	3.65	0.10

Table 3.4: Friedman Tests for Traits and Robot Appearance

Trait	χ^2 (2)	p
Extraversion	63.39	$< .01$
Agreeableness	53.83	$< .01$
Conscientiousness	19.48	$< .01$
Emotional Stability	6.98	0.03
Intelligence	35.57	$< .01$

[2]The Cohen's d (Cohen, 1992) measure for effect size, is calculated using the Wilcoxon Z-statistic rather than the parametric descriptives. This approach is used consistently within the thesis.

Table 3.5: Wilcoxon Signed Rank post-hoc tests

Pair	Mech. — Basic d(p)	Mech. — Humanoid d(p)	Basic — Humanoid d(p)
Extraversion	.58(< .01)*	.86(< .01)*	.52(< .01)*
Agreeableness	.57(< .01)*	.76(< .01)*	.33(< .01)*
Conscientiousness	.16(0.09)	.41(< .01)*	.31(< .01)*
Emotional Stability	.11(0.38)	.31(0.02)*	.24(0.05)
Intelligence	.31(< .01)*	.59(< .01)*	.32(< .01)*

* p is less than corrected α of 0.03

Relationships between Personality Traits The Spearman's ρ coefficients between the different personality traits are shown in tables 3.6 – 3.8. They suggest that there were clear relationships between participant ratings for *all five* personality traits. This suggests that the ratings together might be taken as a rating for *anthropomorphism*, rather than for individual personality traits. This was assessed by examining the internal consistency of ratings for each robot appearance type using Cronbach's α. The Cronbach's α-coeffecients are presented in Table 3.9, and suggest that the ratings for each personality type form an internally consistent scale with a Cronbach's α of more than 0.70. This supports the notion of these ratings being a unidimensional scale of anthropomorphism.

Table 3.6: Spearman correlations between perceived personality traits for mechanoid robot appearance

	Extraversion	Agreeableness	Conscient.	Emot.Stab.
Extraversion				
Agreeableness	0.53***			
Conscient.	0.51***	0.47***		
Emot.Stab.	0.27*	0.17	0.33**	
Intelligence	0.26*	0.25*	0.31**	0.18

a

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 3.7: Spearman correlations between perceived personality traits for basic robot appearance

	Extraversion	Agreeableness	Conscient.	Emot.Stab.
Extraversion				
Agreeableness	0.47***			
Conscient.	0.22	0.34**		
Emot.Stab.	0.20	0.16	0.23*	
Intelligence	0.28*	0.37***	0.46***	0.31**

$^{*}p < .05, ^{**}p < .01, ^{***}p < .001$

Table 3.8: Spearman correlations between perceived personality traits for humanoid robot appearance

	Extraversion	Agreeableness	Conscient.	Emot.Stab.
Extraversion				
Agreeableness	0.51***			
Conscient.	0.29*	0.52***		
Emot.Stab.	0.29*	0.43***	0.53***	
Intelligence	0.39***	07***	0.64***	0.56***

$^{*}p < .05, ^{**}p < .01, ^{***}p < .001$

Discussion of Video Results

Discriminating between robots: The results suggest that the participants in the sample differentiated between the different robot embodiments in terms of personality traits. The participants rated the 'basic' appearance style significantly higher than the 'mechanoid' appearance style, and the 'humanoid' appearance style significantly higher than both for all the personality traits apart from *Emotional Stability*, in which only the 'humanoid' appearance was rated significantly higher than the 'mechanoid' appearance. This suggests that personality ratings are a viable means of differentiating between the different robot appearances.

Dimensionality of personality ratings The results also show a high degree intercollinearity within each appearance style, to the extent that

Table 3.9: Cronbach's α for personality trait ratings for each robot appearance

Appearance	Alpha
Mechanoid	0.73
Basic	0.7
Humanoid	0.82

they seem to form a unidimensional scale for each appearance type. This, suggested that these ratings were more likely the result of using the ratings as a general measure of *anthropomorphism* than of a personality profile as such. It also shows that this is stronger for the 'humanoid' robot than for the other two appearances.

Some of the results from this video study were encouraging, the use of personality ratings allowed participants to distinguish between the three robot appearances, even if the ratings seemed unidimensional. However, it is important to note that none of the participants in this study had *actually interacted with any of the robots.* Some studies have shown a clear effect of the level of embodiment of a robot in terms of interaction (Kose-Bagci et al., 2009; Wainer et al., 2006) and participant responses to robots after a live interaction along the different personality traits should also be assessed.

3.4.2 Live Interaction Study

Introduction

The main purpose of this study was to investigate the extent of which the effects observed in the video study could be replicated in live interactions with actual robots. Because of this, the study was set up to have participants interact with robots that differed from one another in terms of the degree in anthropomorphism in appearance. Because of this, participants would be asked to rate the robots in a similar manner as in the previous video study. In addition, a single Likert-scale item was included that explicitly asked the participant to rate the robot in terms of how much it was like a human.

Methodology

This data was collected as part of a wider study in human-robot proxemics which is described in more detail in chapter 5 and in Appendix 4. In this study, participants interacted with a Peoplebot[3], in one out of two conditions. In the first condition (referred to as *Mechanoid*), a standard Peoplebot was used, while in the second condition (referred to as *Humanoid*) , the robot was fitted with a humanoid head as well as a set of arms (See fig 3.5). The study was performed in the first University of Hertfordshire Robot House which was a ground floor flat near the university. This setting was chosen to increase the ecological validity of this study in terms of situating it in a human-centred environment.

Participants There were 33 participants in this study. These participants were recruited from Studynet, the University of Hertfordshire's Intranet, and were primarily students and staff at the university.

Procedure Participants would arrive at the robot house, and be given a brief standardised introduction to the experiment and a set of instructions. The experiment consisted of the robot approaching the participant in different scenarios, directions and conditions, which are explained fully in chapter 4. After the participants had a chance to interact with the robot, they were given a set of questionnaires to complete. The questionnaire relevant to this section was based on the questionnaire given to participants in the video

[3] Which was a commercially available research platform from Active Robots

Table 3.10: Correlations between personality ratings for the robot participants interacted with.

	Extraversion	Agreeableness	Conscient.	Emot.Stab.
Extraversion				
Agreeableness	0.37**			
Conscient.	0.34**	0.33*		
Emot. Stab	0.25	0.46***	0.37**	
Intelligence	0.49***	0.31*	0.13	0.41**

$* : p < .1, ** : p < .05, *** : p < .01$

study and included a set of pictures of the two different robot appearances, as well as the personality rating questions used in the video study. In addition, a sixth question was introduced: *'How humanlike did you find this robot?'*.

Research Aims There were two research questions in this study relevant for this thesis. The first was whether or not the same unidimensional nature of the participants' responses to the personality ratings would be observed after a live interaction. A significant correlation between a scale formed of these items and the item measuring explicit anthropomorphism could also be taken in support of the notion that this construct was, in fact, a measure of anthropomorphism rather than of a specific set of personality traits.

Results

Personality Traits The question of whether or not responses to the personality trait ratings for the robots formed a unidimensional scale, was addressed using a set of correlation as well as by calculating a Cronbach's α-coefficient. The correlations presented in table 3.10 suggest that the variables were correlated with each other, and the Cronbach measure for internal reliability between the different items was $\alpha = .71$.

This supported the notion of the different personality ratings forming

Figure 3.4: Personality traits by Robot Appearance

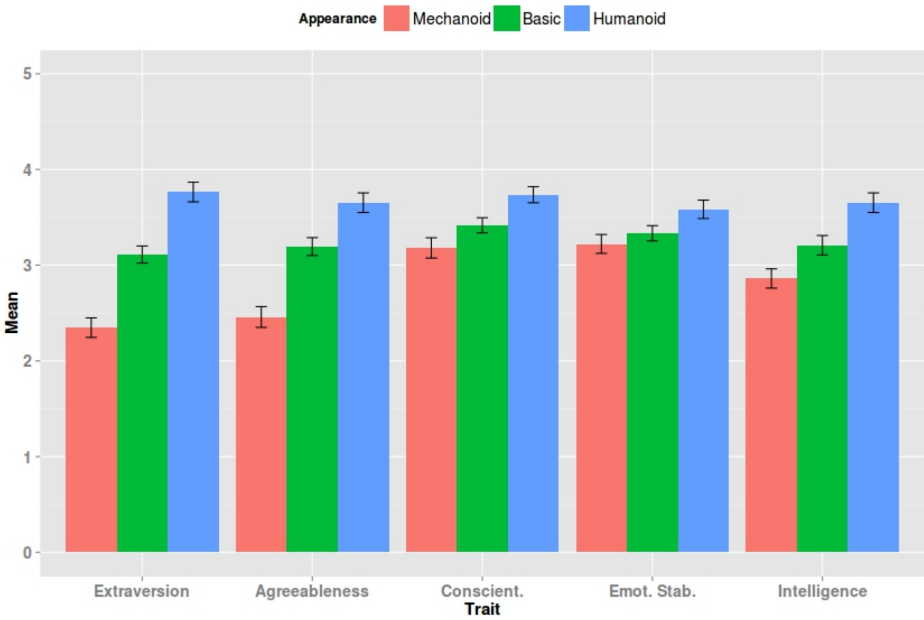
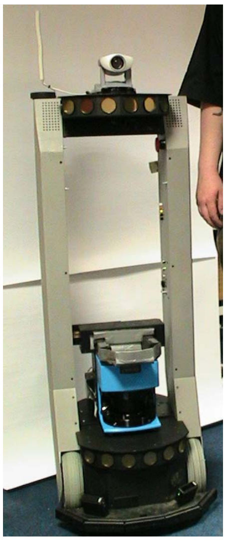


Figure 3.5: Peoplebots used in the *Interaction* study

(a) Humanoid



(b) Mechanoid

a unidimensional construct, and that the items could be used to create a scale.

Personality and Anthropomorphism In order to investigate the relationship between a scale formed of these five personality items, a scale was created using the participant responses, which was correlated with the item intended to measure explicit anthropomorphism. This correlation was significant (Spearman's $\rho(33) = .37, p < .05$). This supported the notion that the unidimensional scale was, in fact, a measure of anthropomorphism.

Discussion

The results from the live interaction study supported the results from the video study. In both, the personality trait measure used form an internally reliable unidimensional scale. In the live interaction this scale is also significantly correlated with a measure of explicit anthropomorphism.

3.4.3 Comments regarding the use of personality trait ratings

While the results from the two studies clearly supported the use of personality trait ratings as a means of discriminating between different types of responses that depended on the degree of anthropomorphism, the unidimensional nature of responses along *all five* personality traits suggest that these measures did in these studies only measure perceived anthropomorphism. This is in itself not a necessarily a bad thing, after all in terms of social expectations, one could argue that a high degree of anthropomorphism would entail a higher degree of social expectations of behaviour in general. As such, this approach to measure social expectations will be investigated further in terms of its relationship to proxemics in Chapter 4.

3.5 Measuring Data in Terms of Expected Social Roles

The findings reported above and in Syrdal et al. (2008a,0) suggest that personality measures allow us to distinguish between expectations of robots. However, they also suggest that these measures, to a large extent seem to be mostly related to a unidimensonal construct of general anthropomorphism. The studies conducted on the Frankenstein syndrome (Nomura et al., 2012; Syrdal et al., 2013b,1) also suggest that, for participants in the UK at least, social expectations, particularly in terms of human-specific characteristics, may not be without its problems. This may reduce the usefulness of personality traits (which are often considered human-specific) as a measure of social expectations and perceptions of robots in HRI situations. In fact, the results from one of the participants in the live interaction study reported above, had to be discarded as the participant refused to assign personality traits to robots on general principle. This, along with the considerations discussed earlier in the chapter, led to the decision to explore how possible users reasoned about the role of a robot within an interaction.

This was done in two stages. The initial stage consisted of an interview study in which a small group of participants were interviewed in-depth about their perceptions of a robot in a video they had recently viewed. This study found that there were clear differences in the type of role they the saw robot having, as well as the roles they wanted it to have. The reasoning behind these differences seemed to be rooted in their individual experience, as we will see below. The findings from the interview study was then combined with findings from related literature in order to develop a short questionnaire-based measure that would allow for the measurement of social expectations based on functional or relational roles.

3.5.1 Interview Study

This study is reported in full in Syrdal et al. (2010a). This study was intended to be a qualitative exploration into how expectations of robots are initially formed and then impact the interpretation and subsequent evaluation of an interaction with a robot. It was intended to be data-driven in order to examine the participants' expectations on their own terms rather than through the more narrow and theory-driven lens that would be necessary for a more quantitative examination (for instance as the predefined scales based on human personality in Fussell et al. (2008); Kiesler and Goetz (2002); Syrdal et al. (2008a)). The study presented here aimed to examine and explore these issues in contrasting case studies, using interview transcripts from three participants. Similar case study approaches had previously been used in HRI studies which have aimed for in-depth exploration of human perceptions of robots (for instance in Turkle et al. (2006). This methodology was intended to complement quantitative methods, allowing me to get an in-depth understanding of the reasoning that leads to particular quantitative results as well as open up new avenues of investigations by raising new possible research questions.

Methodology

This study was conducted by analysing the interview transcripts of three participants in a study intended to evaluate the potential usefulness of affective cues inspired by dog behaviour for the European FP7 Project LIREC.

The interviews were conducted as part of a pilot, in order to test the salience of the cues as well as to elicit responses for the development of a quantitative questionnaire[4].

The video used in this study showed a user and a guest (named Anne and Mark) interacting with a robot that used affective non-verbal cues. The behavioural cues created to be exhibited by the robot were not identical to, but were inspired by, cues used by dogs interacting with humans in the same situations. The video was created at the University of Hertfordshire Robot House, with input from a group of ethologists from the Ethology Department at Eötvös Loránd University (Budapest). The motivation for the study was that if these cues were effective, they would elicit social expectations of the robot and its behaviour that would draw upon existing mental models of dogs and dog-behaviour. The video is described in table 3.11. The underlying 'story arc' of the video was that of a friend visiting the owner of a robot who primarily used it as a moving platform for transporting objects from place to place. This task was inspired by actual tasks performed by helper-dogs for the disabled.

The robot used in the video was a modified Pioneer, a commercially available robot platform, shown in figure 3.6. While it could be argued that it is roughly the same size as a medium-sized dog, and might occupy the same amount of space, it is not in appearance particularly dog-like.

The behaviours of the robot were intended to be analogous to those of dogs. They are described in more detail in Syrdal et al. (2010a), which is reproduced in appendix B. These behaviours, while based on animal behaviours, were modified to account for the differences in sensory modalities between robots and animals as well as the reduced gestural capabilities for

[4] These responses along with a study examining the cues in a quantitative manner can be found in Syrdal et al. (2010b).

Table 3.11: Timeline of the Video

Scene No.	Description
1	Robot/Dog is in dining room. Owner enters from outside, dog/robot greets owner.
2	Robot/Dog is in dining room. Guest enters from outside, robot/dog greets guest and uses social referencing to interact with the owner.
3	Robot/Dog follows owner to the kitchen and is loaded with items for tea and biscuits
4	Robot/Dog tries to gain the guest's attention for help with unloading
5	Owner and the guest have tea and converse with the robot/dog watching.
6	Guest leaves, robot/dog engages in 'farewell' behaviour with guest.

Figure 3.6: The Pioneer robot used in the video

the robot. For instance, in situations where a dog would approach closely to smell someone, the robot would not approach as closely, and use its camera to look at the person. Also the robot would use gross body movements in situations where a dog would be more likely to just move its head.

The behaviours were intended to show differences between how the robot treated the guest and how it greeted its owner, based on their relationship. For example, it would spend longer examining the guest, while at the same time engage in social referencing behaviour (Klinnert et al., 1986) directed at its owner.

Participants

From the larger pool of participants, the interviews of three participants were chosen in order to highlight three particular approaches to understanding the robot.

Two participants were chosen due to their clear membership in the 'early adopter' demographic for consumer electronics, like personal robots. However, they had different backgrounds in terms of technical experience of robots as well as differences in exposure to dogs. This was hoped to allow for explorations into different aspects of how expectations of of robots may form.

The third participant was chosen as a contrast to the previous two. This participant did not have the extensive experience of using computers, but had had experience in using particular technical aids for overcoming problems arising from arthritis.

Participant 1 came from a science background, and was in the process of doing a PhD in the physical sciences, highly proficient with computers, capable of coding programs for data collection and analysis within his field. He grew up with dogs, and his family owned several dogs in his childhood.

Participant 2 came from a computer science background and was in the process of doing a PhD in the subject, and had experience in robotics[5].

Participant 3 was in her mid-forties, and has suffered from debilitating arthritis from an early age. While she did not have formal training in programming or use of computing equipment, she had used computers extensively in her day to day life, and before the interview made references to her experience of voice recognition software that she attempted to use as a substitute for typing, which could be painful due to the arthritis. She did not own a dog.

Procedure

The participants viewed the video and were then asked to participate in an *explicitation interview* (Light, 2006) exploring their experience while watching the video. This interview was unstructured, the dialogue mainly focused on a chronological account of the videos as well as requests from the interviewer for elaboration on statements from the participants, attempting to draw out as much information regarding the issues raised. Care was taken not to mention the dog-inspired origin of the behaviour in order to assess the legibility of the cues. Also, while participants were eventually prompted, to compare the robot to something else, this was not done until the end of the interview, and responses to this prompting was recorded and reported as such.

[5]Despite being involved in robotics research this participant was not involved in the LIREC project, and in fact, was not involved in social robotics at all

Explicitation interviews aim to evoke a revivification of the perceptual experience and one of the benefits of this is that it allows the construction of a narrative to be recorded rather than just the end-product narrative itself (Light, 2006). In this way, the technique allows us to examine how the participants describe their experiences and how these descriptions become the building blocks of a narrative in which their view of the robot emerges.

Analysis Approach

The transcripts were analysed in detail using the Grounded Theory approach in interacting with the data (Henwood and Pidgeon, 2006). This approach was chosen as its open-ended, data-driven nature was deemed suitable for the exploratory nature of this investigation. The initial open coding focused on identifying and coding themes relating to how the participants described the behaviour of the robot and the robot itself. Early on in this process, the salient themes became those relating to attribution of agency, emotive descriptions, referencing of personal experience, descriptions of robot behaviour, and the use of metaphor in describing the robot. This was followed by axial coding, in which the initial themes, and their relationships with each other, were examined across the transcripts of the participants.

In this analysis, participant expectations of the robots were conceptualised as mental models, due to the reliance of explicit reasoning from the explicitation interviews.

Results

For a more in-depth, comprehensive analysis of these interviews, please refer to Syrdal et al. (2010a) reproduced in appendix B. This section will briefly recount some of the findings from the analysis.

Personal Experience The participants grounded their descriptions of the robots and their reasoning about it, within their own experience. Participant 1 referred to their childhood experience of growing up with dogs, Participant 2 took an interest in finding out how the robot could be improved and Participant 3 referenced their own experiences with assistive technologies. Despite this, the robot was not a completely blank slate upon which the participants projected their own needs and experiences, rather it was an interaction between the presentation of the system and the idiosyncrasies of the viewer that led to the formation of the explicit mental models of the robot that were explored in the interviews.

Divergence This is supported by the analysis of the interview transcripts which suggests that Participant 1 and 2 both took an interest in and interpreted the zoomorphic cues as they were intended. They both saw them as communicating emotive information and they both referred to dog behaviour when attempting to describe them. Individual differences did, however, cause them to diverge from this joint narrative, particularly in regards to how dog-like they saw them. Participant 1 repeatedly referenced their own rich experience of dog-behaviour when describing and reasoning about the cues and their purpose, while Participant 2, on the other hand, referencing dogs, also referenced children as well as attempting to reconcile a more technical deconstruction of the robot's behaviour with the affective dimension of the cues.

This divergence also impacted the participants' overall evaluations of the robot in the later stages of the interview. Participant 1's dog-based mental model, while useful for understanding the robot, also seemed to have led to an overall unfavourable evaluation of the robot and its utility, especially when their rich mental model of 'the robot as a dog' led to direct comparisons of the robot with actual dogs. Participant 2, on the other hand, while successfully interpreting the robot's behaviour by using a mental model still reliant on dog metaphors, incorporated other, more technical aspects into this model, which allowed them to look for practical means that could be implemented to allow the robot to overcome its lack of sophistication.

Participant 3, in contrast to both the other participants, did not consider the affective communication aspect of the interaction in her descriptions, choosing instead to focus on the task related aspects of the video. When considering the interactions, Participant 3 focused on ease of use as well as acceptability. They also referenced their own experiences with assistive technologies as well as specific instances where the robot, as it was being portrayed in the video, would be of use.

Dimensions of Divergence The manner in which the participants diverged is reminiscent of that described by Fischer and Lohse (2007), which suggest that there are three main ways in which users approach interacting with a robot, the first is to consider it purely as a mechanical tool, the second is to apply approaches learned from human-human interactions, while the third is to actively elicit information about its technical capabilities.

In this study, all three approaches were evident in how the participants reasoned about the robot. However, the differences between participant 1 and participant 2, who both initially seemed to rely on zoomorphic approaches to interacting with the robot, suggest that rather than being categories that an individual can be a member of, these approaches can be understood as dimensions, and that it is possible for one participant to apply all approaches to differing degrees. If this is the case, then these expectations can be assessed in a similar manner as one would assess those based on human personality.

3.5.2 Developing and Deploying the Social Roles Questionnaire

Based on the work of Dautenhahn et al. (2005), Fischer and Lohse (2007), and Ezer (2009), as well as the interview reported above, a brief questionnaire instrument was devised. This questionnaire, referred to as the University of Hertfordshire Social Roles Questionnaire (UHSRQ), was intended to be used as a supplement to other measures within planned studies conducted within the Adaptive Systems Research Group. Because of this, it needed to be brief enough to not add noticeably to the burden of the participants, and it needed to address the possible social roles that was envisaged for the Robots and Interactive Companions in domestic settings that the UH work within the LIREC and ACCOMPANY projects encompassed. It incorporated 3 items which related to roles based on human interactions (*Servant*,*Friend*,*Colleague*), one item related to zoomorphic interactions (*Pet*), and one item referring to more traditional human-machine interactions (*Tool*). These items were made into Likert scales and are also described in Table 3.12.

This questionnaire was deployed in a survey, in order to investigate the relationship between the items and perform a tentative validation by comparing responses to these items with other usage of computing technology amongst the participants. The initial investigation into the relationship between these items is described in Koay et al. (2014) and summarised here.

The participants in this study were visitors at the Science Gallery in Dublin, Ireland, who were asked to complete a brief survey running on an unattended computer at the HUMAN+ exhibition [6]. This exhibition was an exploration of future possibilities in fields such as genetics as well as robotics and so featured several different robots. The computer used in the survey was part of the exhibit *My Familiar Robot Companion* created by the artists Anna Dumitriu and Alex May in collaboration with researchers from the Adaptive Systems Research Group (Walters et al., 2012). The questionnaire itself consisted of two parts: The first part included demographic information including age and gender, as well as a questions regarding the participants' computers use. These questions were regarding the amount of time the participants spent interacting with computers as well as which single activity they used computers the most for:

- Work/Studies
- Social Media/Email
- Games
- Hobbies
- Other.

The second part consisted of the statement: *'If you were to have a robot, would you like to interact with it as a:'*, followed by the five different possible social roles shown in Table 3.12. The participants were given the opportunity to rate their agreement/disagreement on 5 point Likert scale. While there was a variety of robots and robotic installations within the exhibition, no further guidance as to what sort of robot was being referred to was given to the participants.

[6] http://sciencegallery.com/humanplus/exhibits/

Table 3.12: Social Role Questionnaire Items

Item	Dimension
Servant	Control
Friend	Equality
Tool	Control
Colleague	Equality
Pet	Pet

Table 3.13: Computer Use in Dublin Study

Category	Participants	Percentage
Social Media/Email	114	27.5
Games	63	15.2
Work/School	180	43.4
Hobbies	20	4.8
Other	38	8.2

Results

Demographics 211 males and 214 females responded to the survey. The mean age was 24.8 years, the majority of participants, however, clustered around the age of 20. In terms of computer usage, mean hours per week spent using a computer a week was 21 (median 15). Table 3.13 suggests that the most common usage category with regards to computers was professional/academic use, social media/email was the second most common, and games was the third most common category.

Social Roles Participant responses suggested correlations between the different items in the questionnaire reported in Table 3.14. The structure of these correlations were addressed using a Principal Component Analysis. The initial analysis used the Kaiser criterion (Kaiser, 1960) and found 2 components with an eigen-value about 1. The *'Pet'*-item, however, loaded equally on both variables. This led to a re-examination of the components using the Cattell extraction criteria (Cattell, 1966), which suggests visually assessing the scree-plot and choosing the point at which the slope 'evens out' to better represent of the underlying structure of the data. This Scree Plot is described in Fig. 3.7 and suggests that three factors could be a valid way of of representing this structure, and a 3-factor solution was tentatively chosen. These 3 factors, along with their Varimax rotated loadings are described in Table 3.15.

The first dimension was tentatively called *Equality* as the variables Friend and Colleague loaded on this dimension. A high score on this could suggest that the participant expected to have the robot act in a manner suggesting an equal (social) footing to themselves within interactions, while a low score would suggest the opposite (i.e. that the robot adopts a more deferential role).

The second factor was tentatively called *Control* as the variables Servant and Tool load on this factor. A high score on this dimension would suggest that the participant expects the robot's social role to be one in which the user will exert a high degree of control, while a lower score would suggest that the robot is expected to act in a more autonomous manner.

The third dimension deals almost solely with the *Pet* variable. This suggests that interactions associated with pets are not fully covered by our expectations in terms of equality and control. However, this third factor explains less than the variance of one of the items.

It is also important to note that these are positive expectations. A high score along any of these dimensions suggest that a participant expects and would like to interact with a robot in this manner.

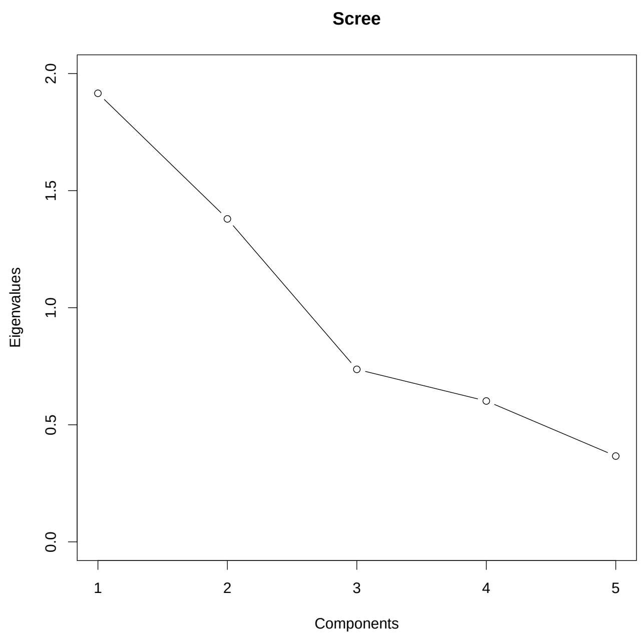
Social Roles and Computer Usage The relationship between the scores along these factors and computer usage was also assessed. The mean score

Table 3.14: Correlations between Social Roles in the Dublin Sample

	Friend	Servant	Pet	Colleague
Friend				
Servant	-0.09			
Pet	0.25***	0.18***		
Colleague	0.62***	-0.09	0.22***	
Tool	-0.34***	0.37***	-0.02	-0.23***

$*p < .05, **p < .01, ***p < .005$

Figure 3.7: Scree-plot



for each factor according to computer usage is described in Table 3.16 and Figure 3.8. There were significant differences in Social Role Factor scores between the different computer activities for all three Social Role Factors.

For *Equality* there was a significant effect for most common activity (Kruskal–Wallis $\chi^2(2) = 12.58$,p< .001. Post-hoc Wilcoxon tests found that participants listing 'Games' as their most common activity scored significantly higher than the two other groups of participants (d< .21, p< .001, corrected α=.03), but there were no significant differences between partic-

Table 3.15: Factor Loadings for Social Role item

	Equality	Control	Pet
Friend	0.86*	-0.17	0.17
Servant	0.02	0.81*	0.24
Pet	0.14	0.09	0.97*
Colleague	0.91*	-0.04	0.03
Tool	-0.23	0.81*	-0.11

* *loads on this factor*

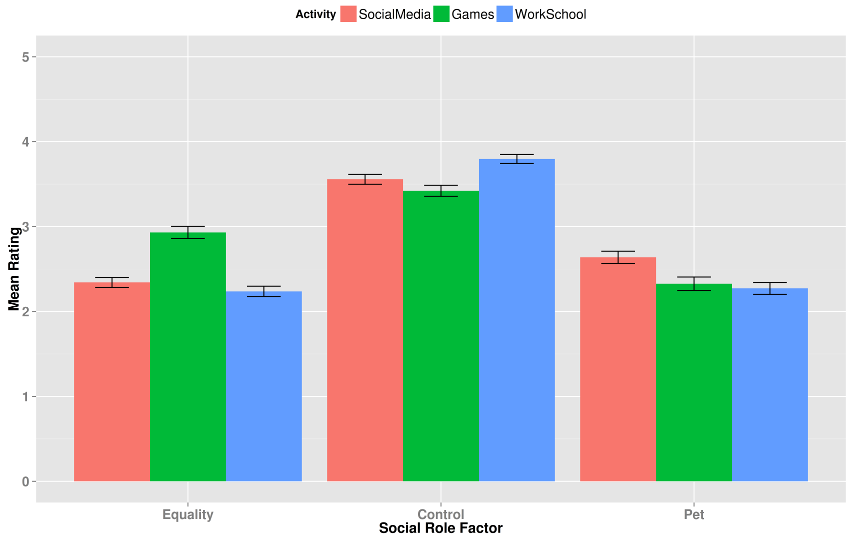
ipants who listed 'Social Media' as their most common computer activity and those who listed 'Work/Studies' (d=.13, p=0.33, corrected α=.03).

For *Control* there was a significant effect for most common activity (Kruskal–Wallis$\chi^2(2)$ = 6.07,p< .05. Post-hoc Wilcoxon tests found differences approaching significance between 'Work/School' and 'Games' (d=.20, p=.04, corrected α=.03) and between 'Work/School' and 'Social Media' (d=.24, p=.05, corrected α=.03), but there was no salient, nor significant difference between 'Social Media' and 'Games' (d=.05, p=.53, corrected α=.03).

For *Pet* there was a trend approaching significance for most common activity (Kruskal–Wallis $\chi^2(2)$ = 5.36, p= .06). Post-hoc Wilcoxon tests found participants listing 'Social Media' would score significantly higher than participants listing 'Work/School' as their most common computer activity (d=.29, p=.02, corrected α=.03) and a non-significant trend suggested that this was also the case when comparing 'Social Media' to 'Games' (d=.12, p=.12, corrected α=.03).

Social Role Summary The results support to some extent the categories described in Fischer and Lohse (2007), in that there were two main dimensions of expectations, and these can be interpreted as two of the categories that they put forth. The *Equality* dimension of expectations are those of

Figure 3.8: Social Role Factor Scores according to Computer Activities



participants who expect the robot to take on a role in which they are expected to interact with it using anthropomorphic social approaches, while the *Control* dimension relate to expectations in which the participants expect to interact with it in a manner in which they exert more direct control, and these two dimensions map neatly on the categories of Fischer and Lohse. It is important to note that these are two dimensions rather than two poles on one dimension, which one would be more likely to expect if one considered these approaches to be exclusive categories. In addition, these dimensions were correlated with each other, and in this study seemed related to an underlying construct which was willingness to interact with a robot at all. The *Pet* item seemed to not completely occupy either dimension, and as such was considered on its own.

These results also supported the notion put forward in section 3.5.1 and in Syrdal et al. (2010a), in that the expectations that participants may initially have of a robot are rooted in idiosyncratic factors that can to some

Table 3.16: Social Role Factors according to Computer Activities

	Activity	Mean Score	Median	SD
Equality	Social Media	2.34	2.5	1.06
	Games	2.93	3.0	1.33
	Work/School	2.24	2.0	1.12
Control	Social Media	3.56	3.5	1.05
	Games	3.42	3.5	1.18
	Work/School	3.80	4.0	0.97
Pet	Social Media	2.64	3.0	1.32
	Games	2.33	2.0	1.43
	Work/School	2.27	2.0	1.26

extent be traced to their personal history. The highest scores for *Equality* were found in the group of participants who rated *Games* as their primary computer activity. It is likely that exposure to games in which participants collaborate and compete with characters apparently controlled by artificial intelligence within computer games may have led to this group of participants viewing interactions with computational artefacts as happening on a more equal footing. In addition, the enjoyable, intrinsically rewarding nature of game-playing may have led to expectations of interactions that were more social in nature.

Participants who reported *Work/School* as the most common type of computer use, comprised the group scoring the highest in the *Control Dimension*. One explanation for this would be the need for control and efficiency in terms of the use of computers in this setting. These interactions would be less intrinsically motivated than game-like interactions, and as such, would be less social in nature.

Participants who reported *Social Media* as their most common use of computers, were the ones who rated the *Pet Dimension* the highest. This might reflect the traditional dual purpose, occupied by many pets,having both an intrinsic social value as well as their value in terms of the services that they can perform (Crowell-Davis, 2008) and this might be reflected in this group of computer user.

3.6 Chapter Summary and Conclusions

This chapter demonstrated two means of examining social expectations of robots. The first means is the use of human personality traits. As suggested in section 3.1, while this allowed for differentiation between different robotic embodiments that varied in terms of anthropomorphism, in the studies performed at the UH robot house, this measure seemed only to measure the degree of anthropomorphic expectations that the participants had of the particular robotic embodiment.

Because of this, and based on literature suggesting that user expectations to some extent can be understood as interactional expectations, the UHSRQ, a set of questionnaire items based on high-level social roles that the robot could occupy was devised and tested in a survey of visitors to a museum. This survey found that responses to these items could be mapped to constructs suggested by previous literature. They could also, tentatively, be related to the individual's past interaction history with computers. This lent some support to their validity for use in examining social expectations in human-robot interaction.

Unlike the work of Ezer (2009), the work in this thesis holds that measures in human-robot interaction need to be practical, i.e. they should be deployable as part of live interaction studies, and be able to show effects even in the relatively small numbers of participants one normally would get for such complex studies. As such, the value of either of these types of measures must be considered in terms of their relationships with other measures relevant to HRI. In the next chapter, we will consider one such element of

Human-Robot Interaction, that of *proxemics*.

Chapter 4

Proxemics

Chapter

Overview

In the previous chapter, two different approaches to measure social expectations using questionnaire-based instruments were discussed. The first approach was the use of questionnaires using personality trait descriptors used for the assessment of human personality. This approach seemed to only truly measure the degree of anthropomorphism that the participants attributed to the robot. The second approach used questionnaire items based on functional and relational roles that a robot companion could occupy. This chapter describes efforts to examine these constructs in live human-robot interaction scenarios, which focus on the study of how human and robots should negotiate social spaces together, also known as *human-robot proxemics*.

4.1 Introduction

4.1.1 Proxemics as a test-bed for Social Interactions

Proxemics is the study of interpersonal spacing in social situations, and as such has received the attention of several branches of the social sciences. The term was coined by Hall and Hall (1969), who used it to compare differences between cultures, in terms of absolute distances between humans within interactions. Other researchers in the field highlighted the importance of relevant orientation (Kendon, 1990). It has also been a focus of interest within the field of HRI (Takayama and Pantofaru, 2009; Walters et al., 2009). From a purely practical perspective, this is rooted in one of the main discernible differences between robots and other types of technology, which is that robots can move in a manner seemingly independent from a human controller. This means that when deployed in human-centred environments, the ability to negotiate spaces with humans in a socially acceptable manner while performing their functions is a necessity (Huttenrauch and Severinson Eklundh, 2002). Much of the research in this particular subfield of HRI has investigated the similarities and differences between human-robot proxemics and human-human proxemics, this has included topics such relative facing (Woods et al., 2006), the role of gaze (Wiltshire et al., 2013), interaction context(Walters et al., 2009) as well as the longitudinal aspects of the interaction (Koay et al., 2007b; Walters et al., 2011), and overall findings suggest that there are many similarities between human interactions and interactions between humans and robots. In fact, some research suggests that the manner in which humans negotiate social space with robots is in itself a source for understanding how humans view robots in terms of their social role (Kim and Mutlu, 2014), and proxemics remain both a conceptual and technical challenge in HRI (Lindner, 2015).

4.1.2 Early contributions to HRI Proxemics

The main contribution of the early research conducted as part of this project has been in investigating the role of individual differences in human-robot proxemics in order to establish comparisons with phenomena observed in human interactions, as well as examining the role of proxemic interactions in terms of relationship building.

Individual Differences in HRI Proxemics

An initial investigation, published in Syrdal et al. (2006), report on a live human-robot interaction study in which participants were approached from several directions. This study examined the role of personality traits in human-robot interaction. In this study, extraversion was associated with greater tolerance to proxemic behaviours which overall were found to be less comfortable to participants. This suggested that participant responses to the robot were social. If this had been general discomfort due to a threatening object coming too close, it is natural to assume that Emotional Stability (or neuroticism) would be the trait had an impact on this tolerance. The role of extraversion, a trait that to a large extent is related to social situations (Matthews et al., 2003), did in this study suggest that it was the social nature of the situation that was responsible for this effect. However, the size of this effect was quite small, and so it was difficult to make any strong conclusions on this basis.

The second investigation is reported in Syrdal et al. (2007b). In this study, 33 participants interacted with PeopleBots[1]. Distance, approach di-

[1] A commercially available research platform, see figure 1 in appendix A for an illustration.

rection, interaction context as well as the participant's ability to control the robot's approach distances were varied. This study found that gender and extraversion both contributed to participants' proxemic preferences and behaviour in a manner that was congruent with what could be expected in human-human interactions.

Proxemics as Relationship-building

In human-human interactions, proxemic behavior and interpersonal spacing is a highly communicative act. Kendon (1990) gives several examples of how humans manage and signal the quality and nature of their interactions through continuous maintenance of appropriate spatial behaviour. Hall and Hall (1969) and Mehrabian (1969) both offer evidence of proxemic behaviour as indicative of the interactants' relationship, mutual attitude and relative status to each other. In fact, Burgoon and Walther (1990) suggest that proxemics behavior can dramatically alter the nature of our relationships, and that changes in how we feel or reason about the people we interact with, depend on responses to such changes in proxemic behaviour. With such richness in human-human interaction being dependent on this spatial interactional dimension, whether or not proxemic interactions may have an impact on human-robot relationships is a valid question.

A study reported in Syrdal et al. (2013a) investigated the role of proxemic interactions in terms of building social relationships between robots and their users. In this study, a small group of participants took part in a long-term study in the UH Robot House, which involved 10 interaction sessions over a space of 6 weeks. They interacted with two different robotic embodiments, who were identical in terms of functionality and expressive capabilities, apart from one being able to move in the shared space with the participant, while the other could not. The findings from this study suggest that participants felt closer to the mobile embodiment as measured by the Inclusion of Other in the Self Scale (IOS) (Aron et al., 1992), as well as rating the mobile robot higher along the *Likeability* dimension of the Godspeed Questionnaire (Bartneck et al., 2009b).

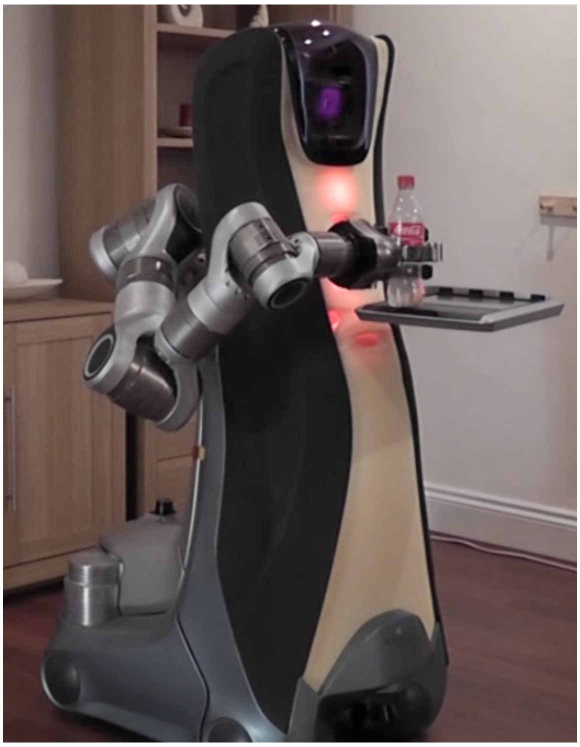
These findings, along with the other cited research within HRI, suggest that human proxemic behaviour and preferences in human-robot interactions are likely to be influenced by social expectations and perceptions of the robot. The work performed as part of this PhD project consists of two stages. The first stage focused on attributed personality traits as social expectations and the on social role expectations.

4.2 Personality Traits

The work focusing on the use of personality traits to describe social expectations of robots, and their impact on proxemics, has been published previously and has been reproduced in the appendices for this thesis. A brief summary will follow.

Syrdal et al. (2008a), reproduced in appendix A, reanalysed the data from the study described in Syrdal et al. (2007b). In this study, 33 participants interacted with two robot varied along two levels of anthropomorphism in their appearance(see fig 1 in appendix A). Participant proxemic preferences were measured using the University of Hertfordshire Subjective Feedback Device (UHSFD), and their post-experimental evaluations of the interactions were measured using comfort scales similar to Syrdal et al. (2006) and Woods et al. (2006). The findings from this study suggested that there was a strong impact from perceived humanlikeness on proxemic preferences. This suggests that robots that are perceived as more human-like, are also subject to higher expectations of conformity to proxemic social norms. However, violations of these proxemic norms did not transfer into a negative evaluation of the interaction. This was likely due to this particular appearance having been rated as more desirable in previous studies (Walters et al., 2008), and as such, this general liking for this robot appearance might have made the participants more charitably inclined to the robot and more forgiving of its violations of their proxemic expectations. This again, suggested that measuring social expectations using a unidimensional scale which (for the majority of participants) is positively correlated with overall evaluations of the robot might be problematic to tease out the complexities of social expectations and proxemics. This would again suggest that focusing on the interaction-based social roles might be more helpful.

Figure 4.1: Care-O-bot®3 placing a bottle on its tray



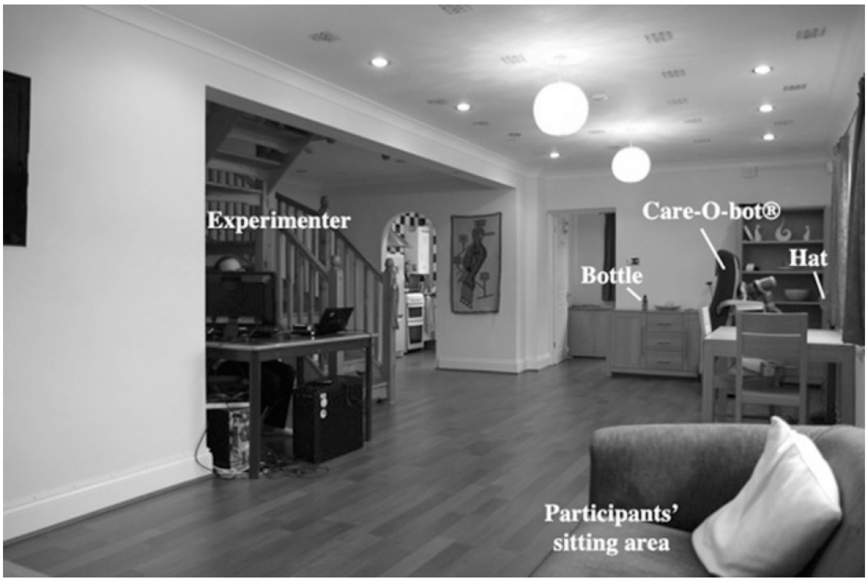
4.3 Social Roles and Proxemics

From a human-human perspective, the emphasis on social roles is in accord with much of the literature on proxemics. Both in terms of the interpersonal distances reported in Hall and Hall (1969) as well as the spatial groupings demonstrated in Kendon (1990), it is the situations and the relationships between people that are the most important in determining how proxemic behaviours are formed. While personality traits or other idiosyncratic factors do play a role in terms of peoples' actual preferences, in particular regarding the experiences of personal space violations, it is a small role compared to situational modifiers, relationships, relative status, gender and other external constraints (Hayduk, 1983). This suggests that, for human-robot proxemics, the perceived social role and status of the robot within the interaction needs to be considered. Therefore, due to the relationship between social role and human-robot proxemics preferences as suggested by the recent work by Kim et al. (2013), and Choi et al. (2013), the prospective users mental model of the robot in terms of social role expectations needs to be assessed.

4.3.1 Setting

This study was conducted in the UH Robot House, which will be described in more detail in Chapter 5. For the purposes of this study, it is enough to state that it is a space dedicated to HRI Studies in an ecologically valid domestic environment as compared to laboratory conditions. The UH Robot House has two floors, four bedrooms and is a fully furnished British house. Only the living room was used for this study. Figures 4.2 and 4.3 show the trial setup, indicating the initial locations of the robot, participant, experimenter and relevant objects within the trial area.

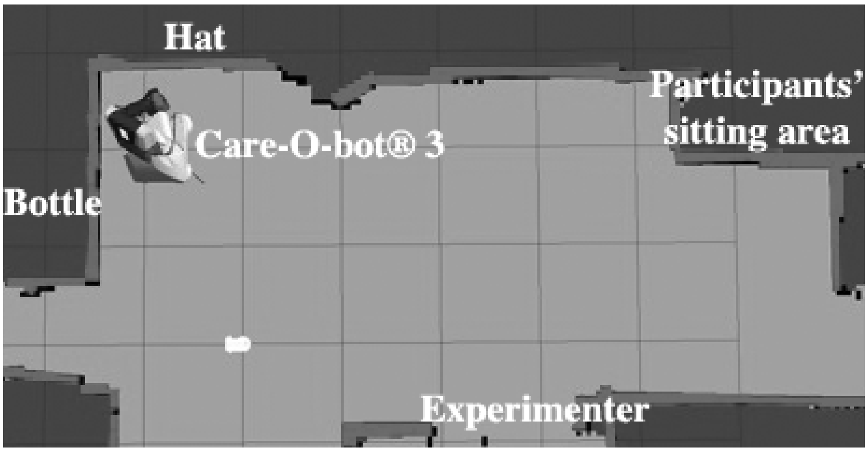
Figure 4.2: The setup and locations of the robot and participant, experimenter and objects within the trial area (Photo)



4.3.2 Robotic Platform

The robotic platform used in this study was a Care-o-bot®3 (Parlitz et al., 2008). This robot is not humanoid in appearance(see figure 4.1), but roughly human-sized. It is capable of omni-directional navigation and is equipped with a highly flexible, commercial arm with seven degrees of freedom as well as with a three-finger hand to support fetch and carry tasks. It has a tray to serve objects and a touch screen panel to facilitate user interaction. The deliberately chosen non-human appearance was designed by a professional team of designers. In order to reduce explicit anthropomorphic attributions, which have been shown to lead to unrealistic expectations of users in HRI. Any specific parts that resemble a face or head, or produce gender specific expressions were avoided. This would allow the robot to be a 'blank canvas' that the user's could project their own expectations of behaviour unto (Woods et al., 2005).

Figure 4.3: The setup and locations of the robot and participant, experimenter and objects within the trial area (Map)

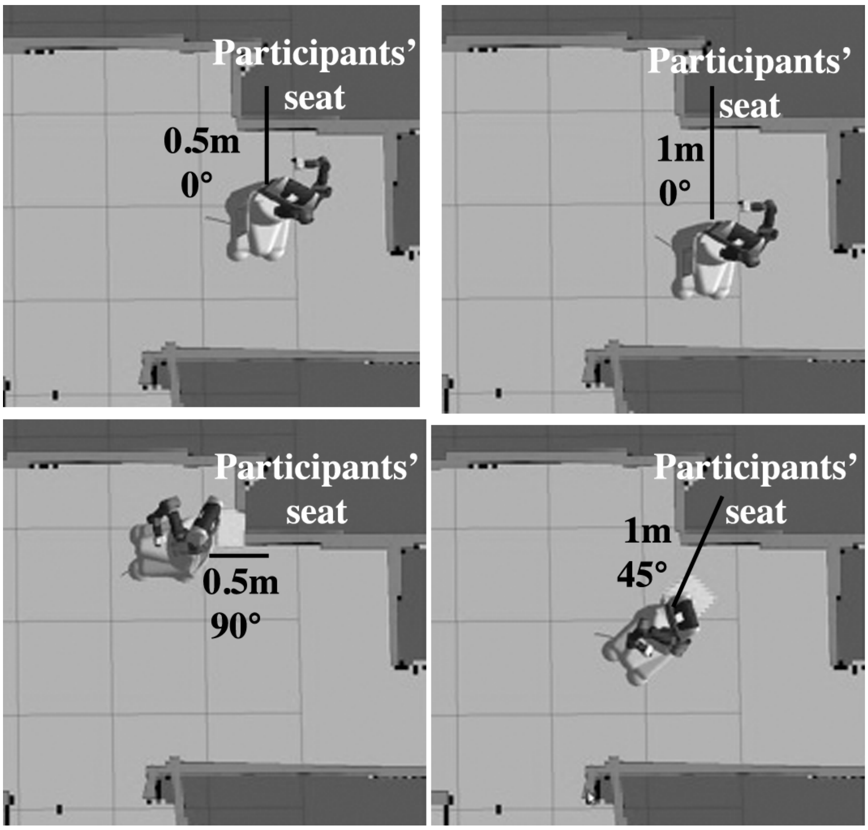


The Care-O-bot®3 supports basic body gestures like bowing or nodding and is capable of utilising a LED light display signals, sound and speech to provide feedback to the user. It is equipped with several laser range scanners, tactile sensors on the fingers, and a stereo camera in the head. In this study, the Care-O-bot®3 was used for fetching either a bottle of soft drink or a woolen hat from their designated locations to the participant who was seated on the sofa. The scenario for the experiment assumed that users require physical assistance from the robot, either by serving a drink or handing over clothes required for going out. The Care-O-bot®3 used its manipulator to take an object from the designated location, and then present it to the participant. If the object was a soft drink bottle, the robot raised its tray, and subsequently placed the bottle on it. If the object was a hat, the robot carried the hat with its hand in front of its chest. It then moved toward one of the four designated pre-defined Human-Robot Proxemic (HRP) poses (position and orientation, see figure 4.4) around the participants to present the object to the participant. In terms of robot control, the experiment used a combination of Wizard-of-Oz (WoZ, a technique which originated in HCI but has been used widely in HRI (Green et al., 2004; Koay et al., 2009)) and autonomous behaviour, as an experimenter would start each step of the sequence.

Signalling Intent

While user expectations and preferences, that arise from the context, platform and social role expectations, can be considered important implicit factors in forming proxemic expectations, there may still be ambiguity which reduces the predictability of the robots behaviour. Humans, and to some extent humanoid robots, have quite a wide range of modalities through which they can signal their proxemic intentions or mitigate violations of proxemic expectations (Burgoon and Jones, 1976). The Care-O-bot®3 despite its human-like size should still be termed an appearance-constrained robot (Bethel and Murphy, 2008). By this, we mean that its appearance is highly constrained by the physical tasks that it is expected to do, as opposed to robots that are intended purely for social HRI tasks, such as KASPAR (Dautenhahn et al., 2009), Geminoids (Ishiguro, 2006), Paro (Wada and Shibata, 2007), or toys like the AIBO or Pleo (Friedman et al., 2003; Jacobsson, 2009). Robots that are constrained in terms of appearance may have to rely on explicit signalling, which sometimes may draw on animal behaviour (Koay et al., 2013; Syrdal et al., 2010b), but are often presented as arbitrary signals, possibly drawing on signalling conventions (e.g. derived from traffic rules (Bethel and Murphy, 2007), to communicate and disambiguate their intentions. The Care-O-bot®3 has an LED display panel which can be used to provide a simple and identifiable feedback signal to facilitate user interaction and safety. This study proposed that the use of simple, colour-coded LED displays can alert the user to ambiguous behaviour which might be potentially hazardous. These LEDs to were signal the main types of behaviour which the robot is currently engaged in. Of interest was both the ability of participants to notice and interpret these signals, and the impact on participant proxemic preferences. Also of interest was how participants conceptions of the robot in terms of social role expectations might influence this.

Figure 4.4: Care-o-bot®3 stops at the four pre-defined HRP approach positions used in the trial. Clockwise from top is the Front Close, Front Far, Side Far and Side Close HRP poses



4.3.3 Relation to Main Research Questions

Overall

This study contributed to the second research question outlined in Chapter 1 by assessing whether or not the role-based measures of social expectations could be used to understand participant preferences in terms of proxemic behaviour. This study's main focus was on determining the participants' overall preferred Care-O-bot®3's pre-defined HRP poses for presenting the two different objects to the participants. This was to create a baseline for designing subsequent interactions with the robot in future studies, so that participants would be comfortable in them. It was also conducted in order to compare proxemics preferences for the Care-o-bot®3 with studies that used different platforms like the Peoplebots used in Koay et al. (2007b). In these studies (for more detail see the studies discussed in section 4.2 and Appendix A) it seemed that relatively minor changes in the appearance of a robot would have a large impact on proxemic preferences, and as such an investigation into the preferences that participants would have of this particular embodiment was necessary. Two different modes of handing over an object to the user were investigated in order to study if proxemic preferences (i.e. how closely and from which direction they preferred the robot to approach) would be influenced by how they were served by the robot.

Social Expectations and Proxemics

In addition to the effect of the appearance of the robot platform, the social nature of the interaction might also impact proxemic preferences. Handing over a bottle is an interaction that might vary based on the social roles of the interactants. Kendon (1990) suggests that positioning based on gaze is important to emphasise the social dimensions of an interaction. Positioning in such a way that mutual gaze is encouraged (such as during a frontal approach) makes an interaction between the two interactants more social in nature, while an interaction in which one interactant is outside of the field of vision of the other is much less so. This suggested that high scores on the *Equality* dimension would presuppose a relationship in which the handing over interaction is a social occasion and so participants with a high score on this dimension should prefer that the robot hands over the bottle from the front to a larger extent than those with lower scores on this dimension.

Likewise, the roles in the *Control* Dimension pre-suppose a more subservient relationship where the robot is more of a servantlike entity, and as such approaches from the side should be preferred to a larger extent for participants with higher scores on this dimension.

On the other hand, the handing over of the hat required more coordination and effort between the robot and the participants in terms of movement, and so here, the context would be a stronger influence than the expectations arising from perceived social role.

Social Expectations and Signalling

The ability of the participants to correctly identify and recognise the intent behind the use of the LED signals was also of interest, especially as it related to the Social Role expectations that the participants had of the robot. If participants Social Role expectations were high on the *Control* dimension, their expected interactions would be characterised by more direct control and oversight of the robot, and as such, there would be less need to infer the robot's intention based on its signals, and less interest in the robot's internal states. The converse should be true for participants scoring higher on the *Equality* dimension.

Hypotheses

- Hypothesis 1:
  - Scores on the *Equality* dimension will correlate with positive ratings on the frontal approach for the Bottle Condition.
- Hypothesis 2:
  - Scores on the *Control* Dimension will correlate with positive ratings on the side approach for the Bottle condition.
- Hypothesis 3:
  - Participants correctly identifying the LED signals will have a higher score on the *Equality* dimension than those who do not.
- Hypothesis 4:
  - Participants correctly identifying the LED signals will have a lower score on the *Control* dimension than those who do not.

4.3.4 Methodology

The overall context was that of a first encounter interaction with the robot (i.e. a guest being served by Care-O-bot®3). The robot would approach the participants for this purpose to the four positions defined above.

The robot used speech and simple expressive behaviours (i.e. different colour LED light signals) to provide feedback to the user as described previously. The different colour LED lights in the robot's chest essentially displayed an Interaction Alert Level. The Interaction Alert Level corresponded to the potential level of hazard present in the task or actions the robot was currently executing, in order to facilitate safe interaction between the user and the robot. The Care-O-bot®3 displays a steady white colour when was ready/safe for interaction, a blinking yellow colour to signal to the user to be cautious around the Care-O-bot®3 when it was moving or navigating and a blinking red colour when it was moving its arm. The purpose of this expressive channel was not revealed to the participants during the trial in order to see if participants could intuitively derive the meaning of the robot's coloured LED light signals.

Procedure

Two experimenters were involved in the trial. An experimenter introduced and explained the trial procedure to the participants, handed out questionnaires to the participants and answered any questions participants might have about the trial. There was also a roboticist present who monitored the robot to ensure it executed its tasks as planned, and monitored the safety for the participants (via a wireless emergency stop button for the robot).

Introduction Participants were initially introduced to the UH Robot House and the Care-O-bot®3. They signed a consent form and completed a demographics questionnaire and a questionnaire regarding social roles, the UHSRQ. They were then shown a live demonstration of the robot autonomously executing its tasks which was based on Condition Bottle (see below). The participants were free to move around to see how the robot performed its tasks. The demonstration was to settle any initial curiosity the participants may have regarding how the robot might perform fetching and presenting objects during the trial.

Figure 4.5: An example of a left-handed participant fetching an object from Care-O-bot®3's tray/hand at the four pre-defined approach positions used in the trial. Clockwise from top is the Front Close, Front Far, Side Far and Side Close HRP poses

Main Trial The main trial consisted of the Care-O-bot®3 fetching and presenting two objects to the participants, delivering it to one of the four possible positions/orientations.The order of approach direction and distance was randomised for each object.In addition, the order of the objects was also randomised. However, a participant would experience all approaches for each object before being exposed to the next object.

The Bottle Delivering the bottle involved the robot leaving its station to fetch a soft drink bottle, lift its tray, place the bottle on its tray, park its arm, move to one of the pre-defined points and present the bottle, using speech (i.e. *'Here is your drink'*) to invite the participants to take it. After the bottle was taken, the robot moved back, lowered its tray and returned to its station.

The Hat Delivering the hat involved the robot leaving its station to fetch a hat from its peg on the wall, move the hat with its hand positioned to its front end in front of its chest, move to one of the pre-defined points, then present the hat, using speech (i.e. *'Here are your clothes'*) to invite the participants to take it. After the hat was taken, the robot moved back, parked its arm and returned to its station. See fig 4.5 for examples of the robot delivering objects to a participant.

For both objects, the participants were asked to sit at a designated location on the sofa. Each condition was repeated four times, each with the robot ending its approach at a different pre-defined point around the user. At the end of the fourth approach for each object, participants were then asked to complete a second questionnaire regarding their experiences before they proceeded to experience the other object.

Final Questionnaire Participants were then asked to complete a final questionnaire, which asked them to recall the colour displayed by the robot's LED display when it moved its arm and when it moved around the room and why the colours were different.

Measures

Participants' social role expectations of the robot were assessed in a pen and paper questionnaire using the University of Hertfordshire Social Roles Questionnaire (UHSRQ) which is described in the previous chapter.As in the survey described there, the term robot was not more closely defined, although the participants had seen the Care-O-bot®3 at this point. Participant responses to the robot's approaches were assessed using a questionnaire. An ad-hoc questionnaire was created for this study, building on previous re-

Table 4.1: Questionnaire items used to assess the participant responses to robot approaches in the study

Item	Factor
It made more sense for giving me this object than some of the other approaches.	Practicality
It was intimidating compared to some of the other approaches.	Hedonic
It was less practical for taking the object than some of the other approaches.	Practicality
It made me feel more comfortable than some of the other approaches.	Hedonic

search carried out at the UH Robot House. These findings suggest that while responses to proxemic behaviour are often discussed in terms of practicality, there are also other factors such as comfort or feelings of threat, that may impact how a participant evaluates an interaction. These factors can be referred to as hedonic factors (Koay et al., 2007b; Sisbot et al., 2005). Due to the large number of approaches, brevity was a major concern in the questionnaire design, with four items being considered the highest number that participants could be expected to complete per approach. The items are presented in table 4.1, and were presented as Likert scales for which participants were asked to rate their response in term of agreement (i.e. 1: Completely Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Completely Agree). After each condition run, participants were also asked to choose which approach was the most comfortable and practical. At the end of the trial, a series of open-ended questions was used to assess participants recall and comprehension of the LED signaling.

Participants

The participants for this study were recruited through advertisements on UH mailing lists and the University Intranet. The sample consisted of participants that were freshly recruited for this study. These participants had never visited the UH Robot House nor seen a real Care-O-bot®3 prior to the study. As such their experiences might be equivalent to a first encounter situation, such as that of a new user or a guest being served by Care-O-bot®3. There were 19 participants in this short-term study (i.e. 12 male and 7 female participants). The mean age for the participants were 26 with a median age of 22.5. Seventy percent of the participants were between the ages of 19 and 25. Nine participants had experience of computer programming, while the other 10 did not. The participants only interacted with the Care-O-bot®3 once within the experimental setting.

4.3.5 Results

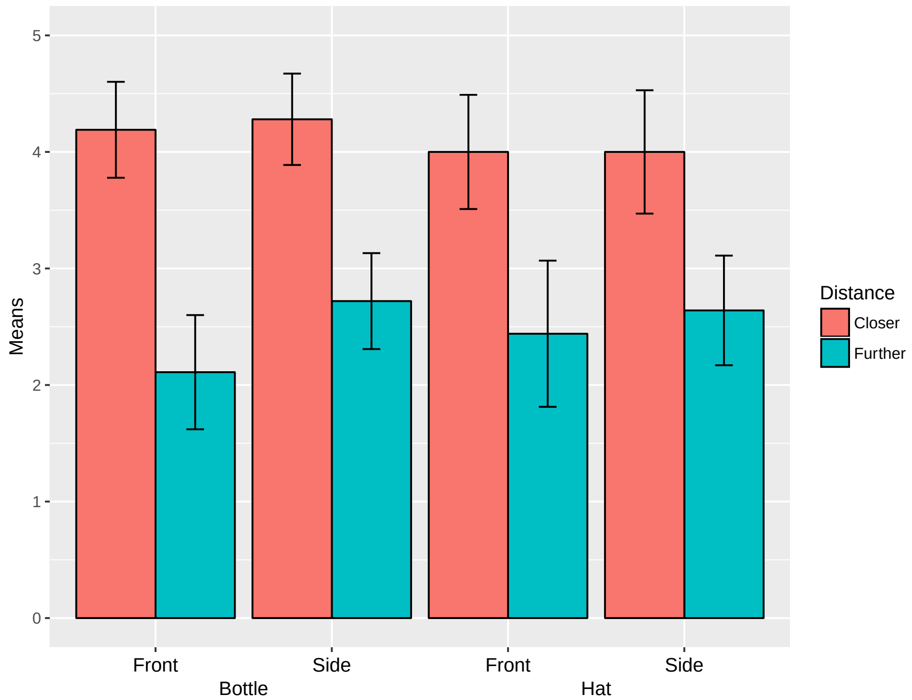
Reliability

The reliability of the approach evaluation measures were assessed through a series of Cronbach's α tests for each condition. The mean Cronbach's α was .79 for the Practicality measure, and .52 for the Hedonic measure. The high score for Practicality is particularly encouraging, although the low sample size of this study meant that it could only tentatively be considered a reliable measure. The lower score for the Hedonic measures is more problematic, and results from this measure will not be considered in this analysis.

Overall Results

Ratings of Approaches Figure 4.6 and table 4.2 show the descriptive statistics for the Practicality ratings.There were no significant main effects for Object ($F(1, 17) = .290, p = .60, \eta^2 = .02$) or Direction($F(1, 17) = 1.076, p = .314, \eta^2 = .06$. There was, however a significant effect for Distance ($F(1, 17) = 43.053, p < .001, \eta^2 = .72$), suggesting that participants viewed close approaches as more practical overall (Marginal Mean Rating of Closer was 4.12, SE .13, Marginal Mean rating for Further was 3.19, SE .17). There were no significant interactions.

Figure 4.6: Practicality Ratings



Light Signalling Overall, participants did not correctly remember the colours of the LED light display for the different behaviours more than could be expected due to chance ($\chi^2(1) = .22, p = .637$). The majority of participants did however, correctly identify the intended function of these lights as one of alerting the participant to the robot's behaviour ($\chi^2(1) = 5.56, p = .02$ (14 Correct, 4 Incorrect, and 1 did not answer the question)). This suggests that over time, participants would potentially be able to utilize such a system to identify the robot's intentions, and that possibly the novelty

Table 4.2: Practicality Ratings

Object	Direction	Distance	Mean Rating	Standard Error
Bottle	Front	Further	2.11	0.25
		Closer	4.19	0.21
	Side	Further	2.72	0.21
		Closer	4.28	0.20
Hat	Front	Further	2.44	0.32
		Closer	4.00	0.25
	Side	Further	2.64	0.24
		Closer	4.00	0.27

of the interaction scenario made it more difficult to retain this information. Moreover, the ability to correctly identify the LED display signal colour when the arm was moving, interacted with overall ratings of object type ($F(1,15) = 4.51, p = .046, \eta^2 = .23$). This effect is shown in table 4.3 and figure 4.7, which show that participants that did not identify the colour used, differentiated between the bottle and the hat, in their ratings, while participants who did correctly identify them, did not. This suggests that the use of the lights had an impact in how the participants perceived the manner in which the object was handed over to them.

Figure 4.7: Interaction effect of participants who correctly identified the colour of the LED light display when the arm is moving and the object type

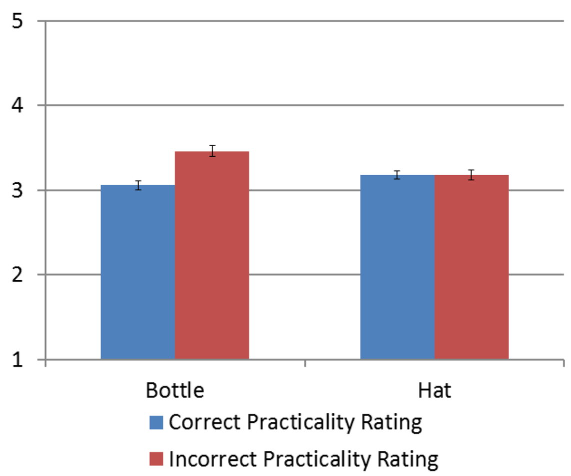


Table 4.3: Interaction effect of participants who correctly identified the colour of the LED light display when the arm is moving and the object type.

Correctly Identified	Object	Mean Rating	SE
Yes	Bottle	3.06	0.11
	Hat	3.18	0.10
No	Bottle	3.46	0.13
	Hat	3.18	0.12

Table 4.4: Correlations between *Equality* dimension and Practicality ratings (Spearman's ρ)

	Equality	Frontal Approach	Side Approach
Equality	1		
Frontal Approach	.584*	1	
Side Approach	.110	.202	1

$* : p < .05$

Social Role Expectations

The relationship between social role expectations as measured by the UH-SRQ and the other measures was also assessed.

Proxemics

Hypothesis 1 — Equality and Approach Directions The relationship between the *Equality* dimension and Practicality ratings for approach directions were assessed using a series of Spearman Correlations. The results from these can be found in table 4.4.

The results support Hypothesis 1 in that participants scoring higher on the *Equality* dimension in terms of social role expectations, were more likely to rate the Frontal Approaches more favourably in terms of Practicality than those scoring lower on this dimension.

Table 4.5: Correlations between *Control* dimension and Practicality ratings(Spearman's ρ)

	Control	Frontal Approach	Side Approach
Control	1		
Frontal Approach	.146	1	
Side Approach	.462*	.202	1

$* : p < .05$

Table 4.6: Control Dimension and Signal Identification

Behaviour	Identification	Mean Control Score (SE)	t-statistic
Robot movement	Correct	3.14(.25)	2.01*
	Incorrect	4.15(.46)	
Arm movement	Correct	3.17(.36)	2.74*
	Incorrect	4.38(.25)	

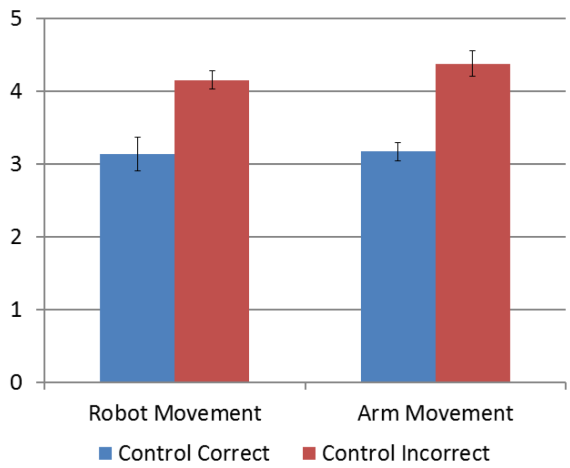
* $p < .05$

Hypothesis 2 — Control and Approach Directions The relationship between the *Control* dimension and practicality ratings for approach directions can be found in table 4.5.

Hypothesis 2 was also supported by the results. Participants with higher scores in the *Control* dimension would rate the side approaches more favourably than participants with lower scores on this dimension.

Hypotheses 3 and 4 — Signalling and UHSRQ Results There was a significant effect for the Control Dimension and correctly identifying the colours of the LED Light Display for the different behaviours. This effect is shown in table 4.6 and figure 4.8, which suggests that participants that correctly remembered the colours used, scored significantly lower on this dimension than participants who did not.

Figure 4.8: Control Dimension and Signal Identification



4.3.6 Discussion

Hypotheses

Both Hypothesis 1 and 2 were supported by the results. Participants did rate the approach directions more congruent with their social role expectations, as more practical for the bottle condition. This suggests that the social role that the participants expected the robot to have, impacted on how they perceived the context of the interaction and in turn, how they expected the robot to perform the task.

Hypothesis 3 and 4, however, were not so clear-cut. While it seems that the *Control* dimension was related to the identification of the signalling used by the robot, in that participants who correctly identified tended to score lower, there was no relationship between the *Equality* dimension and identification of the robot's signals.

Social Role and Proxemics — Conclusions

This study highlighted that how a robot presents itself, or is presented by others, to the user, in terms of expected social roles, significantly impacted preferences in terms of proxemics, as well as the users' ability to correctly process its signals in early interactions. This justifies the use of these types of measures for further building a body of knowledge that can inform future HRI studies in a systematic manner. In particular, the results show that social expectations may significantly impact interactions with robots, even non-humanoid robots.

4.4 Chapter Summary and Conclusions

This chapter introduced *Proxemics* as a salient testbed for human-robot interaction, and also presented results from a set of studies investigating the use of social expectations of robots and how these translated into proxemic preferences and evaluations of proxemic behaviour. In section 4.2, I introduced some early studies done as part of this work (reproduced in appendix A), which suggested that participants' conceptions of the robot in terms of anthropomorphism, did lead to more stringent expectations of adherence to social proxemic norms, but that due to general liking for more anthropomorphic robots, this did not translate into a less favourable evaluation of violations of these.

Because of this, the use of expected social roles within an interaction as offered by the UHSRQ measure, was applied to a specific interaction in which the social roles of the interactants could be expected to mediate the proxemic behaviours of a task. The results from this study suggests that relationships between results from the UHSRQ and evaluations of the proxemic behaviour of a robot are in accordance with what one would expect.

While these results were encouraging, it is important to consider that while this study was conducted within the ecologically valid setting of the robot house, it was still a highly constrained experiment, in which the participants' opportunity for interaction was quite limited. The challenge moving forward from this finding was to investigate whether or not similar effects could be reproduced in more complex scenarios. The results from how the *Control* dimension was related to the recognition of the signals used by the robot to communicate intent, suggests that the UHSRQ dimensions might be related to how participants might cooperate with robots when performing tasks, and the results from both the *Control* and *Equality* dimensions suggest that these two dimensions might both play a role in how participants expect to interact with a robot performing the tasks expected of a home companion. In addition, while the role of such initial social role expectations might be important for a 'first encounter' such as this, their impact might not last beyond the initial interaction.

The next chapters will report from two studies in which participants would interact with robots in a domestic setting over a period of two months, using the robot both in open-ended interaction based on everyday domestic situations as well as in more constrained experimental tasks. In the first study, reported in Chapter 5 the UHSRQ was deployed at the beginning of a long-term study, and the results are intended to investigate how initial social expectations will impact subsequent interactions, both on the task-level, but also on a higher, more open-ended level. The second study, reported in Chapter 6, also consider the impact of initial social interactions, but will also consider how these change over the course of such a study.

Chapter 5

Initial Social Expectations and Long-term Interactions

Overview

The studies outlined in the previous chapter addressed the role of social expectations for preferences and evaluations of robot proxemic behaviour. The studies described in this chapter were aimed at situating human-robot interactions within more complex scenarios. These scenarios were both both narrative based open-ended interactions, as well as more constrained task-based interactions. Both types of interactions, however, were rooted in realistic interactions with future and emergent robotic technologies in domestic environments. This work was conducted within the EU FP7 project LIREC, which used scenario-based methods to focus its technological development as well as to evaluate how potential users may respond to the systems arising from this development. This work is described in full in two papers, Syrdal et al. (2014), and Syrdal et al. (2015). These papers describe these studies in detail as well as the general results from these studies in terms of how participants responded to the technology prototypes. This chapter, focuses on the role of initial social expectations as measured by the UHSRQ, and explores if participant social expectations are able to account for some of the phenomena reported in these two papers.

5.1 Introduction

5.1.1 Scenario-based methods

In the field of human-robot interaction, domestic, human-centered environments present serious challenges for prototyping human-machine interactions. In particular, when addressing future and emergent technologies, it is a challenge to enable interactions that are situated in such a way that they are meaningful to the user, and allow users to translate this experience to their everyday life. Moreover, the experience of such interactions is subjective, and the relationship between interactants, technologies, and situations can be complex and dynamic (Buchenau and Suri, 2000) . On the technical side, cutting-edge technologies often do not have the stability required to function autonomously in an effective and safe manner for sustained periods of time outside of highly constrained settings. However, such feedback is critical for guiding the development of these technologies. This necessitates a high degree of pragmatism and creativity when developing appropriate methodologies for examining how prospective users interact with these technologies, and how these interactions may benefit or hinder the user (Dautenhahn, 2007a).

While there have been studies of actual robots acting autonomously in a domestic environment without continuous oversight by experimenters, either the robots employed have had limited movement capabilities, and served mainly as physically embodied conversational agents (not unlike those described in Bickmore and Cassell (2005), as in the KSERA project (Payr, 2010), or the robots were market-ready products (Fernaeus et al., 2010; Sung et al., 2008) or at a late stage in the development cycle (Kidd and Breazeal 2008). Furthermore, due to the cost in time and resources to set up and run the experiments, live interactions with robotic technologies in complex usage scenarios usually involve only a relatively small number of participants (Huijnen et al., 2011; Walters et al., 2011). While it is often desirable to run studies with the largest number of participants possible for greater generalisability, there is also the need for studies that allow for a wide range of interactions to capture data on human-robot interaction in all its richness. This balance lies at the heart of our efforts to develop, adapt, and use prototyping methodologies for domestic human-robot interaction (Syrdal et al., 2008b).

Prototype Fidelity in Human–Robot Interaction

When considering how different prototyping methods vary from each other, one pertinent dimension is that of fidelity, defined by Hall (Hall, 2001) as '*faithfulness in reproducing the characteristics of the finished product*' (ibid, p. 491). When comparing the fidelity of robotic prototypes to that of software prototypes, there are some clear differences. One argument that has been put forward in HRI for human-centred environments is that the novelty of the systems used requires a high degree of fidelity when prototyping (Green et al., 2006). This view is echoed to some extent by Bartneck and

Hu (2004), who also puts forward the three-dimensional, embodied nature of robots and the spatial and tactile interaction affordances. Bartneck and Hu (2004) also highlights that the complexity of robotic systems makes the issue of fidelity less clear cut than that of software systems. One could consider the fidelity of prototyping human-robot interactions in for user experience in domestic environments projects to have two main dimensions:

- Fidelity of platform
- Fidelity of setting

Fidelity of Platform The fidelity of the robot may vary widely, and we can roughly consider it along two dimensions. One is the physical richness of the prototype. On the low end, we may here consider some studies that have been performed on robots and devices that are only realised in written stories (Blythe and Wright, 2006; Enz et al., 2011) with videos of robots being considered a step up in terms of fidelity (Lohse et al., 2008; Syrdal et al., 2010b). Theatre plays in which actors either pretend to be (Robins et al., 2004) or interact with actual robots in a space shared with the audience (Chatley et al., 2010; Syrdal et al., 2011a) could here be considered the highest level of fidelity apart from actual interactions with physically embodied robots.

However, one should also consider the fidelity of such systems in terms of the realism of their behaviour. This comprises not only the degree to which their behaviour reflects the projected behaviour of the completed technology, but also the degree to which the system is capable of producing these behaviours without being controlled by its developers. A common technique in HRI is the so-called Wizard of Oz (WoZ) methodology (Green et al., 2004), in which the robot portrays seemingly autonomous behaviours, allowing researchers to bypass issues that make it difficult to run the system autonomously. It has been argued, however, that reliance on this methodology comes with serious problems, in particular that it poses a problem due to the possibility of it creating unrealistic interactions and findings that are not grounded in a realistic interaction between users and systems, which in turn threaten the validity of such studies (Fernaeus et al., 2009).

Fidelity of Setting Fidelity of setting can also be understood as ecological validity. By this, we mean to what extent the context in which an interaction takes place is applicable to the context in which a robot will actually be used in the future. As for the fidelity of the system, this is not a unidimensional construct. In this current work, we can understand the fidelity of setting as having two dimensions, physical and contextual. Both may impact the nature of the participant's experience of the system and their subsequent evaluation.

For instance, Walters et al. (Walters et al., 2011) describe a study on participants proxemic expectations of a robot and the relationship between these and their subsequent evaluation of the robot, in a constrained experiment in the University of Hertfordshire Robot House (see below). The setting and environment could be considered high in terms of physical fidelity in the sense that the participants were interacting with an actual robot and were capable of responding to the physicality of the robot, in a physical environment that was similar to that in which such interactions are envisaged to take place. The actual interaction, however, was constrained to providing a proxemic preference while standing or sitting in a specific position.

Lohse et al. (2008) describe a study in which participants watched videos where a user interacted with her own robot in her own home. They were then invited to share their thoughts and opinions about what they had seen. In this study, despite the lack of physical interactivity, users were exposed to a rich and meaningful scenario in which they could see the impact of the robot on the user's everyday experience, thus allowing the participants to understand the role of the robot in its intended setting. However, this was a setting not shared by the participants who only experienced it vicariously.

While we acknowledge that both of these studies provided the researchers with valuable insights, they also illustrate the importance of tying both the level of fidelity and the type of prototype used, to the research objectives of the study (Xu et al., 2012).

5.1.2 Narrative Framing for Contextual Fidelity

The work in the LIREC and ACCOMPANY projects focused on the holistic experience of the participants when interacting with robots in real-life domestic settings. Because of this, we want to present our participants with physical prototypes that behave realistically in a setting which is clearly applicable to the use scenarios of a proposed robotic companion. As discussed, previously the UH Robot House has been used as an ecologically valid test bed for HRI studies, as it is a residential house that has subsequently been adapted for such studies (Walters et al., 2011).

The UH Robot House is furnished as a normal British house, but is also used for technical development in the domains of smart home technology and robot-assisted living. This means that it is equipped with a low-cost, resource-efficient sensor network which can be used to detect and keep track of user activities and other events in the environment (Duque et al., 2013). The autonomous robots used for HRI studies in the house are an integral part of this smart home. The robot house has been used with a range of robots such as the UH Sunflower Robot (Koay et al., 2013), Mobile Robots PeopleBots (Walters et al., 2011) and the Fraunhofer IPA Care-O-bot 3 (Parlitz et al., 2008). This allows for a setting with high-fidelity prototypes both in terms of physicality as well as in behaviour realism.

This setting has provided a solid starting point to address the issue of contextual setting fidelity. While there have been instances of artists using the UH Robot House continuously for 5 days (Lehmann et al., 2013b), the robots and the smart home technology are not stable enough to allow for 24/7 residency by members of the general public, even though this would be desirable for extensive user testing of the systems. Because of this, a narrative framing technique for prototyping using episodic interactions was applied in which narrative was used to frame each individual interaction (Dindler and Iversen, 2007). This would allowed for drawing on the usage scenario as the basis for the narrative, using the robots and the house itself as props for the emergent interactions.

It is important for this process that the UH Robot House is a working house, with kitchen appliances that can be used to cook, a TV that can be used to relax, a doorbell that rings when visitors arrive and so on. This will allow the users to actually perform activities that are congruent with the interaction scenarios envisaged by the researchers.

Previous Work in the Robot House In previous studies such as those described in Chapter 3 and 4 we employed similar methodologies, where we performed a series of episodic interactions within the UH Robot House (Koay et al., 2009) and used similar narrative framing techniques for setting the scene for the different episodes. This allowed us to examine participant responses to a variety of robot behaviours, as well as allowing the participant the chance to consider wider implications of domestic robots (Syrdal et al., 2007c). Note, in this previous work, a smaller Robot House was used (a ground-floor flat), without a sensor network and with the robots controlled primarily via WoZ.

These previous studies were useful for examining the role of habituation in responses to some robot behaviours, as well as providing experience in running such studies away from the confines of the laboratory, but they also suffered from some limitations. The most serious of these was the fracturing of the role of the participant and the robot. While in some of the episodes the participant was asked to take on the role of a robot owner in their own house, in others they were asked to take on the role of a guest (Syrdal et al., 2007c), teacher (Otero et al., 2008) or even co-designer of robot behaviours (Koay et al., 2007a). One side effect of this fracturing was that the participants could never be sure, in a sense, 'what' robot house they were visiting. Was it a house in which they were the active owner, going about their daily business, or was it a house where they were visiting a robot owner, or indeed not a private house at all, but rather a workshop where robot designers elicited their help? Similarly, since the robots were partially remotely controlled by a present researcher, the role of the robot and the researchers were likewise fractured.

This uncertainty regarding roles might have been an impediment to the participants' ability to evaluate the robot and its possible roles outside of the experimental setting, within their everyday lives and beyond the scope of the individual interaction episode. The present study, was intended to overcome these limitations.

5.1.3 Requirements of Narrative Prototyping

Based on this previous work, we arrived at the following requirements for our current study:

- Coherent narrative — The participants need to feel that they are interacting with the same system in the same setting in the open-ended scenarios.
  - Realised through:
    - Using the same interface throughout the study.
    - The environment is kept stable.
    - The participant is always the 'owner' of the house.
    - It is made clear to the participant when they are 'inside' the narrative.
- Agency — The participants need to have a clear idea about what they want to achieve in a session as well as how this can be achieved.
  - Addressed by making sure participants:
    - Understand the interface of the robot.
    - Understand the workings of the house.
    - Know locations of items used in the scenarios.
    - Understand how to use the appliances.
  - Reflected through:
    - Scenarios being based on the system's actual capabilities (autonomously operating smart home).
    - Human technicians monitor the functioning of the system and only intervene in case of faults or bugs appearing.

* The System responds with as much autonomy as possible.[1]

5.2 Meeting the Requirements — Building the Frame

In order to ensure that the system existed within a coherent narrative, the study adopted the two personas that had been used to guide the development work within the UH Robot House. Personas, can be described as highly realised fictional users (a method for design often used in HCI) (Chang et al., 2008). The UH Robot House scenario focused on socially assistive robots for older people living in their own homes, and so the personas were created with this in mind. The specific personas used to guide development in the Robot House are a couple (David and Judy) in their mid-to-late 60s. The personas were fleshed out and realised by considering their work interests, hobbies and specific health issues that would allow us to examine the role of technology within their lives. Below is a brief introduction to the personas and the scenarios derived from them:

> **David** is recently retired from an office-based job, in which he used computers on a daily basis. In his retirement, he is planning to focus on his hobbies. Some of these hobbies are sedentary and require little assistance, like reading and watching documentaries. He also enjoys building military models which requires him to move quite a lot of objects from storage areas to work surfaces. He also needs to take medications regularly to manage a heart condition. For some reason, he often forgets to take this medication and Judy (his wife) needs to remind him of

[1]'*Autonomy*' here refers to autonomy from the researchers/developers/experimenters. While the participant may control the system directly as per the affordances given in the scenario, the system should run with as little input as possible from outside the 'narrative space' of the interaction.

this on a daily basis. Due to arthritis, he also has some mobility issues.

For **Judy** their house is also her primary work place. She works as a consultant, which means that unless she is visiting clients, she spends most of her working hours in the home office. David's recent retirement has led to her getting distracted more easily due to his presence in the house, and there is some tension between them as a result of this. Judy now has adopted a separation of work and leisure, and keeps to her home-office during working hours, only interacting with David during mealtimes and in the evenings and weekends. Like David, she is used to computing technology, relying on it to work effectively from her home office. Unlike David, however, she is more used to solving problems related to computing technologies by herself. She also uses social media and voice communication applications to keep in touch with their children and grandchildren.

Based on these personas, a 'typical' day comprising of episodic usage scenarios where the couple used the robot in their normal everyday activities was created (see Figures 5.9 and 5.10 for a high-level conceptual description and a technical breakdown in Table 1). When designing the study, these episodes were used in two different ways.

The first way was to build two holistic open-ended evaluation scenarios where we could examine the possible roles that the robot could play in these different episodes. These were an attempt to convey the impact of the robot within a wider context. They differed from the usage scenarios in that they were intended for a single user, and would be meaningful to an experimental participant within the context of a one-hour interaction.

Table 5.1: Technical Breakdown of Episode (1)

Scenario Name	**Hobby — Building airfix models**
Origin	User initiated
Companion Embodiment	Sunflower Robot
Chronological overview	1. David uses touch screen to instruct companion to follow him to the model storage area. 2. Companion follows David to storage area. 3. David loads models from storage area onto the robot and instructs robot to move to the dining area workspace. 4. Companion moves to the workspace. 5. David unloads models and starts working. 6. Companion waits for 1 hour, then attracts David attention and suggests a break.
Competencies	* Follow user * Navigation * Accessing schedule for breaks * Attention seeking

The second was to identify specific types of usage that existed across scenarios and abstract these into experimental tasks in which the participant would interact with the robot, performing a task for which the use of the robot would be of benefit to the participant in terms of completing it.

5.2.1 From Persona Scenarios to Interaction Scenarios

The episodes in the persona scenarios were used as the basis for creating two *evaluation scenarios* where we could examine the possible roles that the robot could play in these different episodes. These were an attempt to convey the impact of the robot within a wider context.

They were grounded in an imagined daily life, with the robots in the robot house adopting an assistive role. This imagined life was lent coherence and context by allowing the participant to inform the robot about their preferences in terms of drinks, snacks and leisure activities, and TV programmes that they preferred in their own daily life prior to the first interaction with the robot. Subsequent interactions with the robot would then

Table 5.2: Technical Breakdown of Episode (2)

Scenario name	**Time for lunch**
Origin	Scheduled event
Companion embodiment	Embodied conversational agent (ECA), Sunflower, AIBO
Chronological overview	1. Companion appears on Judy's screen as an ECA, and informs her that she has scheduled lunch for this time. 2. Companion migrates from ECA to Sunflower embodiment and follows Judy to the kitchen. 3. Judy prepares food and asks the companion to find out what David's preferences are for this meal. 4. Companion migrates from Sunflower to AIBO to ask David about his preferences and migrates back to Sunflower to give this information to Judy. 5. Judy loads Sunflower with the plates and food from the kitchen and moves to the dining area.
Competencies	* Accessing schedule * Migration between different embodiments * Navigation * Communication * Attention-seeking

Table 5.3: Technical Breakdown of Episode (3)

Scenario name	**Package delivered**
Origin	Sensor event
Companion embodiment	Sunflower
Chronological overview	1. Delivery person rings the doorbell. 2. Companion is alerted via the robot house sensors. 3. Companion migrates to Sunflower robot and searches for David. 4. Companion attracts David's attention and informs him that there is someone at the door. 5. David and companion go to the door together.
Competencies	* Detecting sensor events * Person finding * Attention seeking * Navigation

draw on these in order to convey a sense of personalisation and context.

The scenarios were performed twice each. They both required the participant to engage in a structured role play-like scenario (Seland, 2009) in order to investigate the role of the robot in a manner that could be directly related to the participant's everyday experience. This was intended to allow the participant insight into the potential impact of the robot on their lives. In addition to high-level evaluation of the experience of using the robot in these scenarios, the scenarios also allowed the researchers to investigate particular issues that were of interest to the research team, in particular the issues of communication and agent migration.

Scenario Instantiation A: Morning and Delivery – Communication

This particular scenario was intended to investigate participants' interactions with, and responses to, the robot in an everyday setting. In addition, this particular study was intended to investigate the role of attention-seeking and other expressive behaviours of the robot. Like the Care-o-bot®3 in the previous chapter, the Sunflower robot that was used in the study is what can be described as 'appearance-constrained', having an appearance that is constrained by required practical functions, rather than having been created for specific anthropomorphic communication modalities. There are several situations that require expressive behaviours from a robot, and this has been a focus for experimental investigations in the UH Robot House, including attention (Koay et al., 2013,0) and relationship-building cues (Syrdal et al., 2010b). In this scenario, the perceived efficacy of these behaviours was examined by integrating episodes which required the robot to attract the attention of the user into the scenario as a whole. The participants' briefing asked them to imagine that they had just woken up. The participant would then go to the sofa and be approached by the robot, which suggested one of three activities through messages on its touch screen: Making/drinking a hot drink, making/eating breakfast, or one of three leisure activities.

The specific activities and the type of drink and breakfast for each participant were determined by their previously indicated preferences. Throughout these tasks, the robot would offer assistance by highlighting the appropriate location for the task, and then, using the sensors attached to the kitchen appliances, it would inform the participants of when the kettle had boiled, toaster had popped, or egg cooker had finished. In addition, while the participant was performing one of these tasks, the robot alerted the participant to the doorbell having been rung, as part of the episode in which the newspaper was being delivered. This episode was introduced in order to investigate the efficacy of the robot's expressive behaviour. Once a participant had completed one of the three activities, there would be a delay of 5 min before the robot suggested the next activity. Once the third activity had been completed, the robot would wait for an additional 5 min and then display the option to end the session. If at any time the participant did not want to engage in any activity yet, the participants had the option to request that the robot wait for a set period of time before the next reminder.

Scenario Instantiation B: Lunch and Internet Phone Call – Migration

This scenario was intended to investigate participants' impressions of the use of the robot in a situation that involved agent migration. Agent migration is a term describing the ability of an agent 'mind' to move between different robot and virtual embodiments (Segura et al., 2012; Syrdal et al., 2009). This allows the agent to take advantage of features and functionalities of more than one embodiment while maintaining the persistent features that make it unique and recognisable from a user's perspective, such as awareness of interaction history and context, as well as persistent customisable feature (Koay et al., 2011).

There are many benefits from such an ability, since it allows for a wider range of functions as the agent is not bound by the constraints of a single robot platform. However, implementing this functionality and using it in HRI experiments pose many technical challenges. There are also many salient issues from an interaction perspective, such as how the agent can retain its perceived identity across different embodiments and how the process of migration, from one embodiment and into another, is signalled for the different embodiments.

In this scenario, the migration took part between a Sunflower and a SONY AIBO robot. Migration was indicated to the participants using the following signals:

- Sunflower
  - Migration into another embodiment:
    * Light comes on, 'head' lifts up to the highest position and tilts once to each side before coming down to the default position.
  - Migration out of an embodiment:
    * Head moves back from default position and down, light switches off.
- AIBO
  - Migration into another embodiment:

    * AIBO lifts its head and stands up, lights come on.

  - Migration out of an embodiment:

    * AIBO lies down and puts head down, lights switch off.

The participants' briefing asked them to imagine that it was the afternoon and they had just returned home. The participant sat on the sofa and was approached by the robot, suggesting two activities, watching TV or having a snack and a drink. The specific TV programme and snack and drink combination was based on their previously indicated preferences. As in Scenario One, the robot offered assistance by highlighting the appropriate location for the task and the specific TV programmes that the participant had previously indicated a preference for.

During this scenario, the activities of the participant were interrupted in order for them to use the AIBO for remote interactions. The Sunflower robot would approach the participant, to either inform them that they had a scheduled Skype call that they needed to make, or that there was an incoming Skype call that they needed to respond to. This Skype call involved a collaborative game that could be played over Skype and which used the AIBO embodiment. The game used was a social mediation game developed as part of a separate research topic by the ASRG and is described in Papadopoulos et al. (2010). The scenario was not intended to investigate the specifics of the social mediation game, rather the migration that it necessitated was the focus of this study, and the game itself was only evaluated incidentally as part of the scenario.

After the Skype interaction was completed, the participant was free to return to their leisure activity. Unlike the 'Morning' scenario, the incoming Skype call presented an event that the participant had to respond to, but all other activities could be delayed.

5.3 From Scenarios to Constrained Tasks

While the *Narrative Evaluation Scenarios* were constructed by directly translating episodes from the *Persona Scenarios*, into a form that would be meaningful within the context of an episodic prototype evaluation, the constrained experiments were instead based on specific interaction types that would arise from the specific capabilities that the robots brought to bear in the Persona Scenarios. These were *Cognitive Prosthetic*, a reminder/memory function, and *Fetch and Carry*, mobile transportation capabilities.

5.3.1 Cognitive Prosthetic

The scenarios identified several instances in which the robot companion would be able to assist the user by providing information. This information could be provided in the form of reminders of appointments, mealtimes, and medicines. In the chosen scenario the robot's task was to remind "David" to take his heart medication. Adherence to a prescribed regimen of medication can be difficult for many patients. Early approaches (as exemplified by Schwartz et al. (1962)) presented this as being caused by a shortfall in the ability of the patient, who was seen as making mistakes. More recent approaches consider a wider range of reasons for non-adherence to prescribed medicine regimens. In addition to the cognitive abilities of the patient, the new approaches also take into account other factors such as the complexity of the medication schedule, perceived efficacy of the treatment, and the perceived risk of side effects (Horne et al., 2005).

While this particular scenario used the robot purely to remind the user of his schedule in a manner similar to that of cognitive prosthetics on handheld platforms (Modayil et al., 2008), this functionality can also be combined with more persuasive technologies that use relational and other strategies in order to encourage habits conducive to the health of the user (Bickmore et al., 2005). However, this was not the focus of the current study, which focused purely on the cognitive prosthetic aspect of such technologies and its impact within the performance of a task.

The experimental instantiation of the Cognitive Prosthetic task involved participants putting Scrabble tiles into the correct spaces of a medicine dispenser on the living room table (see Figure 5, shown later), relying on a master list that had to remain on the kitchen bench. There were 28 spaces for the tiles, and both the position of the tiles in the dispenser and their position on the list in the kitchen were randomized.

Figure 5.1: Medicine tray and Scrabble tiles for the Cognitive Prosthetic Task

5.3.2 Fetch and Carry

The Fetch and Carry task consisted of carrying objects between different rooms. In the persona scenarios, this task was performed during episodes such as mealtimes, where the robot could assist with the movement of prepared food from the kitchen to the dining area returning dishes to the kitchen. It was also considered to be of utility in the episodes where David could use it while engaging in his hobby, for example, to move models and tools from storage to a work surface in a different room.

The term Fetch and Carry comes from Huttenrauch and Severinson Eklundh (2002), who in their case study describe how a user with a mobility impairment uses a mobile robot as a platform for transporting objects that this person would otherwise be unable to move without assistance from another person. This particular task is interesting due to both the utility of the task and the human-robot interaction issues that it highlights.

The Fetch and Carry capability of robots can be of use to a wide variety of users because there are many reasons why they may need assistance for transporting objects, ranging from fall injuries to neurodegenerative conditions like Parkinson's (Kamsma et al., 1995; Walker and Howland, 1991). It is also an interesting task from a human-robot interaction perspective, as it is unique to the physical nature of robots and involves both human and robot interactants negotiating and moving in a shared physical space. As long as the robot is capable of moving between two or more points and is fitted with a suitable container for the transport of objects, a robust and stable realization of this task was well within the current state of the art.

The experimental instantiation of the Fetch and Carry task involved the participants moving 100 plastic balls from a net on the kitchen bench to the living room table using only one hand. This was a constraint that was easily implemented while being challenging to the participants. While the balls were very light, requiring little physical strength, they were quite unwieldy in numbers larger than four or five, so required several trips back and forth to transport them all.

Assistance with both Cognitive Prosthetic and Fetch and Carry tasks can be used in response to changed circumstances, such as recovery from illness and accidents, as well as rehabilitation after strokes, where the prospective user will have to learn new skills to aid in daily living, or gradually recover mastery of old skills.

For experimental instantiation, tasks were chosen, that while not strenuous, would present a challenge to the participants, and in which the use of a robot would have a clear impact on the task. In addition, it was hoped that the experimental constraints would add novelty to the task, allowing us to see the impact of changes in participant task mastery.

5.4 Method

Taken together, the open-ended interaction scenarios and the constrained tasks allowed for the testing of the role of social expectations and responses to robot behaviours in a long-term high-fidelity interaction prototyping study. The study took part over a period of 3 months, where participants interacted with the robots in the Robot House, on average, once a week for about one hour. There were twelve participants in the sample, 8 male and 4 female. Their ages ranged from 18-64 with a mean age of 32. They were recruited through adverts on social media and on the UH Intranet.

5.4.1 Open-ended Interactions

The open-ended interactions used a repeated measures design in which participants would take part in both the scenarios twice. The participants would interact with the robot for Scenario A in Week 3 and 6 and for Scenario B in Week 4 and 7.

At the beginning of each open-ended scenario session, the participants were given a narrative framing of the context of the scenario that they were taking part in, the time of day, and what had immediately transpired before the beginning of the scenario.

Scenario A: Morning began in the morning and the participants were told the following:

> 'Imagine that you have now woken up. In the introductory session, you gave us some preferences for what you would like to do in the early morning. The robot has these preferences and will try to help you do them. When you are ready, you will come out of the bedroom and sit down on the sofa. The robot will then approach you'

Scenario B: Afternoon began in the afternoon:

> 'Imagine that it is afternoon, and you have just returned home and have just sat down on the sofa. You have planned to watch some TV. In the introductory session, you gave us some preferences as to what TV programmes you like to watch and what sorts of snacks and drinks that you prefer to eat. The robot has recorded these preferences. It will also respond to events such

> as phone calls and doorbells. When you are ready to begin, sit down on the sofa and the robot will approach you.'

After this briefing, the scenarios ran as outlined earler. Participants were asked to fill in questionnaires after the scenario was completed.

5.4.2 Constrained Experiments

The constrained experiments used a repeated measures design in which participants performed both tasks, Cognitive Prosthetic and Fetch and Carry with or without the assistance of Sunflower. The study was performed three times, in Week 2, Week 5 and Week 8, in order to provide a longitudinal aspect to the study. In addition, participants were invited to attempt both tasks without the aid of the robot in the Week 1, so that they would be familiar with the tasks before the beginning of the experiment in Week 2.

Use of the Robot

The use of the robot was adapted to each task: For the Fetch and Carry task, participants were allowed to use the extendible tray of the robot as an additional platform to transport the plastic balls to the living room table. The participants could instruct the robot to move between the locations using the touch-screen interface. For the Cognitive Prosthetic task, the participants could access the list through the touch-screen interface. The participants could only access one quarter of the list at any given time, and could only choose which portion of the list to access while in the kitchen. This meant that in order to access the whole list, they would have to make several journeys between the living room and the kitchen over the course of the trial.

Figure 5.2: UH Sunflower Robot

Briefing

Before each task, participants were shown the apparatus involved, and had the task explained to them. For the robot condition, participants were shown how to use the robot, and how to operate the touch-screen interface relevant for that particular task. Participants were asked to try to complete the task as quickly as possible. They were told that their performance was not being assessed, and that if the task took longer than 10 minutes to complete, the experimenters would stop the experiment.

Apparatus

Two different robots were used in this study. The first was the UH Sunflower robot, which uses a Pioneer base (commercially available from MobileRobots), but which has been modified significantly (see figure 5.2). The main mode of direct interaction with this robot is its touch screen which can be used to display information to the user and for issuing commands to the robot. Sunflower also has an extendable tray which can be used to carry light-weight objects. The second robot was a SONY AIBO as shown in figure 5.3. In addition, laptops were used to set up Skype calls.

Figure 5.3: AIBO Robot

5.5 Measures

5.5.1 Constrained Tasks

The primary measure to evaluate the experience of the tasks was the NASA Task Load Index (TLX). This is a questionnaire-based means of measuring perceived workload for specific tasks along several different dimensions. As such, it would allow for an investigation into the relationship between social perceptions of the robot as measured by the UHSRQ and the task itself. It was adopted as it was intended for examining human-machine interactions (Hart and Staveland, 1988). As it is a post-task measure, administering it to a participant would not affect task performance in the manner that a concurrent measure such as a think-aloud protocol might (Russo et al., 1989). Despite it being a subjective, post-task measure, studies have shown it to be a reliable and valid tool for examining task difficulty and performance (Rubio et al., 2004). Since its conception, it has been used across a wide variety of domains and tasks (Hart, 2006). It was chosen over the more focused Human-Robot Interaction Workload Measurement (HRI-WM) (Yagoda, 2010) because the main focus of this study was on the participants' experience of the tasks themselves, rather than an assessment of how they interacted with the robot. The NASA TLX measures workload along six dimensions, shown in Table 5.4.

Table 5.4: Dimensions of the TLX

Dimension	Workload in terms of...
Mental	...reasoning remembering, planning, thinking
Physical	...strength and endurance, dexterity
Temporal	...pace, time pressure, speed
Performance	...success and satisfaction
Effort	...effort needed to accomplish performance
Frustration	...annoyance, frustration, stress

5.5.2 Open-Ended Interactions

5.5.3 Measures

The study used a set of different measures to measure the response of the participants to the robot. These are described in detail in Syrdal et al. (2014), and summarised here. These measures were intended as global measures for the entire session, and participants were asked to consider the system as a whole across embodiments and the different interactions within the session.

System Usability Scale The System Usability Scale (Brooke et al., 1996) is scale formed from 10 Likert Items intended to measure the usability of a system, giving a possible range of responses from 0 to 100. It has been used extensively within the field of Human-Machine Interaction, and overall the mean response in these studies have been around 70, which has led some researchers to conclude that a score significantly above this number suggests a high level of usability (Bangor et al., 2008).

Scenario Experience Scale This scale was developed specifically for this study and is described in full detail in Syrdal et al. (2014), and focuses on how the participant experienced the scenario as a whole in terms of their own everyday experience. It consists of 10 Likert scale items, and had a possible range of 1 to 5. Prior to the subsequent analysis, internal reliability was assessed using Cronbach's alpha (using the psych package (Revelle, 2015) in R.). This analysis found that α-coefficients ranged between .90 and .94 across the sessions, suggesting that the scale was measuring an internally consistent unidimensional construct.

Robot for Self The participants were also asked whether or not they would find the robot suitable for themselves. They were to indicate agreement with this sentiment on a 5-point Likert scale.

Robot for Others Participants were also asked if they thought the robot suitable for *someone else*, for example an elderly person or a person with a disability. Like the above measure, participants were asked to indicate agreement on a 5-point Likert scale.

5.6 Results

5.6.1 UHSRQ Descriptives

The results described in Table 5.5 and figure 5.4 suggests that the sample rated their social roles expectations with quite high scores across all the three dimensions. There was still quite a lot of spread in the sample, which suggested that the possibility of examining whether or not differences along these scores might impact how participants experienced their interactions with the agent in the long-term study was feasible. The correlations reported in table 5.6 suggest that, unlike the museum survey study reported in Chapter 3, these dimensions were not all positively correlated. There was a significant positive correlation between the *Equality* and *Pet* dimensions, but an non-significant negative correlation between the *Control* dimension and the other two. This difference could be due to the fact that the participants had all already agreed to interact with a robot over the period of the study, and as such the UHSRQ discriminated more efficiently *between* different ways of interacting with the robot rather than in the Dublin study in which the desire to interact with a robot in any way, might have been included in each subscale.

Table 5.5: UHSRQ Descriptives

	Mean	SD	Median	Range
Equality	3.58	1.04	4	2-5
Control	3.46	1.08	4	1-4.5
Pet	3.58	1.00	4	2-5

Table 5.6: Spearman's ρ-coefficients between subscales of the UHSRQ

	Equality	Control	Pet
Equality	1.00		
Control	-0.27	1.00	
Pet	0.69*	-0.38	1.00

* $p < .05$

5.6.2 Open-ended Interaction

Global Results

The results along the 4 global measures are described below in Table 5.7, which shows the mean, standard deviation, median and range for each global measure in each session.

Figure 5.4: Boxplots for UHSRQ Subscales

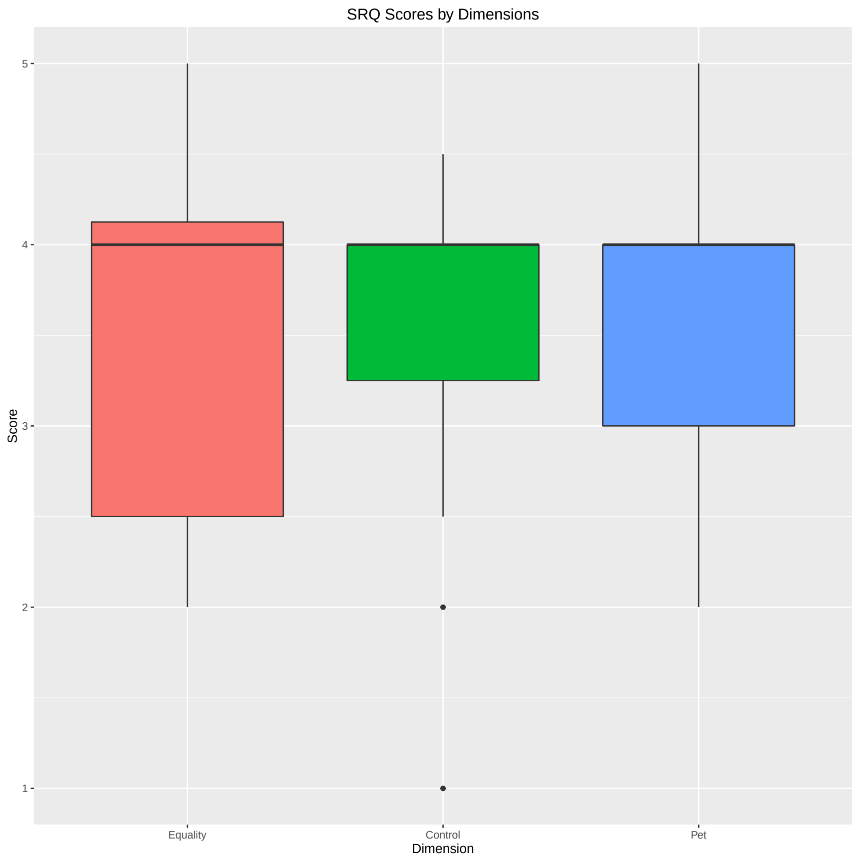


Table 5.7: Results for the 4 Global Evaluation Measures

	Mean	SD	Median	Range
Morning and Delivery 1				
SUS	71.88	13.02	67.50	47.5-90
Scenario Acceptance	3.81	0.84	3.89	2.44-5
Robot for Self	2.45	1.12	3.00	1-4
Robot for Other	4.67	0.49	5.00	4-5
Lunch and Internet Phone Call 1				
SUS	70.83	12.17	71.25	47.5-95
Scenario Acceptance	3.84	0.66	4.00	2.66-5
Robot for Self	2.36	1.03	3.00	1-4
Robot for Other	3.92	0.79	4.00	2-5
Morning and Delivery 2				
SUS	72.95	15.96	75.00	37.5-97.5
Scenario Acceptance	3.82	0.87	4.00	2.11-5
Robot for Self	2.45	1.21	3.00	1-5
Robot for Other	4.82	0.40	5.00	4-5
Lunch and Internet Phone Call 2				
SUS	73.64	20.14	72.50	32.5-97.5
Scenario Acceptance	3.98	0.74	4.11	2.78-5
Robot for Self	2.18	87	2.00	1-3
Robot for Other	4.18	0.60	4.00	3-5

System Usability Scale The System Usability Scale scores did not vary significantly across the sessions (Friedman's $\chi^2(3)$=2.39,p=.50), and did not go significantly above the expected "average" score of 70 in any of the sessions. There was some variation between participants across the study, in particular in Session 1(Morning One) and 4(Lunch Two)

Scenario Acceptance The Scenario Acceptance scores did not vary significantly across the sessions (Friedman's $\chi^2(3)$=1.128,p=.73), but did consistently go above a 'neutral' score of 3 in all the sessions (Wilcoxon signed rank tests $p < .02$). There was, however variation with the sample for all of the sessions, suggesting that individual differences play a role throughout the sessions.

Robot for Self Participant responses for this item did not vary significantly across the sessions (Friedman's $\chi^2(3)$=0.89,p=.83), and did not deviate significantly from a 'neutral' score of 3 in sessions 1-3. However, in the last session, it was significantly lower than this value(Wilcoxon signed rank test, p=.03). There was also quite a lot of variation in responses to this item across the sample in all sessions.

Robot for Others Participant Responses did vary significantly across sessions (Friedman's $\chi^2(3)$=17.44,$p < .01$). However, as suggested in Figure 5.5, and Table 5.7, there were small variations across participants which suggest that responses along this variable were more dependent on the scenario rather than on individual differences between participants.

Global Evaluation Responses — Summary and Tentative Research Questions of the Social Role Questionnaire In summary, for 3 of the 4 global evaluation responses, the differences between sessions were small, but there were still variations *within* the sample. This suggested that individual differences might account for how participants responded to the robot.

UHSRQ and Global Results

System Usability Scale Individual differences in the System Usability Scale were only related to responses to the *Pet*-dimension in the first Morning session, but both of the Lunch sessions were positively correlated with this dimension, suggesting that participants who wished to interact with robots as pets, were more likely to rate the system more favourably in terms of usability. There was a negative relationship between the *Control* dimension and SUS scores for the two Lunch-sessions in which participants who scored the system lower on this scale, were more likely to score higher along

Figure 5.5: Boxplots for Global Evaluation Measures

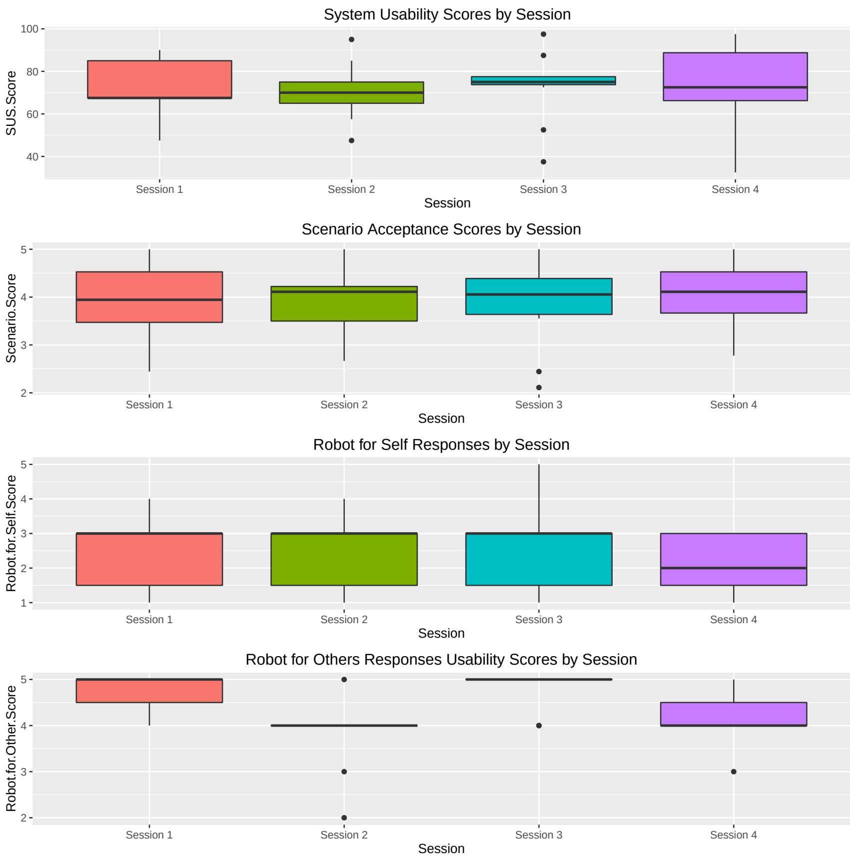


Table 5.8: Global Results and UHSRQ Correlations(Spearman's ρ)

System Usability

	Morning 1	Morning 2	Lunch 1	Lunch 2
Equality	0.47	0.53	0.34	0.45
Control	-0.19	-0.12	-0.63**	-0.52
Pet	.064**	0.43	0.64**	0.59*

*:$p < .1$, **:$p > .05$, ***:$p > .01$

Scenario Acceptance

	Morning 1	Morning 2	Lunch 1	Lunch 2
Equality	0.60**	0.82***	0.69**	0.54*
Control	0.09	-0.44	-0.62	-0.64**
Pet	0.42	0.42	0.54*	0.64**

*:$p < .1$, **:$p > .05$, ***:$p > .01$

Robot for Self

	Morning 1	Morning 2	Lunch 1	Lunch 2
Equality	0.87***	0.79***	0.49*	0.42
Control	-0.36	-0.21	-0.75***	-0.29
Pet	0.68**	0.37	0.52*	0.74***

*:$p < .1$, **:$p > .05$, ***:$p > .01$

Robot for Others

	Morning 1	Morning 2	Lunch 1	Lunch 2
Equality	0.37	0.27	0.00	0.12
Control	-0.32	-0.23	-0.02	-0.10
Pet	0.24	0.16	-0.20	0.17

*:$p < .1$, **:$p > .05$, ***:$p > .01$

this dimension.

Scenario Acceptance Individual differences in responses to the Scenario Acceptance Scale were only correlated with responses to the *Equality* dimension for the morning session, suggesting that participants wanting to interact with the robot as a social equal were more likely to rate the Morning sessions more favourably along this scale. The same relationship was found in the Lunch sessions. However, in the Lunch sessions, the *Pet* dimension also had a similar relationship, in that responses on this dimension was positively correlated with the Scenario Acceptance Scale. The *Control* dimension, however was negatively correlated with the Scenario Acceptance score for both of the Lunch sessions.

Robot for Self The results for this item were similar to those seen for the Scenario Acceptance Scale. A positive correlation between these responses and the *Equality* dimension suggest that participants who scored higher on the this dimension were more likely to want this robot for themselves after both of the morning sessions and the first of the lunch sessions, than those who scored lower on this dimensions. The *Control* dimension was negatively correlated with responses to this item in the first of the Lunch sessions, suggesting that participants who were more likely to want a robot like this after this session tended to score lower on this dimension. The *Pet* dimension was positively correlated with responses to this item in both Lunch sessions as well as the first Morning session, suggesting that participants who wanted to interact with a robot like a pet, were more likely to want the robots after these sessions.

Robot for Other There were no significant correlations, nor any salient trends in the relationships between the dimensions of the UHSRQ and responses to this item for any of these sessions.

5.6.3 Constrained Tasks

General Results

For a full description of the results from the constrained tasks see (Syrdal et al., 2015), but they will be summarised below.

Table 5.9: Mean Differences (SD) Between Human and Robot conditions for TLX Scores by Week and Dimension for the Fetch and Carry task.

Dimension	Session 2	Session 5	Session 8
Mental	-0.08(0.21)	-0.07(0.14)	-0.03(0.15)
Physical	1.82(1.56)	1.26(1.61)	1.01(1.49)
Temporal	-0.92(1.76)	-0.21(1.29)	0.28(1.19)
Effort	1.13(1.04)	0.23(0.90)	1.23(1.29)
Frustration	-0.26(1.61)	0.22(1.33)	-0.03(0.99)
Performance	-1.01(1.58)	-0.63(1.65)	-0.22(0.90)

Table 5.10: Table: Wilcoxon Tests for difference between Human and Robot conditions for TLX Scores by Week and Dimension for the Fetch and Carry Task

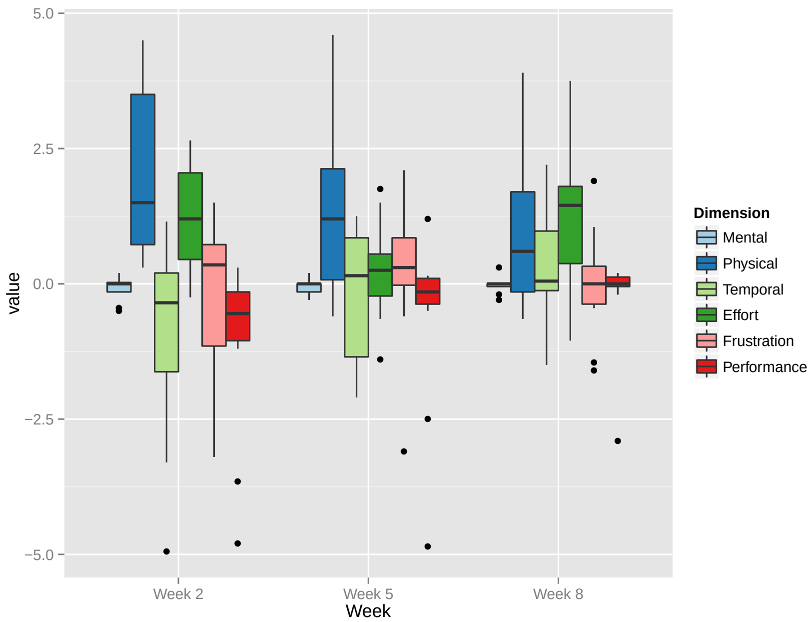
Dimension	Session 2 d (p)	Session 5 d (p)	Session 8 d (p)
Mental	.28(0.33)	.36(0.21)	.23(0.42)
Physical	.95(<.00)***	.59(0.04)**	.53(0.07)*
Temporal	.43(0.13)	.04(0.90)	.22(0.45)
Effort	.75.0(0.01)**	.26(0.37)	.75(0.01)**
Frustration	<.01(>.99)	.32(0.26)	.03(0.92)
Performance	.71(0.01)**	.37(0.20)	.14(0.62)

*$p < .1$,**$p < .05$,***$p < .01$

Fetch and Carry The differences between the Human and Robot condition for the Fetch and Carry task can be found in Table 5.9 and in Figure 5.6. As these describe the *difference*, a positive number will indicate a situation where the participants overall found the Robot condition to have a lower workload along that particular dimension, while a negative will number will indicate that they found the Robot condition to have a higher workload.

The results suggest that participants overall found that the robot had no impact on the *Mental* workload dimension. It impacted beneficially on workload along the *Physical* dimension for all 3 weeks. For the *Temporal* dimension, there was a non-significant trend in which the participant experienced the robot as increasing the workload in the Session 2, but this effect became smaller in the later sessions. In terms of *Effort*, participants felt

Figure 5.6: Boxplots for Differences between Human and Robot conditions for TLX Scores by Week and Dimension for the Fetch and Carry task



that there the robot decreased workload along this dimension in Session 2, but did not feel that this was the case in Session 5. In Session 8, however participants did again feel that the robot decreased workload along this dimension. In terms of *Performance*, participants felt that the robot increased workload in Session 2. This effect diminished in Session 5 and 8.

Cognitive Prosthetic The results for the Cognitive Prosthetic Task can be found in Table 5.11 and Figure 5.7. As for the Fetch and Carry task, a positive result means that the participants viewed the task as having a greater workload when doing it without the assistance of the robot, while a negative number means that the participants saw the task as having more workload along this dimension *with* the robot.

The results suggest that participants found that the robot decreased workload amongst the *Mental* dimension in all sessions, but less so in Session

Table 5.11: Mean Differences (SD) Between Human and Robot conditions for TLX Scores by Week and Dimension for the Cognitive Prosthetic task

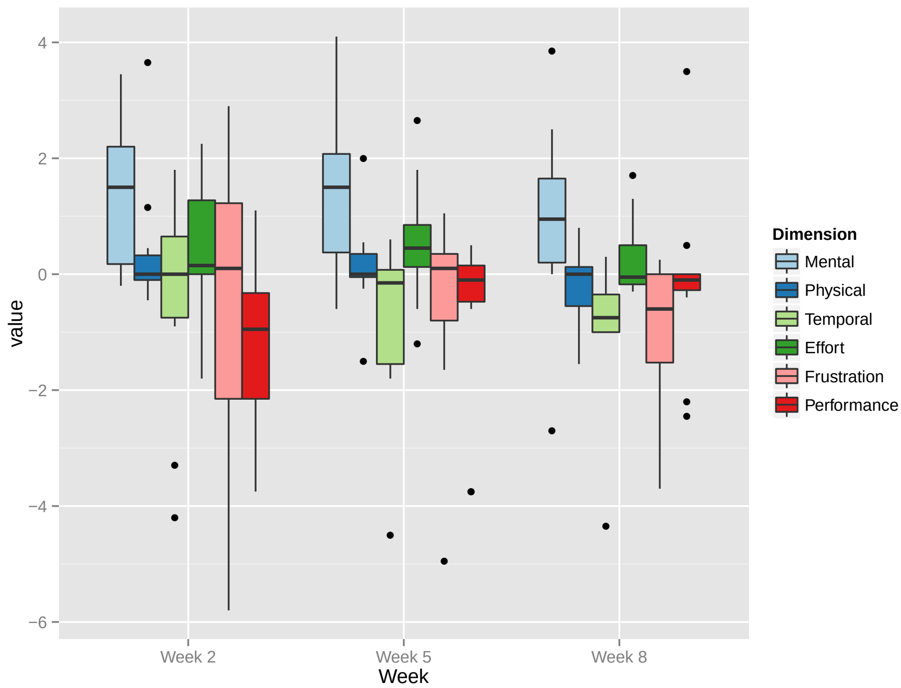
Dimension	**Session 2**	**Session 5**	**Session 8**
Mental	1.26(1.29)	1.48(1.40)	0.93(1.66)
Physical	0.38(1.10)	0.14(0.82)	-0.23(0.71)
Temporal	-0.42(1.75)	-0.89(1.45)	-0.92(1.22)
Effort	0.44(1.05)	0.53(1.05)	0.26(0.68)
Frustration	-0.66(2.76)	-0.50(1.69)	-1.01(1.40)
Performance	-1.10(1.39)	-0.69(1.55)	-0.13(1.53)

Table 5.12: Wilcoxon Tests for difference between Human and Robot conditions for TLX Scores by Week and Dimension for the Cognitive Prosthetic Task

Dimension	Session 2 d(p)	Session 5 d(p)	Session 8 d(p)
Mental	.75(0.01)**	.78(0.01)**	.53(0.07)*
Physical	.19(0.51)	.26(0.36)	.26(0.36)
Temporal	.12(0.69)	.47(0.10)	.78(0.01)**
Effort	.34(0.19)	.44(0.12)	.15(0.61)
Frustration	.09(0.76)	.06(0.83)	.58(0.04)**
Performance	.64(0.03)**	.29(0.31)	.18(0.53)

$^{*}p < .1$, $^{**}p < .05$, $^{***}p < .01$

Figure 5.7: Boxplots for Differences between Human and Robot conditions for TLX Scores by Week and Dimension for the Cognitive Prosthetic task



8. In addition, the participants found that the robot's impact on their experienced workshop in the *Temporal* dimension was negative, this became significant in Session 8. In the *Frustration* dimension, participants found that the robot impacted negatively primarily in Session 8.

Overview of Constrained Task Results

The participants responded to the robot differently within the two tasks, and there was a clear chronological aspect to the these differences, participants' responses to the robot changed over time.

For the Fetch and Carry task, the robot initially impacted the participants' ratings of the physical and temporal dimensions. In week 2, while the robot-assisted task was considered less physically strenuous, the participants found that performing the task within ten minutes (i.e. the temporal dimenesion) became more difficult. This effect for the physical dimension continued in the subsequent weeks. However, the impact of the robot on the temporal dimension diminished, suggesting that participants found it easier to use the robot to complete the tasks in weeks 5 and 8. Furthermore, participants found that the use of the robot required less effort in the last week, suggesting that there was a learning effect, and that participants were able to use the robot more efficiently as time progressed. This was also seen in the manner that the participants reported they used the robot as well as in their observed usage. In week 2, participants would load themselves and the robot and then follow the robot to the living to unload it. They would then return to the kitchen with the robot. In subsequent weeks, some participants would be more likely to not just operate the robot, but rather move around the robot and only load/unload it if they happened to be in the same space as it. This approach employed the robot more efficiently as a supplement to their own capabilities.

For the cognitive prosthetic task, the impact of the robot was less clear-cut. Participants rated doing the task with the robot as having less mental workload as compared to doing it without the robot, and this effect persisted throughout the trials. In addition, participants felt that doing the task with the robot required less effort. Despite this, participants rated the performance dimension of the TLX higher in the robot condition.There was a trend suggesting that for weeks 2 and 5 the use of the robot was seen as more time-consuming; it was also seen as more frustrating across all the trials.

The results reported in Syrdal et al. (2015) and above, suggest that there were individual differences in how participants experienced the impact that the robot had on the two tasks. These individual differences also seemed to be reflected in *how* the participants used the robot in the two different tasks. This was particularly true for the Fetch and Carry task. The UHSRQ measure, which asked the participants *how* they would prefer to interact with a robot, were used to examine the source of some of these differences.

The observed differences between participants in terms of how they interacted with the robot in the Fetch and Carry task suggested that some of them were better able to divide the task between themselves and the robot. The most effective division of the task between human and robot interactant required the participant and robot to move independently of each other. This suggested that two of the dimensions from the UHSRQ, might have an impact. High scores on the Equality dimension might entail an approach to interacting with a robot in which the participant treats the robot as a partner in the interaction, assuming that the robot will do its part, while high scores on the Control dimension might mean that participants will spend more time directly controlling the robot than those with lower scores.

Role of Expected Social Roles

The question of whether or not social role expectations as measured by the UHSRQ could serve to explain these effects, was addressed using a correlational approach. It would be particularly interesting if a measurement taken in the first week, before the participants even had a chance to interact with the robot, could still be seen to have an association with how the participants perceived a robot-mediated task, even weeks later. The analysis presented below is *exploratory* in nature. As such, formal hypotheses would be post-hoc fabrications at best. Rather, the inferential statistics presented below should primarily be considered a measure of the potential of the effects shown. However, there was still some clear questions that could be asked from this analysis. The results above suggest that not only did participants differ in how the use of the robot impacted the workload from this task, but the effect of the robot differed between the tasks over time.

The possible impact of social role expectations as measured by the UHSRQ that the participants completed in the first session of the study, was assessed using a series of Spearman correlations between participant responses on the UHSRQ and the perceived difference in workload between human-only and robot conditions for each of the tasks. A positive correlation between UHSRQ and TLX Dimension would mean that a *high score in the UHSRQ* was associated in a *relatively lower* experienced workload in the robot condition for that particular dimensions, while a negative correlation would mean a *relatively higher* experienced workload in the robot condition.

The correlations shown in tables 5.13–5.18 suggest that the most consistent effect of initial social role expectations could be found for the Fetch and

Table 5.13: Session 2 Fetch and Carry - Social Role Expectations and Robot Impact

Dimension	Equality ρ(p)	Control ρ(p)	Pet ρ(p)
Mental	0.02(0.941)	0.50(0.095)*	0.01(0.98)
Physical	-0.04(0.912)	0.04(0.897)	-0.24(0.444)
Temporal	-0.35(0.263)	0.03(0.915)	-0.18(0.571)
Effort	0.02(0.960)	-0.23(0.472)	-0.05(0.883)
Performance	-0.20(0.538)	-0.26(0.412)	-0.36(0.255)
Frustration	0.27(0.387)	-0.41(0.181)	0.21(0.511)

*:$p < .10$, **:$p < .05$, ***:$p < .01$

Table 5.14: Session 2 Cognitive Prosthetic- Social Role Expectations and Robot Impact

Dimension	Equality ρ(p)	Control ρ(p)	Pet ρ(p)
Mental	0.33(0.290)	0.01(0.969)	0.32(0.313)
Physical	-0.27(0.387)	-0.50(0.09)*	0.18(0.585)
Temporal	0.12(0.722)	0.24(0.448)	-0.33(0.300)
Effort	0.44(0.150)	-0.33(0.297)	0.36(0.247)
Performance	0.02(0.947)	-0.16(0.618)	-0.22(0.494)
Frustration	0.47(0.119)	-0.23(0.473)	0.160(0.625)

*:$p < .10$, **:$p < .05$, ***:$p < .01$

Table 5.15: Session 5 Fetch and Carry - Social Role Expectations and Robot Impact

Dimension	Equality ρ(p)	Control ρ(p)	Pet ρ(p)
Mental	0.37(0.262)	0.18(0.599)	0.50(0.115)
Physical	0.24(0.475)	0.25(0.456)	-0.42(0.193)
Temporal	0.11(0.745)	-0.58(0.061)*	0.24(0.483)
Effort	0.16(0.648)	-0.35(0.290)	-0.05(0.888)
Performance	0.24(0.480)	-0.32(0.333)	0.28(0.406)
Frustration	0.41(0.206)	-0.26(0.441)	0.13(0.711)

*:$p < .10$, **:$p < .05$, ***:$p < .01$

Table 5.16: Session 5 Cognitive Prosthetic - Social Role Expectations and Robot Impact

Dimension	Equality ρ(p)	Control ρ(p)	Pet ρ(p)
Mental	-0.09(0.783)	-0.10(0.774)	-0.10(0.767)
Physical	0.03(0.934)	-0.40(0.226)	0.25(0.451)
Temporal	-0.14(0.679)	0.17(0.621)	-0.22(0.521)
Effort	0.16(0.637)	-0.05(0.891)	-0.08(0.827)
Performance	0.29(0.395)	0.13(0.699)	0.09(0.787)
Frustration	0.04(0.902)	0.30(0.364)	0.05(0.888)

*:$p < .10$, **:$p < .05$, ***:$p < .01$

Table 5.17: Session 8 Fetch and Carry - Social Role Expectations and Robot Impact

Dimension	Equality ρ(p)	Control ρ(p)	Pet ρ(p)
Mental	0.64(0.034)**	-0.60(0.053)*	0.42(0.198)
Physical	0.76(0.007)***	-0.47(0.143)	0.47(0.142)
Temporal	0.29(0.381)	-0.69(0.019)**	0.38(0.245)
Effort	0.48(0.138)	-0.60(0.051)*	0.34(0.312)
Performance	0.05(0.883)	-0.08(0.812)	-0.12(0.717)
Frustration	0.43(0.184)	-0.27(0.416)	0.34(0.312)

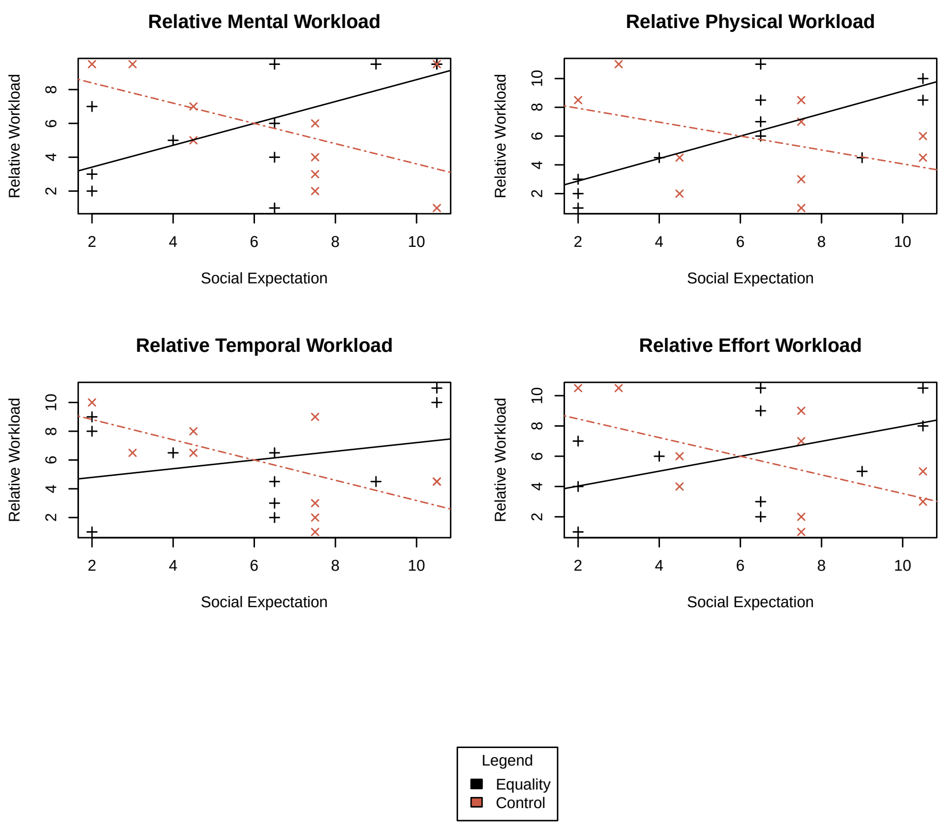
*:$p < .10$, **:$p < .05$, ***:$p < .01$

Table 5.18: Session 8 Cognitive Prosthetic - Social Role Expectations and Robot Impact

Dimension	Equality ρ(p)	Control ρ(p)	Pet ρ(p)
Mental	0.16(0.638)	-0.53(0.091)*	0.01(0.966)
Physical	-0.26(0.438)	0.44(0.177)	-0.46(0.152)
Temporal	0.06(0.852)	0.59(0.056)*	0.27(0.422)
Effort	0.09(0.788)	-0.05(0.875)	0.07(0.849)
Performance	-0.4(0.225)	-0.38(0.254)	-0.1(0.772)
Frustration	-0.24(0.471)	-0.34(0.314)	-0.3(0.374)

*:$p < .10$, **:$p < .05$, ***:$p < .01$

Figure 5.8: Differences in Relationships between Equality and Control and Workload for the Fetch and Carry Task — Session 8



Carry task in Session 8. This effect is described in figure 5.8, and suggest that in terms of relative Physical, Mental, Temporal, and Mental workload, scores on the *Equality*-dimension were associated with a lower workload for the robot condition, while the opposiste was true for the *Control*-dimension.

5.7 Discussion

5.7.1 Social Role Expectations and Evaluations of Open-ended Interactions

The results suggested that how participants conceived of interactions with robots as measured by the UHSRQ *in the initial session* was related to the way that they evaluated the open-ended scenarios along the different global evaluation measures.

Usability as measured by the SUS seemed to mainly correlate with the *Pet*-dimension. From a commonsensical perspective, this is easier to explain for the Lunch sessions. The interactions designed for the AIBO robot were strongly inspired by dog-like behaviours, and so it is not completely unreasonable that participants wishing to interact with a robot like a pet would find such interactions easier than other participants. Also, as noted in Syrdal et al. (2014), participants were observed engaging in pet-like interactions, as a coping mechanism when dealing with the robot's navigation and movement speed, suggesting that a pre-disposition to pet-like interactions might have led them to rate the robot as more easy to interact with due to such coping mechanisms.

The negative relationship between the *Control*-dimension in the Lunch sessions can to a large extent be explained by the indirect way in which the participants would interact with the game, suggesting that the autonomy and shifting needs of the robot within the interaction game was more difficult to cope with by participants whose social expectations of robots involved a high degree of control from the human user.

Scenario Acceptance was strongly related to the *Equality*-dimension across the entirety of the study. This is likely due to the way that the scenarios were built up, with the robot taking a pro-active role in guiding the participant through the scenario. Even though the participant was given the opportunity to control the robot through the touch-screen, the agent's reminders did mean that the participant relied on the robot for cues as to what to do next, and this implied relationship might be considered more appropriate by participants whose social expectations of the robot scored higher on this UHSRQ dimension.

The *Control*-dimension did not have noticeable relationship with the Scenario Acceptance ratings in the first Morning session, but there was a trend for this relationship to be negative throughout the rest of the study. This trend was significant for the second Lunch session. In light of the result for the *Equality* dimension, this negative relationship was perhaps not unexpected, as it may have reflected a general dislike of the pro-active role of the robot, but the lack of a negative relationship for the first session suggests that the participants may have found the role of the robot less problematic in the novel and unfamiliar experimental setting of the first session. The relative strength of the negative correlation was strongest for the Lunch-setting, again suggesting that the semi-autonomous manner in which the AIBO game was played might have been less enjoyable for participants with higher scores along this dimension of the UHSRQ.

The trend was for the *Pet*-dimension to be positively correlated with

Scenario Acceptance ratings throughout the study, but this was only significant in the Lunch-sessions which involved the AIBO game. Again, this is likely due to the pet-like interactions with the AIBO.

Robot for Self There was a positive correlation between this item and the *Equality*-dimension, which was significant for both of the Morning sessions and the first Lunch session. The relative strength of the correlation was strongest for the Morning sessions suggesting that the interactions in which the participant and robot would perform everyday tasks were considered more attractive by participants scoring higher along this dimension.

The *Control*-dimension had a strong negative correlation with the first Lunch session. This is related to the relationship with the SUS score for this session, where the difficulties in responding to the AIBO within the game may have made participants with a high score on this dimension less likely to want a system like this in their own lives.

As for the *Pet*-dimension, it was positively correlated with both Lunch sessions and the first morning sessions. The Lunch sessions could to a large extent be understood through the pet-like interactions that the participants had with the system in these sessions. As noted for the Usability measures, the positive correlation for the first of the morning sessions, was likely related to better coping with the robot's behaviour in the first interaction overall.

Robot for Other None of the UHSRQ dimensions were correlated with responses to this item. In addition, this item was the only item in which responses between *sessions* varied significantly, suggesting that responses to this item was more of a function of the scenario than individual differences between participants. This suggests that the decision as to whether or not this type of technology may be suitable for an elderly or disabled other, is more rooted in practical concerns.

5.7.2 Social Role Expectations and Constrained Task Evaluation

The results suggest that the observed differences between participants in terms of how well they adapted to the robot's behaviour within the *Fetch and Carry* task could be explained by their Social Expectations of the robot as measured by the UHSRQ.

What is interesting, is that the impact of the participant responses to the UHSRQ did not occur immediately after the participants had completed it, but rather became more important in the later stages of the study. The correlations for the Fetch and Carry task suggests that here, the participants who managed to best utilise the robot to reduce their workload on both the mental and the physical dimensions of the TLX were those whose Social Role Expectations were higher on the *Equality*-dimension.

On the other hand, the *Control*-dimension was positively correlated with mental workload change in Session 2, meaning that the participants with a higher score on this dimension felt that the use of the robot reduced their mental workload. By Session 8, however, scores on this dimension were negatively correlated with the change in workload ratings for the mental, temporal and effort dimensions, suggesting that participants with high scores in this dimension, over time found that the robot *increased* their experienced workload along these dimensions.

This suggests that how participants responded to the UHSRQ in the first session, and their views on how they wanted to interact with robots, had a clear impact on how they felt about cooperating with the robot to complete the task, it also suggests that the impact of expectations arising from preconceptions as to how one would interact with a robot, persist beyond the initial interaction, and may impact the ability of people to cooperate with a robot in an effective manner.

5.8 Summary and Conclusions

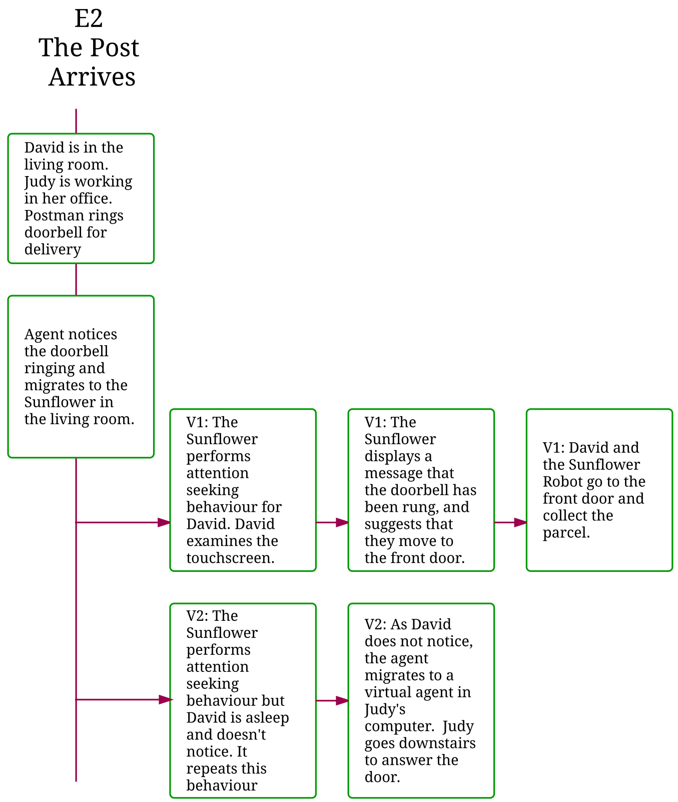
The findings from this chapter extend the findings from the proxemics study reported in the previous chapter, in that they examine the possible impact of social role expectations of robots both from constrained experiments to the richer open-ended interactions, as well as from initial first-encounter meetings to prolonged interactions taking place over several weeks.

They suggest that social expectations as measured by responses to the UHSRQ not only impact how participants evaluate the behaviours of a robot, but they also impact how participants interact with the it, and how effectively they can utilise the robot when performing tasks in concert with the it. What is even more interesting, is that the initial expectations the participations had of the robot prior to any interaction at all, still seem to be related to how well they are able to interact with the robot weeks after their initial interaction. This suggests that social expectations are not unstable constructs that are irrelevant beyond the first actual interaction with a given robot. Rather, such expectations of robots held prior to any interaction may impact the way that user interact with, and how effectively they utilise, the robot to perform their tasks.

However, it is important to note that this study only measured social role expectations *prior* to the interactions which did not allow us to examine whether or not these explicit expectations of the robot matched how the participants *actually* saw the robots during the interactions.

This short-coming was, to some extent, addressed in the study that is described in the next chapter.

Figure 5.9: Episode from 'A Normal Day' for the user personas(1)



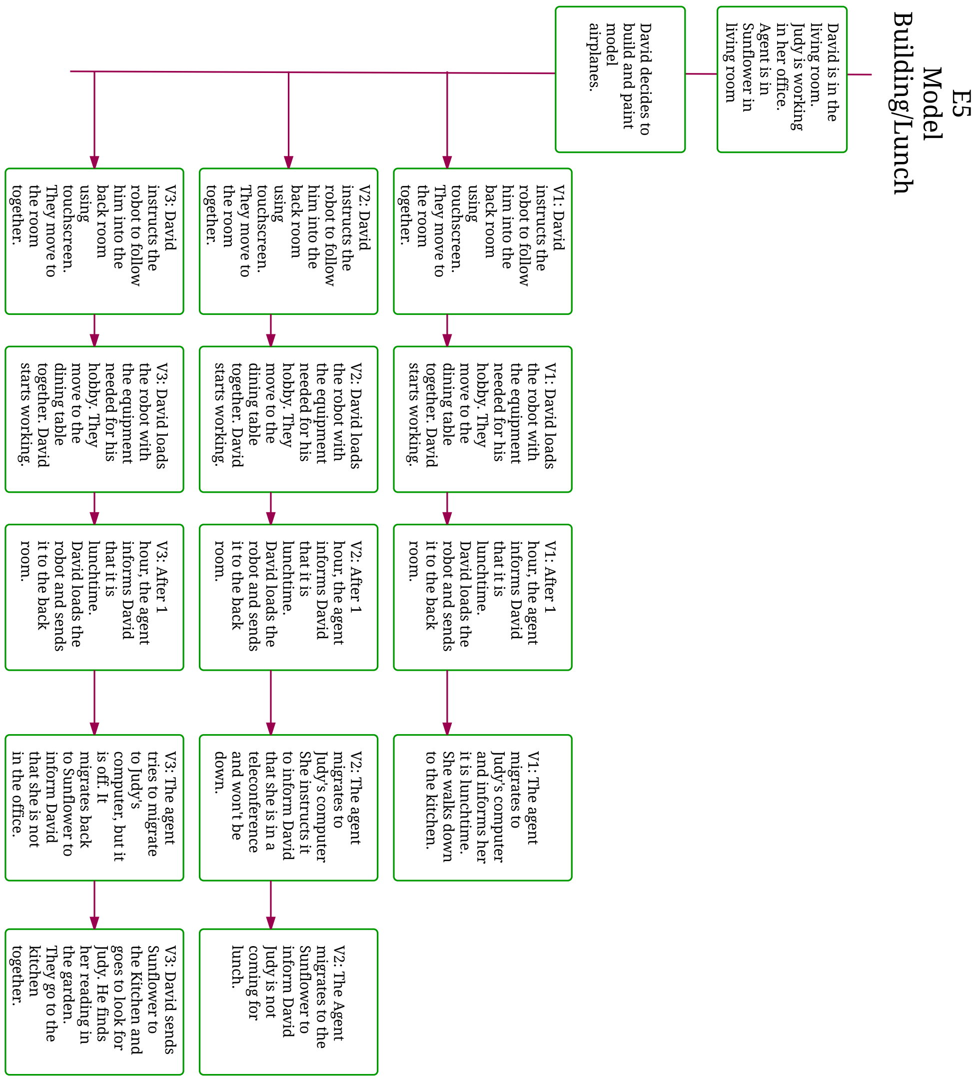


Figure 5.10: Episode from 'A Normal Day' for the user personas(2)

Chapter 6

Changing Social Expectations in Long-term Interactions

This chapter contains the description of another study of Social Role expectations in long-term human-robot interaction, this time examining both how initial Social Role expectations impact long-term interactions with social robots, as well as how these Social Role expectations change over time.

6.1 Introduction

The work presented in chapter 5 introduced the manner in which prototyping was conducted in the University of Hertfordshire Robot House and how this method was used to investigate the role of initial social role expectation for participants' responses to interactions with robots in a long-term study. This chapter outlines a refinement of this approach both in terms of prototyping as well as in terms of how Social Role Expectations were examined.

6.1.1 Changes in Social Expectations

In the study presented in chapter 5, Social Expectations were only examined at the very beginning of the long-term study, and the impact of these *initial* preferences were traced throughout the interaction. This approach, which allowed for an exploration of the impact of pre-interaction expectations on interactions with robots, did not shed any light on whether or not participants' social role expectations of the robot changed across the interaction. Because of this, the UHSRQ was deployed prior to any interaction with the robots, but would be also deployed at several points within the study.

6.1.2 Changes in Prototyping

The previous study had taken the user personas and their proposed interactions with the emergent technologies prototyped in the robot house, and created episodic narratives and constrained experiments based on these. These episodes were coherent both in terms of the role of the user within them as well as the underlying premise of an owner of a robot performing daily tasks, but there was no overarching narrative in which events in one episode impacted the narrative of subsequent episodes, and as such they were disjointed and did not facilitate an understanding of the impact of these technologies in a wider context. In addition, the constrained experiments also broke up the episodes.

To counter these, the second long-term study focused wholly on narrative episodes which together formed a narrative across 9 interaction sessions.

6.2 The Narrative Interaction Episode Framework

The basis for this framework was that all interaction that took place between the user and the robots was part of the narrative framing, and that each episode would be in support of this frame and that elements intended to investigate specific research questions should be presented as naturally occurring elements of it.

6.2.1 Underlying Narrative

The underlying narrative in this study was that the participant took on the role of a new user of an agent embodied in two robotic embodiments as part of a smart house environment. This approach gave the initial uncertainty regarding the robots and their capabilities as well as what the possible interactions the participants were meant to have with them, a natural space that was shared with the fictional user who might also have similar questions. It also allowed one of the researchers to take the role of a 'technician', who would introduce the robots to the user and would also respond to technical problems and queries 'in-character'.

The narrative was broken up into three separate phases:

1. Demonstration

    - This comprised the 'technician-led' part of the user's initial interaction with the technologies, where the researcher taking the role of the technician would conduct a basic demonstration of the robots, their interface, and capabilities. In addition, the technician would oversee the user's initial attempt at using the interface in order to perform some basic tasks. This phase was to be the shortest of the phases, only using the initial stages of the first session of a long-term study.

2. Independent Habituation

    - This phase was intended to give the participant the opportunity to familiarise themselves with the robots and the robot house environment by experiencing a series of narrative episodes with interactions expected to arise as part of an everyday routine for the user. This phase was longer, intended to last for at least 3 sessions beyond the introductory session.

3. Intervention

    - This phase involved active manipulation of the scenario to investigate particular aspects of the interaction that were of interest to the researchers. How participants responded to these changes was intended to shed light on questions regarding these aspects. This phase would last from the end of the habituation phase to the end of the study itself.

These phases built upon each other. The participants would draw on the information and practice they received in the Demonstration phase when performing the tasks in the Habituation phase, and the routine created in the Habituation phase would be used as the norm from which the manipulations of the Intervention phase deviated from.

6.3 Research Aims

The research aims, from the point of view of this PhD project, were focused on Social Role expectations. Firstly, there was an interest in further exploring the findings from the previous long-term study, in order to see whether or not social role expectation held *prior* to an interaction with the robots, would still impact the participants' perceptions and evaluations of the system across the long-term study. Secondly, participant perceptions of the robot in terms of Social Role expectations would also be collected after some of the interactions in order to see whether or not these expectations changed over time, and how such changes happened.

6.4 Methodology

6.4.1 Sessions

Like in the study reported in chapter 5, the interaction sessions had distinct themes. The sessions are described in table 6.1, along with their associated phase.

After having been introduced to, and given the opportunity to interact with, the robots in session 1, the participants goes through a set of sessions in which they perform basic routine tasks, in Session 2 and 3 this mainly involves relaxing and having breakfast and snacks, but in session 4 the participants performs a basic paperwork task (simulated by them typing out the two opening pages of Dickens''A Tale of Two Cities'. Towards the end of this session however, the mobile robot develops a fault, the technician arrives and the participant is told that the robot has to be taken away, unless it recovers in time for the next session.

The next 5 sessions follow the alternating breakfast/lunch pattern, but with the addition of a robot driven narrative. In session 5, the robot is still displaying the same fault, and the technician arrives and drives the robot to the back entrance of the robot house. The participant is told that they will receive a replacement robot, while the original robot is being repaired. In

Table 6.1: Sessions

Number	Phase	Session
1	Demonstration	Introductory Session
2	Habituation	Breakfast at home
3		Late afternoon
4		Paperwork afternoon
5	Intervention	Departure of Mobile robot
6		A day with only the stationary robot
7		Arrival of replacement mobile robot
8		Morning routine and departure of replacement
9		Return of original mobile robot

session 6, the participants spends the majority of the session only interacting with the stationary robot, but a replacement robot arrives in the beginning of session 7. The participant spends session 7 and 8 with the replacement robot and then the original mobile robot is returned at the beginning of session 9, giving the participant a whole session to interact with this robot.

6.4.2 Robots

There were three robots used in the study. They are described in figures 6.1–6.3 and are as follows:

- Sunflower 1 (SF1) — Mobile Sunflower
  - SF1 was identical in its design to the Sunflower robot used in the study reported in chapter 5.
- Sunflower 2 (SF2) — Stationary Sunflower
  - SF2 was identical to SF1. However, for the purposes of this study the pioneer base was covered in cloth, and the participants were told that it could not move. It remained stationary throughout the study, and while it used the same sounds, lights and head

Figure 6.1: Sunflower Embodiment 1 – The mobile robot

movements for expressive behaviours, it would not use gross body movements.

- Sunflower 3 (SF3) — Replacement Mobile Sunflower
  - SF3 was a modified SF1. The head had been removed and the touchscreen had been mounted on the top of its body. It used the same sounds, lights and gross body movements for expressive behaviours, but could not use head movements.

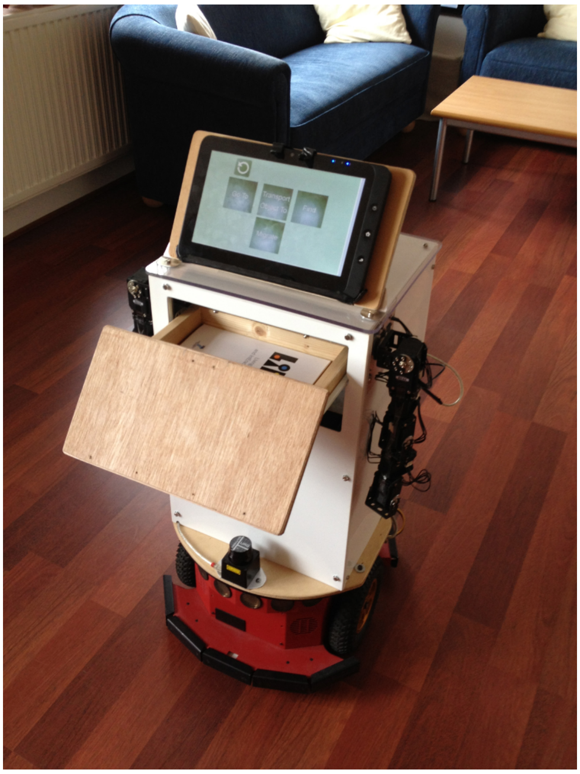
6.4.3 Participants

There were 9 participants in this study 6 female and 3 male. They were recruited via advertisements on the University of Hertfordshire Intranet. The participants were between 21-32 years of age with a median age of 25 years. One of the participants dropped out of the study, after session 6, but their responses up until this point have been retained in the analysis.

Participants did two sessions per week over a month. Since each session lasted about one hour, with additional time beforehand and afterwards to

Figure 6.2: Sunflower Embodiment 2 – The stationary robot

Figure 6.3: Sunflower Embodiment 3 – The replacement robot



set up the system, charging the robot etc., accommodating 18 experimental sessions during a working week was stretching the available resources to the maximum.

6.4.4 Procedure within the Sessions

In the first session, the experimenter who would act as facilitator would welcome the participants to the Robot House, introduce himself and a second experimenter whose responsibility it was to monitor the systems during the trials from a small adjoining office (a converted bedroom not used in the study), and to take on the role of technician during the scenarios when needed. The participants would then be introduced to the Robot House and shown how to use the house's electrical appliances, where the food was kept, where the drawers for cutlery and plates were and so on. After this, the participant would fill in the consent form and a brief demographic questionnaire.

Each interaction session would begin with an introduction the session, which was intended to ground the interaction within the narrative and provide a context for the participant. An example narrative is provided below:

> *In the introductory session you gave us some preferences for what you like to do in the early morning. Your robotic companion has these preferences and will apply them when interacting with you.*
>
> *Now imagine that you have woken up in your bedroom. When you are ready, you will come out of your bedroom, sit down on the sofa, and log in to the robot with your user account and password. The robot will then begin today's session.*

The facilitator would then ask if the participant had any questions about the session, and after answering any questions in an appropriate manner, leave to the facilitator room, allowing the participant to conduct the interaction alone with the robots. Throughout the interaction, the technician would monitor the interaction through networked cameras to ensure the safety of the participant.

The interaction would then take place. The robot and the participant would interact with each other throughout the scenario without any involvement from the experimenters. After the above briefing, the interaction would begin with the agent using SF1 to approach the participant and suggest breakfast and a hot drink. It would remind them of the toaster and kettle having finished, and alert them to a newspaper delivery.

After the interaction, the participant would then meet with the facilitator in order to complete a series of post-interaction questionnaires. They would also have an opportunity to discuss their experience with the facilitator. The session would end with the facilitator and participant arranging a time for the next session.

6.4.5 Measures

Social Roles Expectations

This study used the same questionnaire to measure Social Role expectations as in the previous study. However, due to the fact that these expectations were now tied to both initial preferences as well as to post-interaction evaluations, the wordings of the initial question would change from *'I would like to interact with these robots as a...'* to *'I felt that the robots, in today's interaction were like a...'*. Due to the high number of different questionnaires given to the participants throughout the study, the UHSRQ was only given out in sessions 1,2,4,6,7,8,9 as well as in the post-study evaluation session. These question were phrased to address how the participant felt about the agent rather than the specific robotic embodiments.

Evaluation of the Robots

The evaluation of the robots was done in a similar manner as in the previous study. Usability was assessed using the System Usability Scale (Brooke et al., 1996), Scenario Acceptance was measured using the same measure as described in Chapter 5, and the same ad-hoc Likert items were used to assess perceived suitability for oneself and for others.

In addition, participant perception of emotional closeness to the robots was also assessed. This was done using the Inclusion of Other in Self scale, which was created by Aron et al. (1992) as a measure of perceived interpersonal closeness. The measure used was taken from the questionnaire used by Segura et al. (2012). It measures interpersonal closeness on a scale of 1 (Least experienced interpersonal closeness) to 6 (Most experienced interpersonal closeness). This was done in order to gauge differences between feelings of closeness to the agent both in terms of feelings towards the specific embodiments as well as towards the agent occupying the embodiments, and the IOS was used to elicit participant responses for each embodiment.

Post-Study Evaluation

After the participants had participated in 9 interaction sessions, they were invited back for a final session in which they were asked to consider their experiences of the robots within the study as a whole. They were asked to respond to the different Evaluation measures discussed above, as well as the UHSRQ. Here, the participants were again exposed to two versions of the UHSRQ, one was retrospectively asking the participants for their expectations as in the pre-interaction questionnaire, while the second asked them to address how the participants felt about the agent across the study as a whole.

6.4.6 Analysis

Stability of Social Role Expectations

The previous study suggested that the social role expectations that participants had of the robots prior to the interaction, were related to interactions throughout the study. This suggested that initial expectations had *effects* that were reliable for a duration time. However, the question of whether or not these effects reflected an underlying stability of the expectations themselves or if they changed dependent on the specifics of a given session, remained.

There were two different ways of assessing this. The first was to see whether or not there was a difference between UHSRQ responses before and after the first interaction, while the second was to see whether or not the participant responses to the post-interaction UHSRQ questionnaires changed between the different sessions.

UHSRQ Responses and Evaluations of the Robots

The previous study suggested that the initial responses to the UHSRQ was related to participant evaluations of the robots and their interactions throughout the long-term study. This study sought to explore whether or not this result could be replicated, and if the post-interaction UHSRQ responses were related to the global evaluation measures of the robots. This meant that both the participant responses to the initial UHSRQ responses as

Figure 6.4: Sign in the Robot House

well as their responses to the post-interaction UHSRQ were to be correlated with the global evaluation measures.

UHSRQ Responses and Feelings of Closeness to the Robots

The Inclusion of Other in Self is a measure of interpersonal closeness. Because of this, it would be interesting to see if responses to the UHSRQ, which differentiates between expectations of control, and expectations of more social interactions would be related to responses to this scale.

6.5 Results

6.5.1 Approach to Analysis

When considering these results, it is important to note the exploratory nature of this analysis. For obvious reasons, the sample size is small that generalisability can be problematic, and outliers may dramatically skew the results. Because of this, efforts have been made to allow the reader insight into the distribution of responses across the participants, and both means and medians have been reported as measures of central tendency. In addition, dispersion has been reported using both standard deviation and Range. Finally, boxplots have been produced for all appropriate data, which also shows the interquartile range of the responses. In addition, to avoid the issue of single extreme cases impacting results, most of the inferential statistics are rank-based.

The results described below will be considered in terms of research questions. Initially, UHSRQ scores will be analysed and discussed. This will be followed by discussion of the Global Evaluation measures and their relationship to the UHSRQ. Finally, the IOS responses will be described and their relationship with the UHSRQ will be analysed.

Neutral Score

In this analysis, some times the phrase *'a neutral score of...'* will occur. A neutral score is used to describe what would have been the result if a participant had answered the neutral option on all Likert scales related to a measure. This is intended for illustrative purposes in order to give the reader and idea of how the participants responded. The system usability scale, however has an established body of research which suggests that a reasonably usable system would get a score of around 70 (Bangor et al., 2008), which is what is used as a neutral score for it.

6.5.2 Stability of Social Role Expectations

Initial UHSRQ

Descriptive statistics can be found in table 6.2 and in figure 6.5. They suggest that participants overall rated their interaction expectation higher than a neutral score of 3 for the *Equality* and *Control* UHSRQ subscales, however, as both the table and boxplots suggest, there were clear differences amongst the participants. Also as can be seen in table 6.3, the three subscales of the UHSRQ were correlated with each other. This was different to what was observed in the first narrative study reported in Chapter 5, but similar to the findings from the initial use of the UHSRQ items in Chapter 3. This suggests that, while the constructs may be stable, their relationship to each other may not be. While in itself, this is not necessarily an issue for the validity of the constructs themselves, it may make the comparative effect of the constructs on human-robot interactions difficult to measure.

Table 6.2: Initial UHSRQ Responses

	Mean	SD	Median	Range	d	Wilcoxon p
Equal	3.83	1.00	4	2.5-5	.60	$< .07$*
Control	3.89	0.74	4	2.5-5	.68	$< .04$**
Pet	3.56	1.24	3	2-5	.43	$< .2$

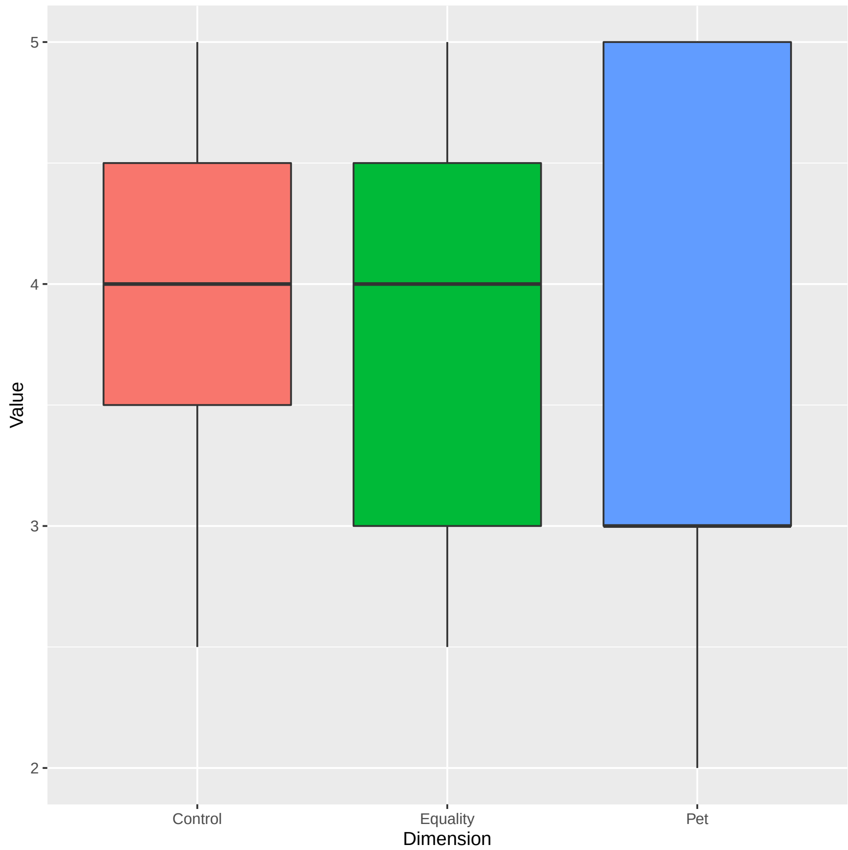
*:$p < .1$, **:$p < .05$, ***$p < .01$

Table 6.3: Spearman Correlations between the UHSRQ Dimensions

	Equality ρ(p)	Control ρ(p)	Pet ρ(p)
Equality	1.00		
Control	0.63(.07)*.	1.00	
Pet	0.90(.01)***	0.60(.08)*	1.00

$*p < 0.1, **p < .05, ***p < .01$

Figure 6.5: Boxplot for initial UHSRQ Responses



UHSRQ Post-Interaction Evaluations

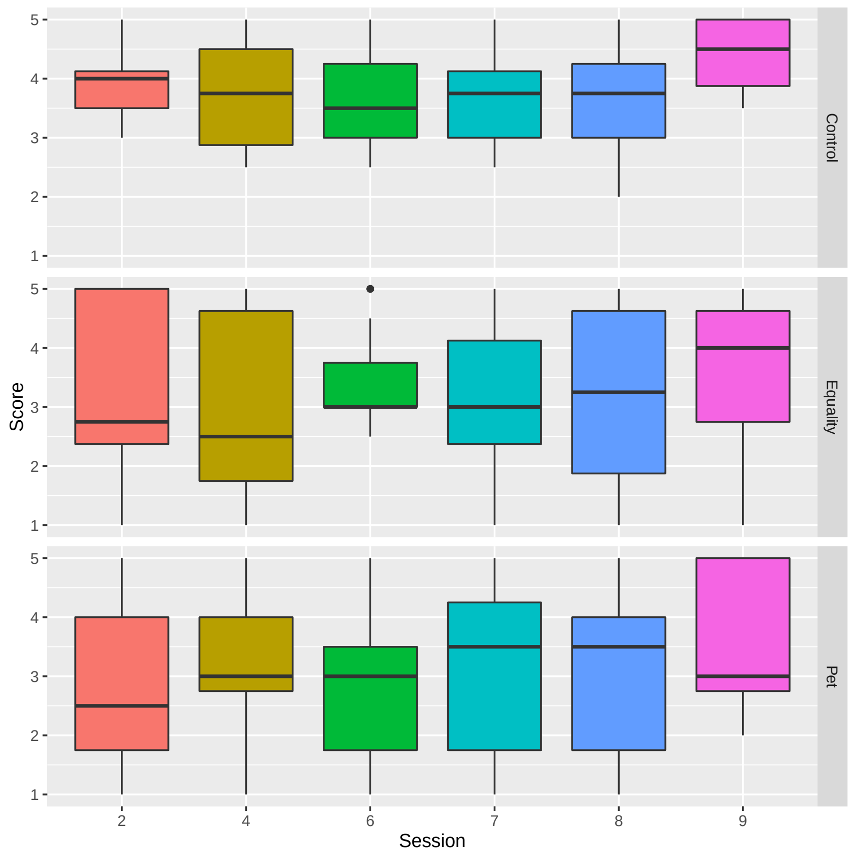
The descriptive statistics can be found in table 6.4 and in figure 6.6. The results suggest that overall, the participants' UHSRQ responses to the interactions were overall only significantly higher than the 'neutral' score of three for the *Control* dimension while this was not the case for the *Equality* or the *Pet* dimensions. However, the spread of scores were much wider within the sample for these two dimensions than for *Control*. This suggests that for the participants, their experience of the robot in terms of the Control dimension was much more uniform than in terms of the other dimensions, and their evaluations along these two dimensions may have been impacted more by idiosyncratic factors. Also notable is that the spread of scores does not decrease as the participants interacted more with the robot.

Table 6.4: Post-Interaction UHSRQ ratings

	Mean	SD	Median	Range	d	Wilcoxon.p
Session 1						
Equality	3.33	1.50	3.50	1–5	.24	0.48
Control	4.39	0.74	4.50	3–5	.86	0.01**
Pet	2.78	1.30	3.00	1–5	.14	0.68
Session 2						
Equal	3.33	1.48	3.00	1–5	.21	0.52
Control	3.83	0.66	4.00	3–5	.78	0.02**
Pet	2.67	1.41	2.00	1–5	.21	0.52
Session 4						
Equal	3.06	1.63	3.00	1–5	.02	0.94
Control	3.67	0.90	3.50	2.5–5	.58	0.08*
Pet	3.00	1.22	3.00	1–5	$<.01$	$>.99$
Session 6						
Equal	3.44	0.86	3.00	2.5–5	.37	0.27
Control	3.69	0.92	3.50	2.5–5	.57	0.09*
Pet	2.88	1.55	3.00	1–5	$<.01$	$>.99$
Session 7						
Equal	3.12	1.33	3.00	1–5	.72	0.83
Control	3.69	0.84	3.75	2.5–5	.60	0.07*
Pet	3.12	1.64	3.50	1–5	.03	0.93
Session 8						
Equal	3.19	1.58	3.25	1–5	.12	0.73
Control	3.69	1.03	3.75	2–5	.49	0.14
Pet	3.00	1.51	3.50	1–5	$<.01$	>99
Session 9						
Equal	3.56	1.47	4.00	1–5	.31	0.35
Control	4.38	0.69	4.50	3.5–5	.86	0.01**
Pet	3.50	1.31	3.00	2–5	.37	0.27

*: $p<.1$, **:$p<.05$, ***:$p<.01$

Figure 6.6: Boxplots for Post-Interaction UHSRQ Scores



Differences between initial UHSRQ scores and Post-interaction Scores

The relative difference between the initial UHSRQ response and the Post-Interaction scores were calculated by subtracting the post-interaction UHSRQ responses from the corresponding pre-interaction score. A positive relative difference would mean that the participants found that their interaction with the robots scored *lower* than their expected score on this dimension, while a negative relative difference meant that their interaction with the robots were rated *higher* than their expected score.

The relative differences between the initial score along each dimensions of the UHSRQ and the post-interaction(actual) scores are presented in table 6.5, and in figure 6.7. The results suggest that, overall, there were small relative differences between the UHSRQ responses given as how participants would *expect* to interact with a robot as answered prior to any interaction with the robots, and the responses to the UHSRQ when measuring how the participants *actually* experienced the interactions. Wilcoxon Signed rank tests found that overall, the difference from responses did not significantly deviate from their preferred scale, except for a negative difference approaching significance for the *Control* dimension in Session 2. The ranges shown in both table 6.5 and figure 6.7, however, suggests that there were difference within the sample. The differences were most pronounced for the *Pet* and *Control* dimensions, but less so for the *Equality* dimension.

Figure 6.7: Boxplots of Relative Differences between Initial and Post-Evaluation Ratings by Session

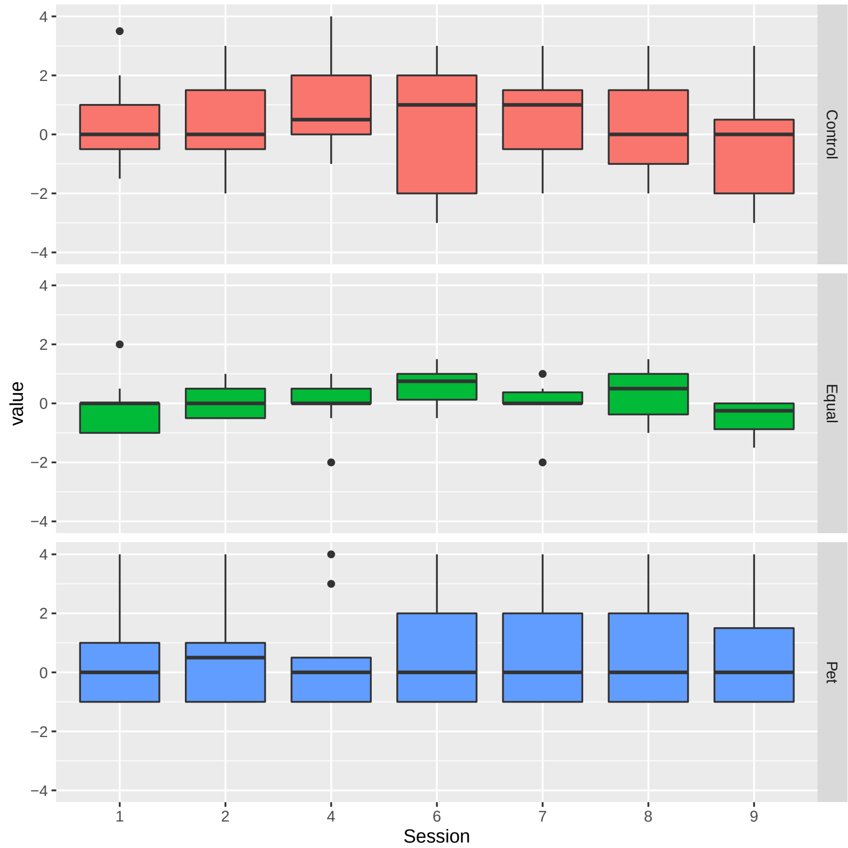


Table 6.5: Relative Differences between initial UHSRQ Scores and UHSRQ ratings of the system after each session

	Mean	SD	Median	Range	d	Wilcoxon.p
Session 1						
Equality	0.50	1.77	0.00	-1–3.5	.03	0.93
Control	-0.50	0.66	-0.50	-1.5–0.5	.60	0.07*
Pet	0.78	1.72	1.00	-1–4	.41	0.22
Session 2						
Equality	0.50	1.66	0.00	-1–4	.06	0.86
Control	0.06	0.81	0.00	-1–1.5	$< .01$	$> .99$
Pet	0.89	1.83	1.00	-2–4	.41	0.22
Session 4						
Equality	0.78	1.75	0.00	-1–4	.28	0.40
Control	0.22	0.87	0.00	-1–2	.18	0.59
Pet	0.56	1.94	0.00	-2–4	.20	0.55
Session 6						
Equality	0.44	1.64	0.50	-2–2.5	.24	0.48
Control	0.25	1.41	0.75	-2.5–2	.17	0.61
Pet	0.75	2.25	0.50	-3–4	.28	0.40
Session 7						
Equality	0.75	1.60	0.25	-1–4	.35	0.29
Control	0.25	1.20	0.00	-1.5–2	.18	0.59
Pet	0.50	2.20	0.50	-2–4	.14	0.67
Session 8						
Equality	0.69	1.75	0.00	-1–4	.27	0.41
Control	0.25	1.28	0.00	-1.5–2	.21	0.52
Pet	0.62	2.07	0.50	-2–4	.20	0.55
Session 9						
Equality	0.31	1.98	0.00	-2–4	.09	0.79
Control	-0.44	1.24	-0.25	-2.5–1.5	.28	0.40
Pet	0.12	1.81	0.00	-3–3	$< .01$	$> .99$

*: $p < .1$, **:$p < .05$, ***:$p < .01$

Differences between Post-Interaction UHSRQ responses

Differences between the UHSRQ responses shown in table 6.4 and figure 6.6 were assessed using a series of Friedman's non-parametric within-group tests. These found that there were no significant differences between the sessions in terms of Equality (Friedman's $\chi^2(5) = 3.22, p = .67$) or the Pet-dimension (Friedman's $\chi^2(5) = 5.67, p = .46$), there were, however differences between the sessions in terms of responses along the Control dimension (Friedman's $\chi^2(5) = 13.02, p = .04$). Table 6.4 suggests that this was primarily caused by higher responses along this dimension for Sessions 1 and 2.

Correlations between Initial Responses and Post-Interaction UHSRQ responses

Table 6.6: Spearman Correlations between initial and post-session UHSRQ responses

Session	Control	Equality	Pet-like
2	0.39,p=0.299	0.065,p=0.869	0.044,p=0.91
4	0.468,p=0.204	0.124,p=0.751	-0.253,p=0.511
6	-0.16,p=0.704	-0.62,p=0.101	-0.244,p=0.561
7	-0.037,p=0.931	0.018,p=0.966	-0.094,p=0.824
8	-0.012,p=0.977	0.091,p=0.829	-0.057,p=0.893
9	-0.354,p=0.39	-0.092,p=0.828	0.033,p=0.939

The relationship between what participants responded in the initial UHSRQ and that of responses to the post-interaction questionnaires are given in table 6.6. This table suggest that these relationships were not only not significant at this sample size but had small and diverging effect sizes, suggesting that there was no consistent relationship between the participants expected interaction and the post-interaction evaluation in terms of the social roles measured by the UHSRQ.

Session 10 Evaluation

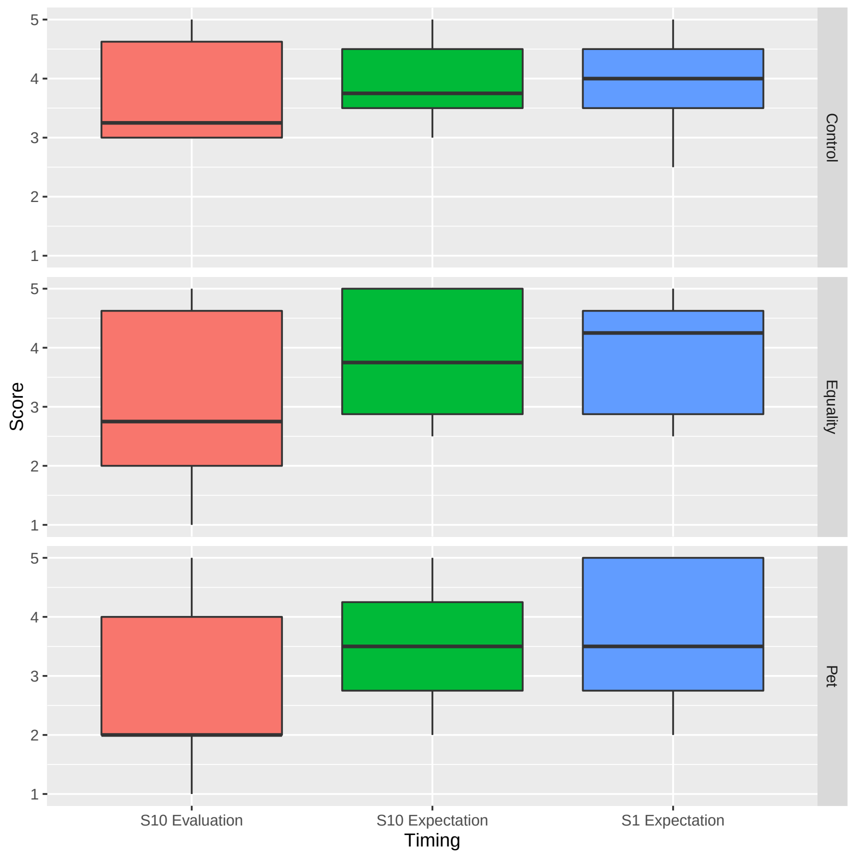
Responses to the Post-study evaluation questionnaire in terms of UHSRQ responses are presented in table 6.7 and figure 6.8. These suggest that for all three subscales, the participants' expectations in terms of preferred interactions did *not* change markedly between the first and last sessions. This suggest that these expectations remained stable throughout the study. The actual interactions with the robots, however did not correspond to these for the *Equality*- and *Pet*-dimensions, as participant responses along these were lower in the post-interaction evaluation. This was not the case for the *Control* dimension. Responses for both pre-interaction expectations as well as post-interaction ratings did not diverge dramatically for this dimension. However, as table 6.8 suggests, the response to the initial UHSRQ provided in the first session was somewhat related to responses related to their Session 10 preferred expectations, but there was no such relationship between Session 1 expectations and Session 10 evaluations.

Table 6.7: UHSRQ Responses Session 10

		Mean	SD	Median	Range	d	Wilcoxon.p
Equality	S1 Expectation	3.88	1.06	4.25	2.5–5	.60	0.07*
	S10 Expectation	3.81	1.16	3.75	2.5–5	.49	0.14
	S10 Evaluation	3.12	1.53	2.75	1–5	.08	0.80
Control	S1 Expectation	3.94	0.78	4.00	2.5–5	.72	0.03**
	S10 Expectation	3.94	0.68	3.75	3–5	.78	0.02**
	S10 Evaluation	3.75	0.93	3.25	3–5	.57	0.09*
Pet	S1 Expectation	3.62	1.30	3.50	2–5	.43	0.20
	S10 Expectation	3.50	1.20	3.50	2–5	.36	0.28
	S10 Evaluation	2.75	1.39	2.00	1–5	.15	0.66

*: $p < .1$, **:$p < .05$, ***:$p < .01$

Figure 6.8: UHSRQ Responses Session 10



Summary — UHSRQ Response

There was a trend in which participant rated their interaction with the robots lower along the *Equality*- and *Pet*-dimension in the post-interaction UHSRQ than their expectations in the pre-interaction. This trend was not significant in itself. It did, however, mean that responses to the Equality and Pet dimensions which were significantly above the 'neutral' score of 3 in the pre-interaction questionnaire were not so in the post-interaction questionnaires.

Because of this, we can tentatively suggest that for the robots used in this study, the participant's evaluation of them along their perceived social

Table 6.8: Spearman Correlation between initial and post-session 10 responses to the UHSRQ

Dimension	S10 Expectation	S10 Evaluation
Control	0.681,p=0.063	0.215,p=0.61
Equality	0.824,p=0.012	-0.039,p=0.927
Pet-like	0.405,p=0.319	0.013,p=0.975

roles was that interactions with them were less social and pet-like in nature than their expected interactions with them.

The opposite was true for the *Control*-dimension for some of the sessions, where it would be significantly lower than the ratings for expectations.

The same picture emerges for the post-study evaluation in session 10. While the expected interactions as measured by the UHSRQ remain the same, the ratings for the *Pet*- and *Equality*- dimensions are lower in the post-interaction ratings, while the *Control*-dimension remain the same.

6.5.3 Global Evaluation Measures and UHSRQ responses

Descriptives of Global Evaluation Measures

The overall responses for the global evaluation measures can be found in table 6.10, and in figures 6.9 and 6.10. There were no overall differences between sessions for the 4 different measures (see table 6.9). The boxplots presented in figures 6.10 and 6.9 also suggest that while there is little within-group variation for the *Robot for Others* measure, there was some variation within the sample for the three other measures. *Scenario Acceptance* and the *Robot for Others* remained significantly higher than their 'neutral' scores throughout the study. Responses along the *System Usability Scale* and *Robot for Self* only went above the expected and neutral scores in the first session.

Table 6.9: Friedman tests for differences between sessions

Measure	χ^2	p
System Usability Scale	6.21	0.40
Scenario Acceptance	2.99	0.70
Robot for Self	4.70	0.58
Robot for Others	7.68	0.17

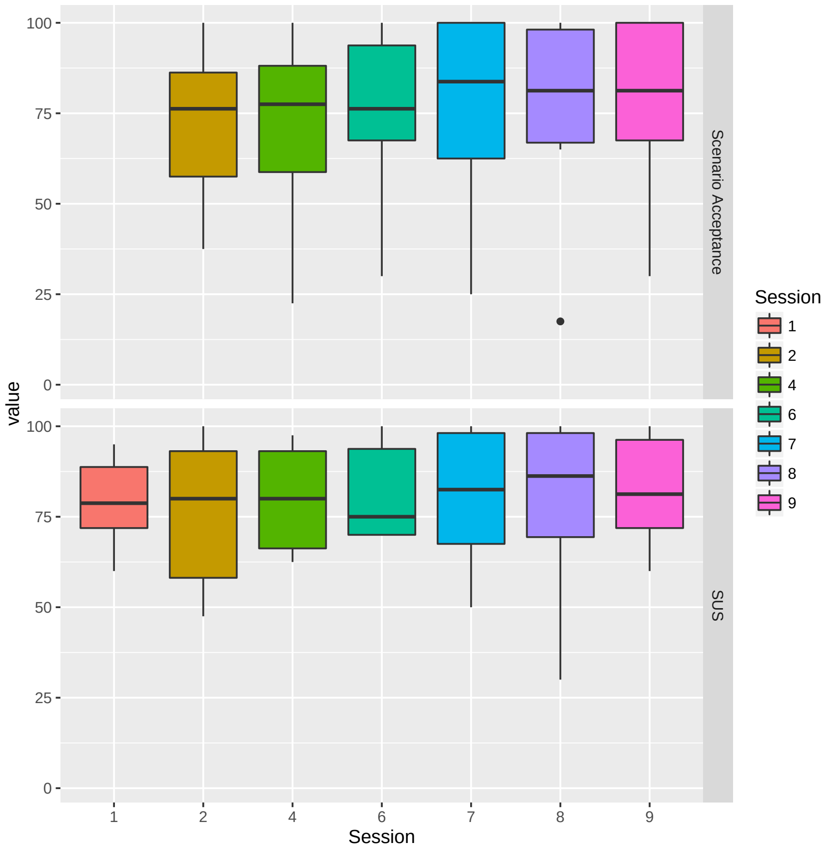
Global Evaluation Measures and UHSRQ Responses

A set of Spearman correlations was run to examine relationships between the different Global Evaluation measures and the UHSRQ responses

Global Evaluation Measures and Initial Preferences/Expectations

Table 6.11 show Spearman correlations between the responses that the participants gave on the UHSRQ before *any* interaction with the robots in the first session, and their post-interaction ratings of the interactions with the robots each session. They suggest that the most important dimension in terms of its relationship with differences between participants in Global

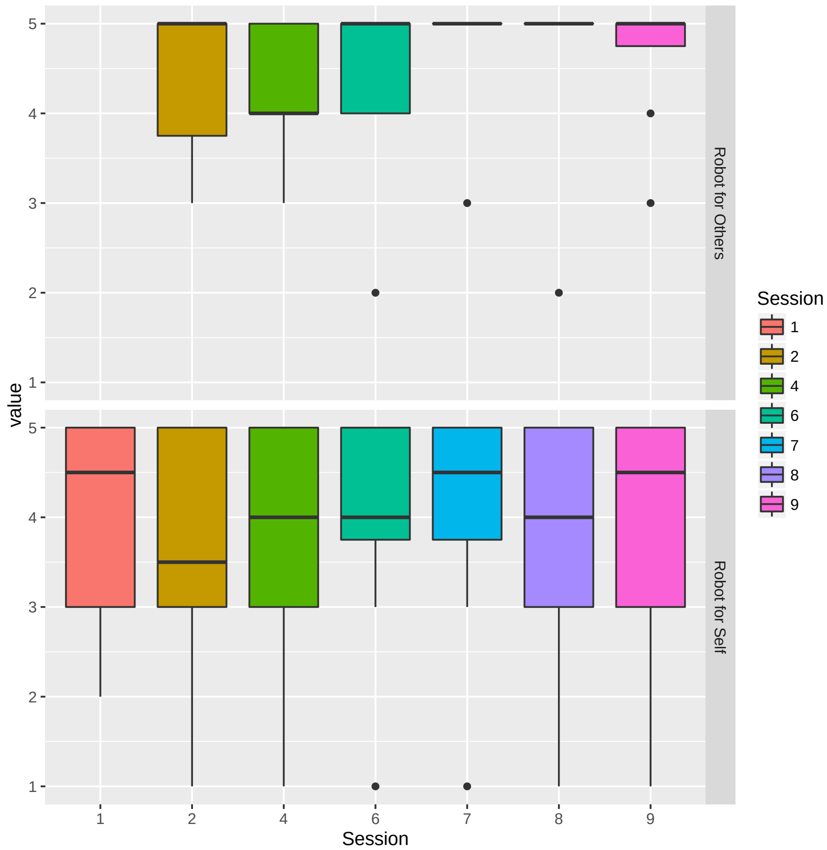
Figure 6.9: Scenario Acceptance and SUS responses to the Interaction Sessions



Evaluation measures was *Equality*, while the *Control* dimension was the least important. As observed in chapter 5, participant responses to the UHSRQ in the initial session, impacted their evaluations of the interactions throughout the long-term study.

Global Evaluation Measures and Post-Interaction UHSRQ Responses Table 6.12 shows Spearman correlations between the evaluation measures and post-interaction UHSRQ responses. In contrast to the Pre-interaction measures, responses along the Post-interaction UHSRQ was not as strongly related to the Global Evaluation measures, the exception being,

Figure 6.10: Robots for Self and Others responses to the Interaction Sessions



sessions 4 and 8, where responses along the *Control*-dimension was related to the Global evaluation measures.

Session 10 Evaluation

Overall The responses from the participants when asked about their impression of the robots when thinking about the study as a whole can be found in table 6.13 and figure 6.11. They suggest participants rated the robots above the expected or neutral score for all of the measures except for the *Robot for Self* measure, possibly indicating that the participants saw the robots as usable, and working within the provided scenario, but that they saw them primarily as an aid for somebody who had particular needs that the robots could be used for, rather than something that they needed in their current situation.

Session 10 Evaluations and UHSRQ Measures The relationships between UHSRQ measures and the Session 10 retrospective evaluations can be found in table 6.14. The table suggests that responses along the *Equality*-dimension in the pre-interaction questionnaire had clear positive correlations with participant evaluations of the robot along all 4 measures, while pre-interaction responses along the *Pet*-dimension were positively correlated with SUS and *Robot for Others* responses. The restated expectations in Session 10 had a similar relationship with the global evaluation measures, but the *Equality*-dimension was not significantly correlated with the *Robot for Self* measure.

The UHSRQ evaluations, however, did not have as strong a relationship with global evaluation measures as the expectations. For the *Equality*-dimension, a strong relationship was only seen for the *Scenario Acceptance* and the *Robot for Self* measures, while only *Scenario Acceptance* was related to the *Pet*-dimension.

Figure 6.11: Global Evaluation Measures Across Study

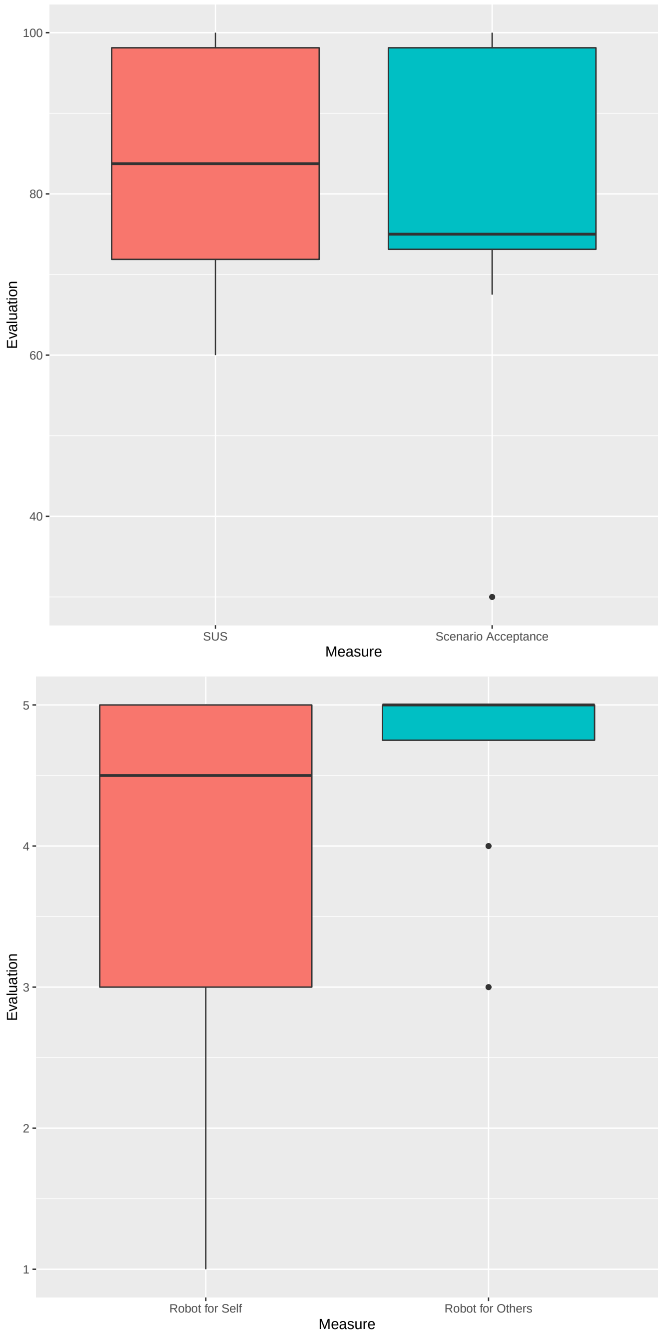


Table 6.10: Global Evaluation Measures for Interaction Sessions

	Mean	SD	Median	Range	d	Wilcoxon p
Session 1						
SUS	78.89	11.40	75.00	60–95	.63	0.06*
Robot For Self	4.00	1.12	4.00	2–5	.65	0.05**
Session 2						
SUS	76.67	19.69	82.50	47.5–100	.38	0.26
Scenario Acceptance	72.50	20.12	77.50	37.5–100	.72	0.03**
Robot for Self	3.67	1.32	4.00	1–5	.40	0.23
Robot for Others	4.44	0.88	5.00	3–5	.86	0.01**
Session 4						
SUS	81.11	14.15	80.00	62.5–97.5	.63	0.06*
Scenario Acceptance	72.78	25.20	85.00	22.5–100	.68	0.04**
Robot for Self	3.89	1.36	4.00	1–5	.49	0.14
Robot for Others	4.33	0.71	4.00	3–5	.86	0.01**
Session 6						
SUS	81.25	13.16	75.00	70–100	.63	0.06*
Scenario Acceptance	75.31	23.05	76.25	30–100	.68	0.04**
Robot for Self	3.88	1.36	4.00	1–5	.46	0.17
Robot for Others	4.38	1.06	5.00	2–5	.72	0.03**
Session 7						
SUS	80.31	19.39	82.50	50–100	.46	0.17
Scenario Acceptance	76.56	27.15	83.75	25–100	.65	0.05*
Robot for Self	4.00	1.41	4.50	1–5	.49	0.14
Robot for Others	4.75	0.71	5.00	3–5	.86	0.01 **
Session 8						
SUS	78.44	25.63	86.25	30–100	.31	0.36
Scenario Acceptance	76.25	28.13	81.25	17.5–100	.63	0.06*
Robot for Self	3.75	1.39	4.00	1–5	.40	0.23
Robot for Others	4.62	1.06	5.00	2–5	.86	0.01**
Session 9						
SUS	81.88	15.74	81.25	60–100	.56	0.09*
Scenario Acceptance	78.44	24.13	81.25	30–100	.68	0.04**
Robot for Self	3.88	1.46	4.50	1–5	.45	0.18
Robot for Others	4.62	0.74	5.00	3–5	.86	0.01**

*:$p < 0.1$, **:$p < .05$, ***:$p < .01$

(Wilcoxon p is a test of difference between observed ratings and a "neutral" score of 3 for the Robot for Self and Robot for Other, a "neutral" score of 50 for the Scenario Acceptance Scale, and the reported average score of 70 for the SUS)

Table 6.11: Spearman Correlations between initial UHSRQ responses and Global Evaluation Measures

	Equality ρ	p	Control ρ	p	Pet ρ	p
Session 1						
SUS	0.71	0.03**	0.43	0.25	0.47	0.20
Robot for Self	0.61	0.08*	0.30	0.43	0.54	0.13
Session 2						
SUS	0.62	0.08*	0.14	0.71	0.34	0.37
Scenario Acceptance	0.63	0.07*	0.10	0.79	0.40	0.28
Robot for Self	0.71	0.03*	0.28	0.47	0.51	0.16
Robot for Others	0.31	0.42	-0.11	0.79	0.09	0.82
Session 4						
SUS	0.39	0.30	0.16	0.68	0.14	0.72
Scenario Acceptance	0.58	0.10	0.10	0.79	0.43	0.25
Robot for Self	0.76	0.02**	0.36	0.35	0.71	0.03**
Robot for Others	0.62	0.08*	0.20	0.61	0.62	0.08*
Session 6						
SUS	0.45	0.27	0.48	0.23	0.24	0.57
Scenario Acceptance	0.78	0.02**	0.54	0.17	0.62	0.10
Robot for Self	0.73	0.04**	0.60	0.11	0.78	0.02**
Robot for Others	0.30	0.47	0.21	0.62	0.22	0.60
Session 7						
SUS	0.88	0.01***	0.44	0.27	0.67	0.07*
Scenario Acceptance	0.86	0.01**	0.45	0.27	0.69	0.06*
Robot for Self	0.81	0.01**	0.52	0.19	0.70	0.05*
Robot for Others	0.52	0.18	0.23	0.59	0.50	0.20
Session 8						
SUS	0.79	0.02**	0.31	0.46	0.63	0.09*
Scenario Acceptance	0.80	0.02*	0.40	0.33	0.63	0.09*
Robot for Self	0.61	0.11	0.25	0.55	0.49	0.21
Robot for Others	0.52	0.18	0.23	0.59	0.50	0.20
Session 9						
SUS	0.52	0.19	0.14	0.74	0.27	0.52
Scenario Acceptance	0.85	0.01**	0.46	0.25	0.67	0.07*
Robot for Self	0.64	0.09*	0.31	0.46	0.57	0.14
Robot for Others	0.38	0.35	0.08	0.86	0.28	0.51

*:$p < .10$, **:$p < .05$, ***:$p < .01$

Table 6.12: Spearman Correlations between Global Evaluation Measures and Post-Interaction UHSRQ Responses

	Equality ρ	p	Control ρ	p	Pet ρ	p
Session 1						
SUS	0.55	0.13	0.08	0.85	0.34	0.37
Robot for Self	0.34	0.38	0.00	1.00	0.43	0.25
Session 2						
SUS	0.56	0.11	0.30	0.43	0.42	0.27
Scenario Acceptance	0.61	0.08*	0.21	0.59	0.57	0.11
Robot for Self	0.64	0.06*	0.21	0.58	0.60	0.09*
Robot for Others	0.50	0.18	0.25	0.52	0.53	0.14
Session 4						
SUS	0.45	0.22	0.72	0.03**	0.22	0.58
Scenario Acceptance	0.65	0.06*	0.73	0.02**	0.21	0.58
Robot for Self	0.40	0.29	0.58	0.10	-0.15	0.70
Robot for Others	0.42	0.27	0.59	0.10	0.00	1.00
Session 6						
SUS	0.32	0.44	0.21	0.61	0.15	0.73
Scenario Acceptance	0.05	0.90	0.06	0.90	0.18	0.67
Robot for Self	0.11	0.79	0.14	0.75	0.20	0.64
Robot for Others	0.42	0.30	0.50	0.21	0.55	0.16
Session 7						
SUS	0.32	0.43	-0.09	0.83	0.40	0.32
Scenario Acceptance	0.38	0.35	-0.02	0.96	0.48	0.23
Robot for Self	0.42	0.30	0.06	0.89	0.49	0.22
Robot for Others	0.34	0.41	0.09	0.83	0.52	0.18
Session 8						
SUS	0.49	0.22	0.56	0.15	0.49	0.22
Scenario Acceptance	0.52	0.18	0.64	0.09*	0.51	0.19
Robot for Self	0.77	0.02**	0.78	0.02**	0.75	0.03**
Robot for Others	0.43	0.29	0.66	0.07*	0.53	0.17
Session 9						
SUS	-0.11	0.80	-0.37	0.37	0.02	0.97
Scenario Acceptance	0.05	0.90	-0.43	0.29	0.41	0.31
Robot for Self	0.27	0.52	-0.23	0.58	0.34	0.41
Robot for Others	0.22	0.60	-0.24	0.56	0.66	0.07*

*:$p < .1$, **:$p < .05$, ***:$p < .01$

Table 6.13: Global Evaluation Measures Across Study

	Mean	SD	Median	Range	d	Wilcoxon p
SUS	83.44	15.81	83.75	60–100	.62	0.06*
Scenario Acceptance	77.50	23.26	75.00	30–100	.72	0.03**
Robot for Self	3.88	1.46	4.50	1–5	.45	0.18
Robot for Other	4.62	0.74	5.00	3–5	.86	0.01**

*:$p < .1$, **:$p < .05$, ***:$p < .01$

Table 6.14: Session 10 Global Evaluations and UHSRQ Responses

Measure	Equality ρ	p	Control ρ	p	Pet ρ	p
Initial Expectations						
SUS	0.86	0.01***	0.46	0.26	0.64	0.08*
Scenario Acceptance	0.69	0.06*	0.28	0.51	0.53	0.18
Robot for Self	0.64	0.09*	0.31	0.46	0.57	0.14
Robot for Others	0.75	0.03**	0.57	0.14	0.72	0.04**
Session 10 Expectations						
SUS	0.95	0.01***	0.27	0.51	0.86	0.01***
Scenario Acceptance	0.75	0.03**	0.23	0.59	0.67	0.07*
Robot for Self	0.53	0.17	0.28	0.50	0.37	0.37
Robot for Other	0.65	0.08*	0.37	0.36	0.56	0.15
Session 10 Evaluations						
SUS	0.45	0.26	0.27	0.51	0.47	0.24
Scenario Acceptance	0.72	0.04**	0.51	0.20	0.67	0.07*
Robot for Self	0.65	0.08*	0.61	0.11	0.62	0.10
Robot for Other	0.36	0.38	0.36	0.38	0.31	0.45

*:$p < .1$, **:$p < .05$, ***:$p < .01$

Summary — Global Evaluation Measures and UHSRQ responses

Correlations between the pre-interaction UHSRQ responses and the Global evaluation measures suggest that, similarly to the study reported in chapter 5, pre-interaction social expectations were related to the way participants evaluated the robots and their interactions with them. The most consistent relationship between these was that between the *Equality*-dimension and the *Robot for Self* measure, which suggests that participants which rated expectations higher along this dimension were more likely to want a system behaving in the manner that the individual scenarios had shown throughout the study.

In contrast, responses from the post-interaction UHSRQ did not have a strong relationship with the evaluation measures. The most notable exception to this was for session 4 and 8, where the *Control*-dimension was correlated with the evaluation measures. This trend was also present when the participants rated their experience of the robots across the whole study. Participant UHSRQ responses prior to the study began were the most strongly related to the participants' evaluations of the robots, while their actual experience of the robots in terms of social roles was less important for how they evaluated the robot.

6.5.4 UHSRQ responses and feelings of closeness to the robots.

Descriptives of the Inclusion of Other in Self (IOS) scale

The results from the inclusion of other in self scale can be found in table 6.15. This table suggest that while there were some differences between how participants rated their feelings of closeness to the robots using the IOS scale, this trend was not significant (Friedman's $\chi^2(5) = 6.57, p = 0.25$), as there were large differences within the sample in each session.

Table 6.15: Descriptives from the Inclusion of Other in Self (IOS) scale

	Mean	SD	Median	Range	d	Wilcoxon p
Session 2	3.56	1.33	4.00	1–5	.12	0.72
Session 4	3.11	1.27	3.00	1–5	.24	0.47
Session 6	2.88	1.64	2.50	1–5	.33	0.32
Session 7	3.31	1.49	4.00	1–6	.03	0.94
Session 8	3.31	1.44	4.00	1–5	.07	0.83
Session 9	3.75	1.91	4.00	1–6	.12	0.72

Pre-Interaction UHSRQ and IOS responses

The relationship between pre-interaction UHSRQ responses and the IOS ratings for each session is described in table 6.16. This suggest that there is no relationship between how participants responded to the UHSRQ in the initial session and their IOS responses.

Table 6.16: Spearman Correlations between IOS and Initial UHSRQ Responses

Session	Equality ρ	p	Control ρ	p	Pet ρ	p
Session 2	0.36	0.34	-0.18	0.64	0.32	0.40
Session 4	0.02	0.97	-0.32	0.40	0.04	0.93
Session 6	-0.34	0.41	-0.12	0.78	-0.29	0.48
Session 7	-0.06	0.88	-0.23	0.59	-0.12	0.79
Session 8	0.03	0.95	-0.27	0.52	-0.04	0.92
Session 9	-0.02	0.97	-0.11	0.80	-0.10	0.81

Post-Interaction UHSRQ and IOS responses

Table 6.17 shows the correlations between the post-interaction UHSRQ responses and IOS Scores for the agent. It suggest that there *are* relationships between the different UHSRQ subscales and the IOS scores. These relationships are positive, with the exception of a small insignificant correlation with the *Control* dimension in session 2. This suggests that a higher degree of closeness with the agent was associated with higher levels of one or more of the social role dimensions as measured by the UHSRQ.

There were significant relationships between IOS scores and the *Equality*-dimension in all sessions except for Session 9. The *Pet*-dimension was significantly correlated with IOS scores in Sessions 2,5,7 and 8. The *Control*-dimension was only significantly related to IOS scores in Sessions 6 and 8.

Table 6.17: Spearman Correlations between Post-Interaction UHSRQ Responses and IOS Scores

	Equality ρ	p	Control ρ	p	Pet ρ	p
Session 2	0.72	0.03**	-0.17	0.67	0.84	0.01***
Session 4	0.66	0.05**	0.53	0.14	0.48	0.19
Session 6	0.80	0.02**	0.87	0.01***	0.72	0.04**
Session 7	0.63	0.10*	0.43	0.29	0.74	0.03**
Session 8	0.79	0.02**	0.77	0.02**	0.82	0.01***
Session 9	0.56	0.14	0.19	0.65	0.57	0.14

*:$p < .1$, **:$p < .05$, ***:$p < .01$

Session 10 Evaluations

The IOS scores for the Session 10 evaluations can be found in table 6.18. This suggests that IOS rating did not deviate from a "neutral" score of 3.5. The correlations shown in 6.19, suggest no strong salient relationships between UHSRQ expectations either in the pre-interaction responses or in the Session 10 responses. The Session 10 UHSRQ evaluation responses, however show a significant correlation between responses on the *Equality*- and *Pet*-dimension and IOS responses to original mobile robot and the agent.

Table 6.18: Feelings of Closeness in Session 10 Evaluation

	Mean	SD	Median	Range	d	Wilcoxon.p
IOS Agent	3.50	1.69	4.00	1–6	$< .01$	$> .99$

Table 6.19: Feelings of Closeness to the Agent and UHSRQ responses in Session 10 Evaluations

	Equality ρ	p	Control ρ	p	Pet ρ	p
Session 1 Expectations	-0.08	0.85	-0.19	0.65	-0.10	0.82
Session 10 Expectation	0.20	0.64	-0.09	0.83	0.35	0.39
Session 10 Evaluations	0.76	0.03**	0.26	0.53	0.62	0.10*

*:$p < .1$, **:$p < .05$, ***:$p < .01$

Summary — Feelings of Closeness and UHSRQ Responses

There were no strong or salient relationships between pre-interaction responses to the UHSRQ and IOS responses. There were however, relationships between the UHSRQ post-interaction evaluation responses and IOS responses, and this pattern was repeated for the Session 10 post-study questionnaire was well.

6.6 Discussion

6.6.1 The Results and the Research Questions

Research Question 1 — UHSRQ Changes

While some of the participants reported responses to the post-interaction UHSRQ questionnaire that were different from their expectations, these differences were not significant, suggesting that the participants overall did not rate the robots' actual behaviour significantly different from their expectation in terms of Social Roles, the only exception to this was that participants rated the robots higher along the *Control*-dimension in the Session 1 post-interaction responses than they did in their initial expectations. This difference, however, was not apparent in the subsequent sessions. There was a trend in which the participants overall rated the robots as lower along the Equality- and Pet-dimension in the post-interaction questionnaire than what their initial expectations were, but there were large individual differences between participants, which led to these differences not being significant.

While this finding might suggest that the pre-interaction expectations and the post-interaction evaluations measured the same constructs, the lack of any clear relationship between the initial UHSRQ responses and those in the post-interaction questionnaires suggest that they were in fact measuring different things. The relationship between the *expected* social roles as measured by the UHSRQ in Session 1 and Session 10, along with the lack of such a relationship with the *perceived* social roles in this session suggests that the *expectations* remained constant, but that these were separate from the constructs used in the evaluation. This is also supported by their relationships with the other measures in the study and indicate that this is too simple a view, and we will consider this in the following sections.

Research Question 2 — UHSRQ and Global Evaluation results

In terms of how UHSRQ responses related to the global evaluation measures, there were some differences between the post-interaction ratings and the pre-interaction expectations. While the initial expectations along the *Equality* and, to a lesser extent, the *Pet* dimensions were significantly related to several of the global evaluation measures across the sessions, this was not the case for the *Control* dimension.

The post-interaction perceptions as measured by the UHSRQ, related differently to the global scores. While there were significant relationships between responses to the global evaluation measures and the UHSRQ post-interaction evaluations, these were only apparent in sessions 2, 4 and 8. In addition, the *Control*-dimension was the most strongly related to these.

This suggests that the initial UHSRQ responses were more important to how the participant evaluated the robots than the post-interaction UHSRQ responses. It also suggests that *overall* participants who rated their preferred social roles for the robots as higher on the *Equality*-dimension, overall rated their interactions with the robot more positively. This could mean that these participants were overall more positive to robots in general (as they were expecting to delegate more autonomy to these), but it could also mean that these particular participants were more positive to the over-arching scenario in which the robots would take a pro-active role in suggesting activities and reminding participants of their preferences.

Research Question 3 — UHSRQ and IOS Responses

In one way one could argue that the relationship between UHSRQ and IOS responses were the inverse of the relationship between UHSRQ and Global Evaluation responses.

There were no significant or salient relationships between reported feelings of closeness to the agent and responses to the initial expectations measured by the UHSRQ in the first session. There were, however, relationships between feelings of closeness as measured by the Inclusion of Other in Self questionnaire and the post-interaction UHSRQ questionnaire. The trend observed in table 6.17 suggest that higher scores on the UHSRQ scales were associated with greater feelings of closeness with the robots, particularly for the *Equality*-dimension of the UHSRQ for which this trend was significant for sessions 2-9. This trend was also significant for the *Pet*-dimension for sessions 2,4,6,7,8,9. For the *Control*-dimension, this trend was only significant for sessions 6 and 8, and was not apparent at all for session 2 and 9.

These relationships suggest that participants' affective responses to the robots were not impacted by the social roles they expected a robot to inhabit. It does seem, however, that participants' experiences of closeness to the robots were related to their perception of the social roles they felt the robots inhabited in the particular interaction.

6.6.2 Contrasting initial Expectations with post-interaction expectations

Expectancy Violations

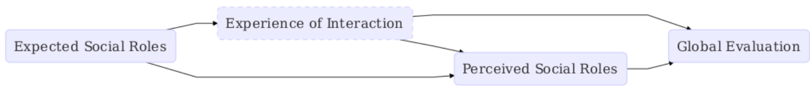
When considering the results from this study, there are several things that stand out. The first is that overall, there were no significant differences between the pre-interactions expectations that the participants had of the robots compared to the post-interaction evaluation of the robots in terms of UHSRQ responses. While the trend for *all* of the sessions was that participants tended to rate the robots as *lower* in the subsequent sessions, the median scores of the differences tended to be close to zero. This suggests that the lack of a significant difference was not just a matter of lacking statistical power. This is in support of the results reported by Fischer (2006) and Fischer and Lohse (2007), which showed that participants' preconceptions of an artificial interaction partner were quite stable constructs and not easily influenced by the interactions. It also, at first glance, suggests that it may difficult to interpret these results in terms of expectancy violations of social expectations, i.e. Burgoon and Walther (1990) or Syrdal et al. (2008a).

The only dimension which did exhibit a significant deviation between pre-interaction and post-interaction UHSRQ scores was the *Control*-dimension after session 2. Results suggest that participants rated the robots higher on this dimension in the post-interaction questionnaire than they had done in their expectations prior to the study. One should also note that this particular result ran counter to the trend in the other sessions.

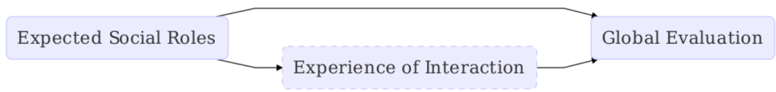
In addition, the participants' UHSRQ responses in the initial *expectation* questionnaires and the post-interaction *evaluation* questionnaires were *not* correlated. This suggests the lack of a significant difference between pre- and post- interaction questionnaires may be due to lacking statistical power, rather than that these constructs were interchangeable.

The relationship between the initial UHSRQ responses and the global evaluation questionnaires, can be interpreted as a expression of expectancy violations. Participant who expected the robot to be more like a social equal were more likely to rate the interaction with the robot more favourably in terms of the global interaction measures.

Figure 6.12: Expectancy Violations and Robust Mental Models approaches to the experiment



(a) Expectancy Violation



(b) Robust Mental Model

Robust Mental Models

The results for the global evaluation measures could also be in line with Fischer (2006) as well as the findings reported in Chapter 5. Rather than the initial expectations being a standard from which the participants evaluated deviations, the UHSRQ responses may have formed the basis for how the participant interacted with the robot. This line of thought would suggest that participants who came into interactions expecting a robot which was pro-active in suggesting actions and offered to share the activities with the user, would not just evaluate a robot like this better, but would be better able to use such a robot in a manner applicable to their own daily life. This would in term reinforce the evaluation of the robot. The opposite would be true for someone expecting a passive tool.

Contrasting the Two

Figure 6.12 illustrates the two approaches and outlines how they would work in terms of how participants evaluated the behaviour of the robots. Figure 6.12(a) describe the proposed pathway in which the participants' expectations of the robots would be either met or violated. This violation would then impact the evaluation of the robots. While there *is* a relationship between the initial UHSRQ scores and the evaluation of the interaction, the relationship between the post-interaction UHSRQ scores and the evaluation scores is much weaker. In addition, there were no differences between how participants rated the robots along the UHSRQ in the initial and post-interaction responses. Because of this, it is difficult to accept an Expectancy Violation approach to understanding these findings.

The approach of Fischer (2006) as described in Figure 6.12(b), is better able to explain the results. If the participants retained their initial expectations of the robots, this not only impacted their interactions with the robot, but also how they subsequently viewed the interactions. This would allow the initial expectations of the robots to influence the evaluations throughout the study.

The results reported in this chapter does not allow us to investigate how the interactions were influenced. However, the study reported previously in Chapter 5, in which participants' task-based interaction were influenced throughout a study over several weeks, contains this sort of data. That study did not take post-interaction UHSRQ measurements, so the relationships between these and other post-interaction outcomes were not clear, but it did show a relationship between initial UHSRQ scores and how such a task-based interaction was experienced.

Taken together, these two studies suggest that (for some aspects of the interactions at least), initial preconceptions of how participants view the social role the robot remain important, not only for short-term initial interactions, but also over time. This suggests that initial framing of the role in the interactions, such as seen in Groom et al. (2011), needs to be done as the robot is introduced, and might also need to be incorporated in the initial design of a robot, as it may be difficult to move away from these, once participants engage in interactions with it.

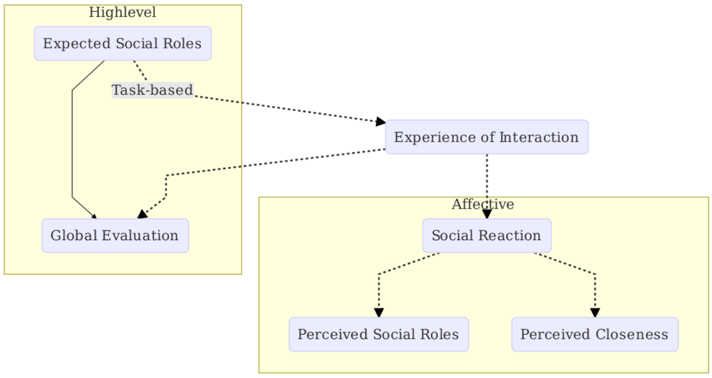
Feelings of Closeness

However, this point can only be made when considering the *Global Evaluation* measures. If we are to examine the results from the *Inclusion of Other in Self* scale, there seems to be a distinct relationship between post-interaction UHSRQ scores and how close participants felt to the robots. This close relationship between IOS scores and in particular the *Equality*- and *Pet*-dimensions, is indicative that the participants' *experience* of the social role inhabited by the robots is linked to the participants' experienced relational/affective closeness to them. Agnew et al. (1998) shows that IOS scores relate to several relation-specific questions, and as such, the correlations with the dimensions of the UHSRQ which suggest an experienced anthropo- or zoomorphic relationship, is not surprising. What is surprising is that there seems to almost no relationship at all between IOS scores and the responses given in the initial UHSRQ questionnaire. The IOS, and the post-evaluation UHSRQ questionnaires seem to be almost completely focused on the relational aspects of the interactions and less so on the outcomes of the interactions.

6.6.3 A note on statistical power

The small sample size in this study means that one should be careful when discounting possible effects. Some of the non-significant relationships seen in this study may in fact be detectable in larger samples. However, the results here highlight the larger effects, and as such, these are more likely to impact interactions with such technologies.

Figure 6.13: The role of the UHSRQ in the Long-term Studies



6.6.4 Conclusions

This suggests that there were two sets of evaluations. One was a high-level evaluation of the robot within the context of the scenario, along with an assessment of the robots being appropriate either for the participants themselves, or for someone with needs that could be met using the robots. This evaluation could, to some extent, be anticipated by the responses that the participants had to the UHSRQ questionnaire prior to taking part in the study.

The other evaluation seems to have been a purely social response to the interaction with the robot, and while there is a clear relationship between the IOS and the Post-Interaction UHSRQ score, it is less clear what the causality here is. It is most likely, however, that they are both representative of the perceived sociality of the robot within the interaction.

Figure 6.13 outline the possible relationships. While the relationships between Initial Expectations and the Experience of the Interaction cannot really be inferred from this study, the results from the task-based study reported in Chapter 5, do support the inclusion of this link. Likewise, the inclusion of an underlying Social Reaction as the underlying cause for the relationship between Post-Interaction UHSRQ score and IOS Scores is intended to highlight the dual nature of the participants' response to the robots and the interactions they had with them.

This outcome suggests that in-situ social aspects of an interaction with the robots are important, in particular to foster working relationships with robots (The importance of human-agent relationships are noted by Bickmore et al. (2005)), and that the UHSRQ questionnaire can be used to examine human perceptions of robots in terms of such relationships. It also strongly supports the observation of Fischer (2006) and Otero et al. (2008) that participants find it difficult to change their conception of what they already understand the robot to be, and how they should interact with it. The results from this study is in line with that of Fischer (2006) that sociality and autonomy are influential dimensions of this reasoning. While studies like as those reported by Shen et al. (2011) and Groom et al. (2011) do highlight a certain malleability of such reasoning, if participants are primed *prior* to interactions, it seems that they are difficult to alter once the interaction takes place.

Chapter 7

Summary and Conclusions

7.1 Introduction

This thesis represents an exploration into notions of social expectations of robots. In chapter 1 and 2, I highlighted the heterogeneities of Human-Robot Interaction. These heterogeneities, I argued, were an obstacle in interpreting the results obtained using one robotic platform, in a study with specific interactions, to other studies. Because of this, I wished to see whether or not human social expectations of robots could be used as a viable means of examining some of the mechanisms in human-robot interactions. The thesis I advanced was that *it is possible to measure the social expectations and perceptions that humans have of robots in an explicit and succinct manner, and these measures are related to how humans interact with, and evaluate, these robots.* This thesis was twofold, relying on both the meaningful *measurement* of such expectations, and a *relationship* between these measures and other salient results from HRI studies.

The results presented in the preceding Chapters can be taken in support of this thesis.

7.2 Summary

7.2.1 Research Question 1 — Measurements of Social Expectations

In chapter 3, I presented results from two sets of studies attempting to measure participants' perceptions of robots in terms of social expectations. The first approach, inspired by Kiesler and Goetz (2002), used human personality traits. This found that, at least in the setting of the studies done in the University of Hertfordshire's research on robot companions, responses formed a unidimensional scale that seemed to measure the degree of *human-likeness* that the participants perceived the robots as having, rather than a way to differentiate between robots in terms of human personality traits. In fact, in one of these studies, responses along these traits *did* correlate with an explicit measure of humanlikeness.

The second approach was inspired by Dautenhahn et al. (2005) and proposed that social expectations could be examined in terms of social roles that could be inhabited by a robot companion. These roles were used in a questionnaire instrument similar to that used by Ezer et al. (2009), and a Principal Component Analysis suggested that roles could be divided into three dimensions:

- *Equality*
  - The degree to which participants expect to interact with a robot using anthropomorphic approaches on a footing similar to a someone with at least some social agency.
- *Control*
  - The degree to which participants expect to interact with a robot

in a manner that allows the user to exert direct control over the robot. utilitarian manner.

- *Pet*
  - The degree to which participants expect to interact with a robot in a manner similar to that of a pet.

These dimensions were related to the participants' usage patterns of computing technology, and found a weak, but consistent relationship between the main use that the participants employed computers for, and their scores on these dimensions. These results were encouraging and supported the use of this questionnaire in studies which involved live interactions between humans and robots.

Taken together, thse results are in support of the first part of the thesis advanced, in that they suggest that social expectations are measurable and can be used to distinguish between different types of robots and between different types of technology-use patterns in participants.

7.2.2 Research Question 2 — Relating Measures of Social Expectations to Interactional Outcomes

The second part in the thesis advanced was supported by the empirical work presented in subsequent chapters that suggested relationships between social expectations and human-robot interactions in terms of proxemic preferences, task collaboration, and open-ended interactions.

Proxemics

Chapter 4 described how the two approaches to measuring social expectations were used in studies investigating human-robot social spaces, or human-robot *proxemics*. The results from the studies investigating the relationship between social expectations measured using human personality traits did, to some extent, support the notion put forward in chapter 3, that these could be considered a measure of humanlikeness. Participants' personality ratings of the robots they interacted with were related to the degree that they expected the robots to adhere to proxemic norms for human-human interactions.

The social role measurements also exhibited a relationship to participants' proxemic preferences. Participants' proxemic preferences from the robot were congruent with the social roles that they expected the robot to adhere to. In addition, participants who correctly interpreted the light-signals used by the robot to signal intent, tended to score higher on the Equality dimension.

These results supported the use of social role based measurements for examining the role of human social expectations in HRI, and that initial social expectations could be shown to impact how participants evaluated robot behaviour.

This impact was studied further in the subsequent chapters which expanded the scope of interaction beyond proxemics.

Initial Social Expectations and Long-term Interactions

The study presented in chapter 5 examined the impact of social expectations as measured by the social roles questionnaire (UHSRQ) on a set of interactions. It found that UHSRQ responses taken in the first week of a 9 week study were related to the participant evaluations of open-ended interactions for the entire period. In additions, participants responses to the UHSRQ in the first week seemed to be related to not only their preferences in terms of cooperating with the robotic partner in task-focused interactions, but also seemed to impact the effectiveness of their collaboration with the robot in order to complete their tasks.

These results suggested a persistent effect for the social role expectations participants had of the robots prior to any interactions with them. Also, this effect impacted interactions across two months of weekly interactions. What this study did not investigate was whether or not participant's perceptions of the robots in terms of the social roles they inhabited changed over this period.

7.2.3 Changing Social Expectations in Long-term Interactions

The issue of changing social role expectations over a sequence of interactions was one of the issues addressed by the study described in chapter 6. This study replicated the findings of the previous study, that participant expectations of robots in terms of the social roles they expect them to inhabit, prior to any interaction with the robots, has a persistent impact on subsequent evaluations that they have of human-robot interactions over time.

In addition, this study examined how participants perceived the robots in terms of social roles after the interactions as well. The relationship between *initial expectations* and the participants' evaluation of the interactions with the robots were similar as observed in chapter 5, in that they had a persistent effect across the 6 week study. The *post-interaction perceptions* in terms of social roles, however, were more closely related to the participants' social response to the robots within the interaction.

7.3 Contribution to Knowledge

The work presented in this thesis has drawn on a wide body of knowledge to examine social dimensions of HRI. In particular, the work presented here relates to the work by Fischer and Lohse (2007) as well as Ezer (2009). Like Ezer (2009), I used a questionnaire-based measurement tool based around the sort of practical/social roles a robot companion could have within a human-robot interaction and examined the dimensionality of these responses. I also went beyond Ezer's approach, which was purely survey-based, in that I also examined how these initial expectations of robots impacted subsequent live interactions with robots over time. In addition, the work presented in this thesis has shed some light on the nature of the persistence of these social expectations. Fischer and Lohse (2007) suggests that social expectations of robots in terms of interactional capabilities are persistent in terms of their impact on interactions. I have provided more evidence of this being the case, not just within a single interaction, but that this also seems to be the case for series of interactions taking place over several weeks. In addition, the work presented in chapter 6 further examined the relationship between pre-interaction social *expectations*, post-interaction social *perceptions* and the *evaluation* of the robots and their impact.

7.4 Methodological Contribution

The work presented in this thesis, while not intended to be about methodological advances, still contributed to the methodology of the field of HRI. This was particularly true when considering the prototyping approach outlined in chapter 5, where the use of narrative framing with high-fidelity prototypes were used to convey the experience of long-term interactions with domestic companion robots (Syrdal et al., 2014), in addition, the UHSRQ questionnaire provides an easy-to-use tool which is relatively short, and can be used in conjunction with other studies without placing excessive demands on participants in Human-Robot Interaction studies.

7.5 Limitations

This work suffer from many of the limitations that could be said to apply to large swathes of the field of HRI as discussed in chapter 1. The interactions presented were done with a limited set of robots, the Care-o-bot®3, AIBO and the Sunflower Robots, and all of the interactions were focused on interactions between a single human user and a domestic companion robot. In addition, the number of participants was, due to the constraints of running repeated live interactions with robotic research prototypes, low for the HRI studies. The participants, while in terms of cultural backgrounds diverse, were also recruited from a limited pool of participants resident in the area local to the University of Hertfordshire, with the majority of participants students and staff at UH. While this does not necessarily invalidate the findings from these studies, it does suggest that one should be careful in naïvely applying the findings from the studies reported here to other types of robots and with other groups of participants.

7.6 Future Work

The are several immediate avenues of investigation on the basis of the work presented here. The first is to use the UHSRQ measurement tool in other interactions and with other groups of participants in order to see whether or not the results obtained from these can be related to the ones that have been presented in this thesis, and how any differences have presented themselves. In particular, relating the task-based results from chapter 5 to interactions that are centered around work-related contexts would be very interesting. Also, the scenarios used for the basis of the studies presented in chapters 5 and 6 presuppose that the residents in a house with a domestic robot companion also are its owners and sole users. However more recent approaches to the use of domestic robot companions, in particular for eldercare, posit the robot companion as the central hub around which exists a complex set of residents, professional care professionals, next-of-kin etc., and these primary and secondary users will all, to differing degrees, interact with the robot (Lehmann et al., 2013a). Different users may have different expectations of the robot, and use-scenarios presented by Sorell and Draper (2014) do suggest that untangling the differing social expectations held by these users is essential to ensure that the preferences, interests and needs of each user is met. Because of this, examining social expectations in multi-user scenarios is a natural extension of this work.

While the role of culture could be considered as a limitation of the studies presented in this thesis, it also presents an opportunity to further investigate the social roles that robots may inhabit. Given that social roles vary across cultures, and social conceptions of robots also seem to vary Kaplan (2004); Syrdal et al. (2011b), the relationship between these across different cultures could be a fruitful avenue of further research.

Another strand of research that this work suggests relate to the results from the results presented in Chapter 6, which suggested that while initial expectations of robots were related to expected task and interactonal outcomes, post-interaction social perceptions, were more strongly related to more affective dimensions of the interactions. The causality of this remains unclear, however, research has suggested that social behaviours can work to mitigate negative aspects in interactions, either as a coping mechanism (Luczak et al., 2003) or as a means to maintain a human-machine relationship through possible breakdowns (Syrdal et al., 2014). Examining the dynamics of these phenomena could be interesting in terms of interface design, especially considering how robotic agents may build trust throughout interactions (Ososky et al., 2013b).

This would also benefit from work that would further our understanding as to how initial, pre-interaction expectations of robots are created. In the studies presented in Chapters 4–6, initial expectations are conceptually a characteristic of the participants, and no attempt was made to manipulate these. The narrative framing method as presented in chapter 5 may be a valuable tool in creating frames that explicitly posit the robot as inhabiting specific roles, and as such UHSRQ responses can be used to measure both the effectiveness of the frame on participants' expectations, but also on the impact of the expectations on other interactional outcomes. In addition, the strategies that robots can leverage to influence the social perceptions that humans interactants have of them within the interaction can also be examined.

7.7 Closing Remarks

In Chapter 1, I advanced my thesis, and the research questions that needed to be answered in its defence. The first of these was whether or not a reliable, meaningful way of measuring human social expectations of robots could be realised using a questionnaire based method. The second was to see if such measurements would shed light on other human-robot interaction outcomes. The results presented in 3, suggests that such measurements are possible, and the results from the subsequent chapters suggest that they do have a relationship to other outcomes as well. While these findings can be taken in defence of the thesis advanced, they also suggest that a continued focus on the social nature of the interaction is a source of insight, even in interactions that are not overtly social in nature, such as the constrained tasks in chapter 5, and even with robots that are not humanoid in shape.

References

Agnew, C. R., Van Lange, P. A., Rusbult, C. E., and Langston, C. A. (1998). Cognitive interdependence: Commitment and the mental representation of close relationships. *Journal of Personality and Social Psychology*, 74(4):939.

Albright, L., Kenny, D. A., and Malloy, T. E. (1988). Consensus in personality judgments at zero acquaintance. *Journal of Personality and Social Psychology*, 55(3):387.

Andonova, E. (2006). On changing mental models of a wheelchair robot. In Fischer, K., editor, *Proceedings of the Workshop on 'How People Talk to Computers, Robots, and Other Artificial Communication Partners, Hansewissenschaftskolleg, Delmenhorst, April 21-23*, pages 131–139.

Arkes, H. R. (1991). Costs and benefits of judgment errors: Implications for debiasing. *Psychological Bulletin*, 110(3):486.

Aron, A., Aron, E. N., and Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology*, 63(4):596.

Asimov, I. (1968). *I, Robot (a collection of short stories originally published between 1940 and 1950).* London: Grafton Books.

Asquith, P. J. (1997). Why Anthropomorphism is Not Metaphor: Crossing Concepts and Cultures in Animal Behaviour Studies. In Mitchell, R. W., Thompson, N. S., and Miles, H. L., editors, *Anthropomorphism, Anecdotes, and Animals*, pages 22–35. SUNY Press, Albany, N.Y.

Ballard, L., Sabanovic, S., Kaur, J., and Milojevic, S. (2012). George Charles Devol, Jr. [History]. *Robotics Automation Magazine, IEEE*, 19(3):114–119.

Bangor, A., Kortum, P. T., and Miller, J. T. (2008). An empirical evaluation of the system usability scale. *Intl. Journal of Human–Computer Interaction*, 24(6):574–594.

Bartneck, C. and Forlizzi, J. (2004). A design-centred framework for social human-robot interaction. In *Robot and Human Interactive Communication, 2004. ROMAN 2004. 13th IEEE International Workshop on*, pages 591–594. IEEE.

Bartneck, C. and Hu, J. (2004). Rapid prototyping for interactive robots. In *Proceedings of The 8th Conference on Intelligent Autonomous Systems*

(IAS-8), pages 136–145.

Bartneck, C. and Hu, J. (2008). Exploring the abuse of robots. *Interaction Studies*, 9(3):415–433.

Bartneck, C., Kanda, T., Ishiguro, H., and Hagita, N. (2009a). My robotic doppelgänger-a critical look at the uncanny valley. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 269–276. IEEE.

Bartneck, C., Kulić, D., Croft, E., and Zoghbi, S. (2009b). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International Journal of Social Robotics*, 1(1):71–81.

Bartneck, C., Rosalia, C., Menges, R., and Deckers, I. (2005). Robot abuse: a limitation of the media equation. In *Proceedings of the interact 2005 workshop on agent abuse, Rome*.

Belpaeme, T., Baxter, P., De Greeff, J., Kennedy, J., Read, R., Looije, R., Neerincx, M., Baroni, I., and Zelati, M. C. (2013). Child-robot interaction: Perspectives and challenges. In *Proceedings of the 5th International Conference on Social Robotics, ICSR 2013, 27-29 October 2013, Bristol, 8239 LNAI*, pages 452–459. Springer.

Bennett, C. and Sabanovic, S. (2013). Perceptions of affective expression in a minimalist robotic face. In *Human-Robot Interaction (HRI), 2013 8th ACM/IEEE International Conference on*, pages 81–82. IEEE.

Bethel, C. L. and Murphy, R. R. (2007). Non-facial/non-verbal methods of affective expression as applied to robot-assisted victim assessment. In *Proceedings of the ACM/IEEE international conference on Human-Robot Interaction (HRI'07)*, pages 287–294. ACM.

Bethel, C. L. and Murphy, R. R. (2008). Survey of non-facial/non-verbal affective expressions for appearance-constrained robots. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, 38(1):83–92.

Bethel, C. L. and Murphy, R. R. (2010). Review of human studies methods in HRI and recommendations. *International Journal of Social Robotics*, 2(4):347–359.

Bickmore, T. and Cassell, J. (2005). Social dialongue with embodied conversational agents. In *Advances in natural multimodal dialogue systems*, pages 23–54. Springer.

Bickmore, T. W., Caruso, L., Clough-Gorr, K., and Heeren, T. (2005). "It's just like you talk to a friend" - Relational agents for older adults. *Interacting with Computers*, 17(6):711–735.

Blythe, M. A. and Wright, P. C. (2006). Pastiche scenarios: Fiction as a resource for user centred design. *Interacting with Computers*, 18(5):1139–1164.

Boden, M. (2009). Relationships with robots. In *Presentation given at the Future of AI & Self-Adaptive Software, Artificial Intelligence and*

Adaptive Software Workshop on ICT and Ageing, SENIOR Project, held in Brussels, December 2009.

Borkenau, P. and Liebler, A. (1992). Trait inferences: Sources of validity at zero acquaintance. *Journal of Personality and Social Psychology*, 62(4):645.

Broadbent, E., Lee, Y. I., Stafford, R. Q., Kuo, I. H., and MacDonald, B. A. (2011). Mental schemas of robots as more human-like are associated with higher blood pressure and negative emotions in a human-robot interaction. *International Journal of Social Robotics*, 3(3):291.

Brooke, J. et al. (1996). SUS-a quick and dirty usability scale. *Usability evaluation in industry*, 189(194):4–7.

Buber, M. (1970). I and Thou (W. Kaufmann, Trans.). *New York: Scribner.*

Buchenau, M. and Suri, J. F. (2000). Experience prototyping. In *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques*, pages 424–433. ACM.

Burgoon, J. K. and Jones, S. B. (1976). Toward a theory of personal space expectations and their violations. *Human Communication Research*, 2(2):131–146.

Burgoon, J. K. and Walther, J. B. (1990). Nonverbal expectancies and the evaluative consequences of violations. *Human Communication Research*, 17(2):232–265.

Čapek, K., Selver, P., and Playfair, N. (1923). *RUR:(Rossum's Universal Robots): a Fantastic Melodrama in Three Acts and an Epilogue.* London: S. French.

Carlson, T. and Demiris, Y. (2012). Collaborative control for a robotic wheelchair: evaluation of performance, attention, and workload. *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on*, 42(3):876–888.

Castano, E., Kofta, M., Bain, P., Park, J., Kwok, C., and Haslam, N. (2009). Attributing human uniqueness and human nature to cultural groups: Distinct forms of subtle dehumanization. *Group Processes & Intergroup Relations*, 12(6):789–805.

Cattell, R. B. (1966). The scree test for the number of factors. *Multivariate behavioral research*, 1(2):245–276.

Chang, Y.-n., Lim, Y.-k., and Stolterman, E. (2008). Personas: from theory to practices. In *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*, pages 439–442. ACM.

Chanseau, A., Dautenhahn, K., Koay, K. L., and Salem, M. (2017). What is a critical task for a dometic robot to perform? *Submitted Paper.*

Chatley, A. R., Dautenhahn, K., Walters, M. L., Syrdal, D. S., and Christianson, B. (2010). Theatre as a discussion tool in human–robot interaction experiments—A pilot. In *Advances in Computer-Human Interactions, 2010. ACHI'10. Third International Conference on*, pages 73–78. IEEE.

Choi, J. J., Kim, Y., and Kwak, S. S. (2013). The impacts of intergroup relations and body zones on people's acceptance of a robot. In *Human-Robot Interaction (HRI), 2013 8th ACM/IEEE International Conference on*, pages 107–108. IEEE.

Clark, H. H. (1999). How do real people communicate with virtual partners. In *Proceedings of 1999 AAAI fall symposium, psychological models of communication in collaborative systems*, pages 43–47.

Cohen, J. (1992). A power primer. *Psychological bulletin*, 112(1):155.

Copeland, B. J. (2000). The Turing test. *Minds and Machines*, 10(4):519–539.

Copeland, J. and Proudfoot, D. (2009). Turings test. In *Parsing the Turing Test*, pages 119–138. Springer.

Cowley, S. J. and Macdorman, K. F. (2006). What baboons, babies and tetris players tell us about interaction: a biosocial view of norm-based social learning. *Connection Science*, 18(4):363–378.

Craik, K. (1943). The nature of explanation. *Cambridge: Cambridge University Press.*

Crowell-Davis, S. L. (2008). Motivation for pet ownership and its relevance to behavior problems. *Compendium*, 30(8):423.

Dautenhahn, K. (2002). Design spaces and niche spaces of believable social robots. In *Robot and Human Interactive Communication, 2002. Proceedings. 11th IEEE International Workshop on*, pages 192–197. IEEE.

Dautenhahn, K. (2004). Robots we like to live with?!- a developmental perspective on a personalized, life-long robot companion. In *Proceedings of the 13th IEEE International Workshop on Robot and human interactive communication, 2004. ROMAN 2004. 13th IEEE International Workshop on*, pages 17–22. IEEE.

Dautenhahn, K. (2007a). Methodology and themes of human-robot interaction: a growing research field. *International Journal of Advanced Robotic Systems*, 4(1):103–108.

Dautenhahn, K. (2007b). Socially intelligent robots: dimensions of human–robot interaction. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 362(1480):679–704.

Dautenhahn, K., Nehaniv, C. L., Walters, M. L., Robins, B., Kose-Bagci, H., Mirza, N. A., and Blow, M. (2009). KASPAR–a minimally expressive humanoid robot for human–robot interaction research. *Applied Bionics and Biomechanics*, 6(3-4):369–397.

Dautenhahn, K., Woods, S., Kaouri, C., Walters, M. L., Koay, K. L., and Werry, I. (2005). What is a robot companion—Friend, Assistant or Butler? In *Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on*, pages 1192–1197. IEEE.

Davis, H. (1997). Animal Cognition versus Animal Thinking: The Anthropomorphic Error. In Mitchell, R. W., Thompson, N. S., and Miles, H. L., editors, *Anthropomorphism, Anecdotes, and Animals*, pages 335–347. SUNY Press, Albany, N.Y.

Dindler, C. and Iversen, O. S. (2007). Fictional inquiry — Design collaboration in a shared narrative space. *CoDesign*, 3(4):213–234.

Draper, H., Sorell, T., Bedaf, S., Syrdal, D. S., Gutierrez-Ruiz, C., Duclos, A., and Amirabdollahian, F. (2014). Ethical dimensions of human-robot interactions in the care of older people: Insights from 21 focus groups convened in the uk, france and the netherlands. In *International Conference on Social Robotics*, pages 135–145. Springer.

Duffy, B. R. (2003). Anthropomorphism and the social robot. *Robotics and autonomous systems*, 42(3):177–190.

Duque, I., Dautenhahn, K., Koay, K. L., Willcock, I., and Christianson, B. (2013). Knowledge-driven user activity recognition for a smart house. development and validation of a generic and low-cost, resource-efficient system. In *The Sixth International conference on advances in computer–human interactions (ACHI 2013), Nice, France.*

Enz, S., Diruf, M., Spielhagen, C., Zoll, C., and Vargas, P. A. (2011). The social role of robots in the future - an explorative measurement of hopes and fears. *International Journal of Social Robotics*, 3(3):263–271.

Eyssel, F. and Hegel, F. (2012). (S) He's got the look: Gender stereotyping of robots. *Journal of Applied Social Psychology*, 42(9):2213–2230.

Eyssel, F., Hegel, F., Horstmann, G., and Wagner, C. (2010). Anthropomorphic inferences from emotional nonverbal cues: A case study. In *Proceedings of the 19th IEEE International Symposium in Robot and Human Interactive Communication (RO-MAN 2010)*, pages 646–651. IEEE.

Eyssel, F. and Kuchenbrandt, D. (2011). Manipulating anthropomorphic inferences about NAO: The role of situational and dispositional aspects of effectance motivation. In *RO-MAN, 2011 IEEE*, pages 467–472. IEEE.

Eyssel, F. and Kuchenbrandt, D. (2012). Social categorization of social robots: Anthropomorphism as a function of robot group membership. *British Journal of Social Psychology*, 51(4):724–731.

Eyssel, F. and Loughnan, S. (2013). It Don't Matter If You're Black or White? - Effects of Robot Appearance and User Prejudice on Evaluations of a Newly Developed Robot Companion . In *Social Robotics*, pages 422–431. Springer.

Eyssel, F. and Reich, N. (2013). Loneliness makes the heart grow fonder (of robots)on the effects of loneliness on psychological anthropomorphism. In *Human-Robot Interaction (HRI), 2013 8th ACM/IEEE International Conference on*, pages 121–122. IEEE.

Ezer, N. (2009). *Is a robot an appliance, teammate, or friend? Age-related differences in expectations of and attitudes towards personal home-based robots.* PhD thesis, Georgia Institute of Technology.

Ezer, N., Fisk, A. D., and Rogers, W. A. (2009). More than a servant: Self-reported willingness of younger and older adults to having a robot perform interactive and critical tasks in the home. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 53, pages 136–140. SAGE Publications Sage CA: Los Angeles, CA.

Fernaeus, Y., Håkansson, M., Jacobsson, M., and Ljungblad, S. (2010). How do you play with a robotic toy animal?: A long-term study of pleo. In *Proceedings of the 9th international Conference on interaction Design and Children*, pages 39–48. ACM.

Fernaeus, Y., Jacobsson, M., Ljungblad, S., and Holmquist, L. E. (2009). Are we living in a robot cargo cult? In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction(HRI '08)*, pages 279–280. ACM.

Fiore, S. M., Badler, N. L., Boloni, L., Goodrich, M. A., Wu, A. S., and Chen, J. (2011). Human-robot teams collaborating socially, organizationally, and culturally. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 55, pages 465–469. SAGE Publications Sage CA: Los Angeles, CA.

Fischer, K. (2006). The role of users preconceptions in talking to computers and robots. In Fischer, K., editor, *Proceedings of the Workshop on 'How People Talk to Computers, Robots, and Other Artificial Communication Partners, Hansewissenschaftskolleg, Delmenhorst, April 21-23*, pages 112–130.

Fischer, K., Foth, K., Rohlfing, K. J., and Wrede, B. (2011). Mindful tutors: Linguistic choice and action demonstration in speech to infants and a simulated robot. *Interaction Studies*, 12(1):134–161.

Fischer, K. and Lohse, M. (2007). Shaping naive users' models of robots' situation awareness. In *RO-MAN 2007-The 16th IEEE International Symposium on Robot and Human Interactive Communication*, pages 534–539. IEEE.

Fong, T., Nourbakhsh, I., and Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and autonomous systems*, 42(3):143–166.

Friedman, B., Kahn Jr, P. H., and Hagman, J. (2003). Hardware companions?: What online AIBO discussion forums reveal about the human-robotic relationship. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 273–280. ACM.

Fussell, S. R., Kiesler, S., Setlock, L. D., and Yew, V. (2008). How people anthropomorphize robots. In *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction (HRI'08)*, pages 145–152. ACM.

Gill, A. J., Oberlander, J., and Austin, E. (2006). Rating e-mail personality at zero acquaintance. *Personality and Individual Differences*, 40(3):497–507.

Goetz, J., Kiesler, S., and Powers, A. (2003). Matching robot appearance and behavior to tasks to improve human-robot cooperation. In *Robot and Human Interactive Communication, 2003. Proceedings. ROMAN 2003. The 12th IEEE International Workshop on*, pages 55–60. IEEE.

Goldberg, L. R. (1999). A broad-bandwidth, public domain, personality inventory measuring the lower-level facets of several five-factor models. *Personality psychology in Europe*, 7:7–28.

Gombrich, E. H. (1995). *The story of art*, volume 15. Phaidon London.

Goodrich, M. A., Morse, B. S., Engh, C., Cooper, J. L., and Adams, J. A. (2009). Towards using unmanned aerial vehicles (UAVs) in wilderness search and rescue: Lessons from field trials. *Interaction Studies*, 10(3).

Green, A., Huttenrauch, H., and Eklundh, K. S. (2004). Applying the wizard-of-oz framework to cooperative service discovery and configuration. In *Robot and Human Interactive Communication, 2004. RO-MAN 2004. 13th IEEE International Workshop on*, pages 575–580. IEEE.

Green, A., Hüttenrauch, H., and Topp, E. A. (2006). Measuring up as an intelligent robot–on the use of high-fidelity simulations for human-robot interaction research. In *Proceedings of the 2003 Performance Metrics for Intelligent Systems (PerMIS) Workshop,(Gaithersburg, MD, USA)*.

Greenberg, S., Marquardt, N., Ballendat, T., Diaz-Marino, R., and Wang, M. (2011). Proxemic interactions: the new ubicomp? *interactions*, 18(1):42–50.

Groom, V., Srinivasan, V., Bethel, C. L., Murphy, R., Dole, L., and Nass, C. (2011). Responses to robot social roles and social role framing. In *Collaboration Technologies and Systems (CTS), 2011 International Conference on*, pages 194–203. IEEE.

Guthrie, S. E. (1997). Anthropomorphism: A Definition and a Theoryr. In Mitchell, R. W., Thompson, N. S., and Miles, H. L., editors, *Anthropomorphism, Anecdotes, and Animals*, pages 50–58. SUNY Press, Albany, N.Y.

Hall, E. T. and Hall, E. T. (1969). *The hidden dimension*, volume 1990. Anchor Books New York.

Hall, R. R. (2001). Prototyping for usability of new technology. *International Journal of Human-Computer Studies*, 55(4):485–501.

Hart, S. G. (2006). NASA-task load index (NASA-TLX); 20 years later. In *Proceedings of the human factors and ergonomics society annual meeting*, volume 50, pages 904–908. Sage Publications.

Hart, S. G. and Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *Advances in psychology*, 52:139–183.

Haslam, N., Bain, P., Douge, L., Lee, M., and Brock, B. (2005). More Human Than You: Attributing humanness to self and others. *Journal of Personality and Social Psychology*, 89(6):937–950.

Haslam, N. and Pedersen, A. (2007). Attitudes towards asylum seekers: The psychology of exclusion. In Lusher, D. and Haslam, N., editors, *Yearning to breathe free: Seeking asylum in Australia*, pages 208–218. Sidney, Australia: Freedom Press.

Hayduk, L. A. (1983). Personal space: Where we now stand. *Psychological bulletin*, 94(2):293.

Heise, D. R. (1969). Some methodological issues in semantic differential research. *Psychological Bulletin*, 72(6):406.

Henwood, K. and Pidgeon, N. (2006). Grounded theory. *Research Methods in Psychology*, 3:342–365.

Ho, C.-C. and MacDorman, K. F. (2010). Revisiting the uncanny valley theory: Developing and validating an alternative to the godspeed indices. *Computers in Human Behavior*, 26(6):1508–1518.

Horne, R., Weinman, J., Barber, N., Elliott, R., Morgan, M., Cribb, A., and Kellar, I. (2005). Concordance, adherence and compliance in medicine taking. *London: NCCSDO*, 2005:40–6.

Huijnen, C., Badii, A., van den Heuvel, H., Caleb-Solly, P., and Thiemert, D. (2011). "Maybe It Becomes a Buddy, But Do Not Call It a Robot" Seamless Cooperation between Companion Robotics and Smart Homes. In Keyson, D., Maher, M., Streitz, N., Cheok, A., Augusto, J., Wichert, R., Englebienne, G., Aghajan, H., and Kröse, B. J., editors, *Ambient Intelligence*, volume 7040 of *Lecture Notes in Computer Science*, pages 324–329. Springer Berlin Heidelberg.

Huttenrauch, H. and Severinson Eklundh, K. (2002). Fetch-and-carry with CERO: observations from a long-term user study with a service robot. In *Robot and Human Interactive Communication, 2002. Proceedings. 11th IEEE International Workshop on*, pages 158–163. IEEE.

Ishiguro, H. (2006). Android science: conscious and subconscious recognition. *Connection Science*, 18(4):319–332.

Jacobsson, M. (2009). Play, belief and stories about robots: A case study of a pleo blogging community. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*, pages 232–237. IEEE.

John, O. P., Angleitner, A., and Ostendorf, F. (1988). The lexical approach to personality: A historical review of trait taxonomic research. *European journal of Personality*, 2(3):171–203.

Johnson-Laird, P. (2004). The history of mental models. In Manktelow, K. and Chung, M. C., editors, *Psychology of reasoning: Theoretical and historical perspectives*, page 179. Psychology Press.

Jones, O. (2012). *Chavs: The demonization of the working class.* Verso Books, London, UK.

Joosse, M., Lohse, M., Pérez, J. G., and Evers, V. (2013). What you do is who you are: The role of task context in perceived social robot personality. In *Robotics and automation (ICRA), 2013 IEEE international* *conference on*, pages 2134–2139. IEEE.

Kahn Jr, P. H., Ishiguro, H., Friedman, B., Kanda, T., Freier, N. G., Severson, R. L., and Miller, J. (2007). What is a human?: Toward psychological benchmarks in the field of human–robot interaction. *Interaction Studies*, 8(3):363–390.

Kahn Jr, P. H., Kanda, T., Ishiguro, H., Freier, N. G., Severson, R. L., Gill, B. T., Ruckert, J. H., and Shen, S. (2012). robovie, you'll have to go into the closet now: Children's social and moral relationships with a humanoid robot. *Developmental psychology*, 48(2):303.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and psychological measurement*, 20(1):141–151.

Kamsma, Y. P., Brouwer, W. H., and Lakke, J. P. (1995). Training of compensational strategies for impaired gross motor skills in parkinson'disease. *Physiotherapy Theory and Practice*, 11(4):209–229.

Kaplan, F. (2004). Who is afraid of the humanoid? Investigating cultural differences in the acceptance of robots. *International journal of humanoid robotics*, 1(03):465–480.

Kendon, A. (1990). *Conducting interaction: Patterns of behavior in focused encounters*, volume 7. CUP Archive.

Kiesler, S. and Goetz, J. (2002). Mental models and cooperation with robotic assistants. In *CHI'02 extended abstracts on Human Factors in Computing Systems*, pages 576–577. ACM.

Kim, Y., Kwak, S. S., and Kim, M.-s. (2013). Am I acceptable to you? Effect of a robot's verbal language forms on peoples social distance from robots. *Computers in Human Behavior*, 29(3):1091–1101.

Kim, Y. and Mutlu, B. (2014). How social distance shapes human–robot interaction. *International Journal of Human-Computer Studies*, 72(12):783–795.

Klinnert, M. D., Emde, R. N., Butterfield, P., and Campos, J. J. (1986). Social referencing: The infant's use of emotional signals from a friendly adult with mother present. *Developmental Psychology*, 22(4):427.

Koay, K., Syrdal, D., Dautenhahn, K., Arent, K., Kreczmer, B., et al. (2011). Companion migration–initial participant' feedback from a video-based prototyping study. In Wang, X., editor, *Mixed Reality and Human-Robot Interaction*, pages 133–151. London: Springer.

Koay, K. L., Lakatos, G., Syrdal, D. S., Gácsi, M., Bereczky, B., Dautenhahn, K., Miklósi, A., and Walters, M. L. (2013). Hey! there is someone at your door. a hearing robot using visual communication signals of hearing dogs to communicate intent. In *Artificial Life (ALIFE), 2013 IEEE Symposium on*, pages 90–97. IEEE.

Koay, K. L., Sisbot, E. A., Syrdal, D. S., Walters, M. L., Dautenhahn, K., and Alami, R. (2007a). Exploratory study of a robot approaching a person in the context of handing over an object. In *AAAI 2007 spring symposium: Multidisciplinary collaboration for socially assistive* *robotics*, pages 18–24.

Koay, K. L., Syrdal, D. S., Ashgari-Oskoei, M., Walters, M. L., and Dautenhahn, K. (2014). Social roles and baseline proxemic preferences for a domestic service robot. *International Journal of Social Robotics*, 6(4):469–488.

Koay, K. L., Syrdal, D. S., Walters, M. L., and Dautenhahn, K. (2007b). Living with robots: Investigating the habituation effect in participants' preferences during a longitudinal human-robot interaction study. In *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on*, pages 564–569. IEEE.

Koay, K. L., Syrdal, D. S., Walters, M. L., and Dautenhahn, K. (2009). Five weeks in the robot house–exploratory human-robot interaction trials in a domestic setting. In *Advances in Computer-Human Interactions, 2009. ACHI'09. Second International Conferences on*, pages 219–226. IEEE.

Kose-Bagci, H., Ferrari, E., Dautenhahn, K., Syrdal, D. S., and Nehaniv, C. L. (2009). Effects of embodiment and gestures on social interaction in drumming games with a humanoid robot. *Advanced Robotics*, 23(14):1951–1996.

Lehmann, H., Syrdal, D. S., Dautenhahn, K., Gelderblom, G., Bedaf, S., and Amirabdollahian, F. (2013a). What should a robot do for you?-Evaluating the needs of the elderly in the UK. In *The 6th International Conference on Advances in Computer–Human Interactions (ACHI), Nice, France, February*, pages 83–88.

Lehmann, H., Walters, M. L., Dumitriu, A., May, A., Koay, K. L., Saez-Pons, J., Syrdal, D. S., Wood, L., Saunders, J., Burke, N., et al. (2013b). Artists as HRI Pioneers: A Creative Approach to Developing Novel Interactions for Living with Robots. In *Proceedings of the 5th International Conference on Social Robotics-Volume 8239*, pages 402–411. Springer-Verlag New York, Inc.

Levy, D. (2009). *Love & Sex with robots - The evolution of human-robot relationships*. Duckworth Overlook, London, UK.

Light, A. (2006). Adding method to meaning: a technique for exploring peoples' experience with technology. *Behaviour & Information Technology*, 25(2):175–187.

Lindner, F. (2015). A conceptual model of personal space for human-aware robot activity placement. In *Intelligent Robots and Systems (IROS), 2015 IEEE/RSJ International Conference on*, pages 5770–5775. IEEE.

Lohse, M., Hanheide, M., Wrede, B., Walters, M. L., Koay, K. L., Syrdal, D. S., Green, A., Huttenrauch, H., Dautenhahn, K., Sagerer, G., et al. (2008). Evaluating extrovert and introvert behaviour of a domestic robota video study. In *Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on*, pages 488–493. IEEE.

Luczak, H., Roetting, M., and Schmidt, L. (2003). Let's talk: Anthropomorphization as means to cope with stress of interacting with technical devices. *Ergonomics*, 46(13-14):1361–1374.

Mataric, M. R. (2007). *The robotics primer*. MIT Press, Cambridge.

Matthews, G., Deary, I. J., and Whiteman, M. C. (2003). *Personality traits*. Cambridge University Press, Cambridge, UK.

Mehrabian, A. (1969). Significance of posture and position in the communication of attitude and status relationships. *Psychological Bulletin*, 71(5):359.

Mitchell, R. W. (1997). Anthropomorphism and Anecdotes: A Guide for the Perplexed. In Mitchell, R. W., Thompson, N. S., and Miles, H. L., editors, *Anthropomorphism, Anecdotes, and Animals*, pages 407–428. SUNY Press, Albany, N.Y.

Mitchell, R. W., Thompson, N. S., and Miles, H. L. (1997). *Anthropomorphism, anecdotes, and animals*. SUNY Press.

Modayil, J., Levinson, R., Harman, C., Halper, D., and Kautz, H. A. (2008). Integrating sensing and cueing for more effective activity reminders. In *AAAI 2008 Fall Symposium: AI in Eldercare: New Solutions to Old Problems*, pages 60–66.

Moore, R. K. (2012). A bayesian explanation of the 'uncanny valley' effect and related psychological phenomena. *Scientific reports*, 2:864.

Mori, M. (1970). The uncanny valley. *Energy*, 7(4):33–35.

Murphy, R. R. (2004). Human-robot interaction in rescue robotics. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on*, 34(2):138–153.

Murphy, R. R., Nomura, T., Billard, A., and Burke, J. L. (2010). Human–robot interaction. *Robotics & Automation Magazine, IEEE*, 17(2):85–89.

Mutlu, B. and Forlizzi, J. (2008). Robots in organizations: the role of workflow, social, and environmental factors in human-robot interaction. In *Human-Robot Interaction (HRI), 2008 3rd ACM/IEEE International Conference on*, pages 287–294. IEEE.

Nass, C., Steuer, J., Tauber, E., and Reeder, H. (1993). Anthropomorphism, agency, and ethopoeia: Computers as social actors. In *INTERACT'93 and CHI'93 conference companion on Human factors in computing systems*, pages 111–112. ACM.

Nass, C., Steuer, J., and Tauber, E. R. (1994). Computers are social actors. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 72–78. ACM.

Nomura, T., Kanda, T., and Suzuki, T. (2006). Experimental investigation into influence of negative attitudes toward robots on human–robot interaction. *AI & SOCIETY*, 20(2):138–150.

Nomura, T., Sugimoto, K., Syrdal, D. S., and Dautenhahn, K. (2012). Social acceptance of humanoid robots in japan: A survey for development of the frankenstein syndrome questionnaire. In *Humanoid Robots (Humanoids), 2012 12th IEEE-RAS International Conference on*, pages 242–247. IEEE.

Norman, D. A. (1999). Affordance, conventions, and design. *interactions*, 6(3):38–43.

Norman, D. A. (2002). *The Design of Everyday Things*. Basic Books, New York, N.Y.

Ososky, S., Philips, E., Schuster, D., and Jentsch, F. (2013a). A picture is worth a thousand mental models: Evaluating human understanding of robot teammates. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 57, pages 1298–1302. SAGE Publications Sage CA: Los Angeles, CA.

Ososky, S., Schuster, D., Phillips, E., and Jentsch, F. G. (2013b). Building appropriate trust in human-robot teams. In *AAAI Spring Symposium: Trust and Autonomous Systems*.

Otero, N., Alissandrakis, A., Dautenhahn, K., Nehaniv, C., Syrdal, D. S., and Koay, K. L. (2008). Human to robot demonstrations of routine home tasks: Exploring the role of the robot's feedback. In *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction (HRI '08)*, pages 177–184. ACM.

Papadopoulos, F., Dautenhahn, K., Ho, W. C., and Walters, M. (2010). Aibocom: Designing robot enhanced human-human remote communication technology. In *the 2nd International Conference on Kansei Engineering and Emotional Research*.

Parlitz, C., Hägele, M., Klein, P., Seifert, J., and Dautenhahn, K. (2008). Care-o-bot 3 — Rationale for human-robot interaction design. In *Proceedings of 39th International Symposium on Robotics (ISR), Seul, Korea*, pages 275–280. Citeseer.

Payr, S. (2010). Closing and closure in human-companion interactions: analyzing video data from a field study. In *Proceedings of the 19th IEEE International Symposium in Robot and Human Interactive Communication (RO-MAN 2010)*, pages 476–481. IEEE.

Phillips, E., Ososky, S., Grove, J., and Jentsch, F. (2011). From tools to teammates toward the development of appropriate mental models for intelligent robots. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 55, pages 1491–1495. SAGE Publications.

Powers, A., Kiesler, S., and Goetz, J. (2003). Matching robot appearance and behavior to tasks to improve human-robot cooperation. *Human-Computer Interaction Institute*, page 105.

Quigley, M., Conley, K., Gerkey, B., Faust, J., Foote, T., Leibs, J., Wheeler, R., and Ng, A. Y. (2009). ROS: an open-source Robot Operating System. 3:5.

Reeves, B. and Nass, C. (1996). *The Media Equation: How people treat* *computers, television, and new media like real people and places*. CSLI Publications and Cambridge university press.

Revelle, W. (2015). *psych: Procedures for Psychological, Psychometric, and Personality Research*. Northwestern University, Evanston, Illinois. R package version 1.5.8.

Robins, B., Dautenhahn, K., and Dubowski, J. (2004). Investigating Autistic children's attitudes towards strangers with the theatrical robot — A new experimental paradigm in human-robot interaction studies. In *Robot and Human Interactive Communication, 2004. ROMAN 2004. 13th IEEE International Workshop on*, pages 557–562. IEEE.

Rubio, S., Díaz, E., Martín, J., and Puente, J. M. (2004). Evaluation of subjective mental workload: A comparison of SWAT, NASA-TLX, and workload profile methods. *Applied Psychology*, 53(1):61–86.

Russo, J. E., Johnson, E. J., and Stephens, D. L. (1989). The validity of verbal protocols. *Memory & cognition*, 17(6):759–769.

Salem, M., Eyssel, F., Rohlfing, K., Kopp, S., and Joublin, F. (2013). To err is human (-like): Effects of robot gesture on perceived anthropomorphism and likability. *International Journal of Social Robotics*, 5(3):313–323.

Saminaden, A., Loughnan, S., and Haslam, N. (2010). Afterimages of savages: Implicit associations between primitives, animals and children. *British Journal of Social Psychology*, 49(1):91–105.

Schwartz, D., Wang, M., Zeitz, L., and Goss, M. E. (1962). Medication errors made by elderly, chronically ill patients. *American Journal of Public Health and the Nations Health*, 52(12):2018–2029.

Segura, E. M., Cramer, H., Gomes, P. F., Nylander, S., and Paiva, A. (2012). Revive!: reactions to migration between different embodiments when playing with robotic pets. In *Proceedings of the 11th international conference on interaction design and children*, pages 88–97. ACM.

Seland, G. (2009). Empowering end users in design of mobile technology using role play as a method: Reflections on the role-play conduction. In *Human Centered Design*, pages 912–921. Springer.

Shen, Q., Kose-Bagci, H., Saunders, J., and Dautenhahn, K. (2011). The impact of participants' beliefs on motor interference and motor coordination in human–humanoid interactions. *IEEE Transactions on Autonomous Mental Development*, 3(1):6–16.

Siegel, M., Breazeal, C., and Norton, M. I. (2009). Persuasive robotics: The influence of robot gender on human behavior. In *Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on*, pages 2563–2568. IEEE.

Sisbot, E. A., Alami, R., Siméon, T., Dautenhahn, K., Walters, M., and Woods, S. (2005). Navigation in the presence of humans. In *Humanoid Robots, 2005 5th IEEE-RAS International Conference on*, pages 181–188. IEEE.

Skubic, M., Perzanowski, D., Blisard, S., Schultz, A., Adams, W., Bugajska, M., and Brock, D. (2004). Spatial language for human-robot dialogs. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, 34(2):154–167.

Sorell, T. and Draper, H. (2014). Robot carers, ethics, and older people. *Ethics and Information Technology*, 16(3):183–195.

Stampp, K. M. (1971). Rebels and sambos: The search for the negro's personality in slavery. *The Journal of Southern History*, 37(3):367–392.

Suchman, L. (2007). *Human-machine reconfigurations: Plans and situated actions*. Cambridge University Press.

Sung, J.-Y., Grinter, R. E., Christensen, H. I., and Guo, L. (2008). Housewives or technophiles?: understanding domestic robot owners. In *Human-Robot Interaction (HRI), 2008 3rd ACM/IEEE International Conference on*, pages 129–136. IEEE.

Syrdal, D. S., Dautenhahn, K., Koay, K. L., and Ho, W. C. (2014). Views from within a narrative: Evaluating long-term human–robot interaction in a naturalistic environment using open-ended scenarios. *Cognitive Computation*, 6(4):741–759.

Syrdal, D. S., Dautenhahn, K., Koay, K. L., and Ho, W. C. (2015). Integrating Constrained Experiments in Long-term Human-Robot Interaction using Task-and Scenario-based Prototyping. *The Information Society*, 31(3).

Syrdal, D. S., Dautenhahn, K., Koay, K. L., Walters, M. L., and Ho, W. C. (2013a). Sharing spaces, sharing lives–the impact of robot mobility on user perception of a home companion robot. In *Proceedings of the 5th International Conference on Social Robotics, ICSR 2013, 27-29 October 2013, Bristol, 8239 LNAI*, pages 321–330. Springer.

Syrdal, D. S., Dautenhahn, K., Koay, K. L., Walters, M. L., and Otero, N. (2010a). Exploring human mental models of robots through explicitation interviews. In *Proceedings of the 19th IEEE International Symposium in Robot and Human Interactive Communication (RO-MAN 2010)*, pages 638–645. IEEE.

Syrdal, D. S., Dautenhahn, K., Walters, M. L., and Koay, K. L. (2008a). Sharing spaces with robots in a home scenario—Anthropomorphic attributions and their effect on proxemic expectations and evaluations in a live HRI trial. In *Proc. AAAI Fall 2008 Symposium: AI in Eldercare: New Solutions to Old Problems*, pages 7–9.

Syrdal, D. S., Dautenhahn, K., Walters, M. L., Koay, K. L., and Otero, N. R. (2011a). The theatre methodology for facilitating discussion in human-robot interaction on information disclosure in a home environment. In *RO-MAN, 2011 IEEE*, pages 479–484. IEEE.

Syrdal, D. S., Dautenhahn, K., Woods, S., Walters, M. L., and Koay, K. L. (2006). 'Doing the right thing wrong' - Personality and tolerance to uncomfortable robot approaches. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 183–188. IEEE.

Syrdal, D. S., Dautenhahn, K., Woods, S. N., Walters, M. L., and Koay, K. L. (2007a). Looking good? Appearance preferences and robot personality inferences at zero acquaintance. In *AAAI Spring Symposium: Multidisciplinary Collaboration for Socially Assistive Robotics*, pages 86–92.

Syrdal, D. S., Koay, K. L., Gácsi, M., Walters, M. L., and Dautenhahn, K. (2010b). Video prototyping of dog-inspired non-verbal affective communication for an appearance constrained robot. In *Proceedings of the 19th IEEE International Symposium in Robot and Human Interactive Communication (RO-MAN 2010)*, pages 632–637. IEEE.

Syrdal, D. S., Koay, K. L., Walters, M. L., and Dautenhahn, K. (2007b). A personalized robot companion?—The role of individual differences on spatial preferences in HRI scenarios. In *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on*, pages 1143–1148. IEEE.

Syrdal, D. S., Koay, K. L., Walters, M. L., and Dautenhahn, K. (2009). The boy-robot should bark!— Children's impressions of agent migration into diverse embodiments. In *Proceedings of the New Frontiers in Human-Robot Interaction, a symposium at the AISB2009 Convention.* SSAISB.

Syrdal, D. S., Nomura, T., and Dautenhahn, K. (2013b). The frankenstein syndrome questionnaire–results from a quantitative cross-cultural survey. In *Proceedings of the 5th International Conference on Social Robotics, ICSR 2013, 27-29 October 2013, Bristol, 8239 LNAI*, pages 270–279. Springer.

Syrdal, D. S., Nomura, T., Hirai, H., and Dautenhahn, K. (2011b). Examining the frankenstein syndrome - an open-ended cross-cultural survey. In Mutlu, B., Bartneck, C., Ham, J., Evers, V., and Kanda, T., editors, *ICSR*, volume 7072 of *Lecture Notes in Computer Science*, pages 125–134. Springer.

Syrdal, D. S., Otero, N., and Dautenhahn, K. (2008b). Video prototyping in human-robot interaction: Results from a qualitative study. In *Proceedings of the 15th European conference on Cognitive ergonomics: the ergonomics of cool interaction*, page 29. ACM.

Syrdal, D. S., Walters, M. L., Otero, N., Koay, K. L., and Dautenhahn, K. (2007c). He knows when you are sleeping-privacy and the personal robot companion. In *Proc. workshop human implications of human–robot interaction, association for the advancement of artificial intelligence (AAAI07)*, pages 28–33.

Takayama, L., Ju, W., and Nass, C. (2008). Beyond dirty, dangerous and dull: what everyday people think robots should do. In *Proceedings of* *the 3rd ACM/IEEE international conference on Human robot interaction*, pages 25–32. ACM.

Takayama, L. and Pantofaru, C. (2009). Influences on proxemic behaviors in human-robot interaction. In *Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on*, pages 5495–5502. IEEE.

Tapus, A., Ţăpuş, C., and Matarić, M. J. (2008). User–Robot personality matching and assistive robot behavior adaptation for post-stroke rehabilitation therapy. *Intelligent Service Robotics*, 1(2):169–183.

Turkle, S. (1997). *Life on the Screen: Identity in the Age of the Internet.* Simon & Schuster, New York, N.Y.

Turkle, S. (2007). Authenticity in the age of digital companions. *Interaction studies*, 8(3):501–517.

Turkle, S., Taggart, W., Kidd, C. D., and Dasté, O. (2006). Relational artifacts with children and elders: the complexities of cybercompanionship. *Connection Science*, 18(4):347–361.

Tversky, A. and Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185(4157):1124–1131.

Wada, K. and Shibata, T. (2007). Social effects of robot therapy in a care house-change of social network of the residents for two months. In *Robotics and Automation, 2007 IEEE International Conference on*, pages 1250–1255. IEEE.

Wainer, J., Feil-Seifer, D. J., Shell, D. A., and Mataric, M. J. (2006). The role of physical embodiment in human-robot interaction. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 117–122. IEEE.

Walker, D. and Paterson, N. (2008). James May's Big Ideas:Man-Machine. Premiered on BBC2 2008.

Walker, J. E. and Howland, J. (1991). Falls and fear of falling among elderly persons living in the community: occupational therapy interventions. *American Journal of Occupational Therapy*, 45(2):119–122.

Walters, M. L., Dautenhahn, K., Te Boekhorst, R., Koay, K. L., Syrdal, D. S., and Nehaniv, C. L. (2009). An empirical framework for human-robot proxemics. SSAISB.

Walters, M. L., Oskoei, M. A., Syrdal, D. S., and Dautenhahn, K. (2011). A long-term human-robot proxemic study. In *RO-MAN, 2011 IEEE*, pages 137–142. IEEE.

Walters, M. L., Syrdal, D. S., Dautenhahn, K., Dumitriu, A., May, A., Christianson, B., and Koay, K. L. (2012). My familiar robot companion: Preferences and perceptions of charly, a companion humanoid autonomous robot for living with you. In *Advances in Autonomous Robotics*, pages 300–312. Springer.

Walters, M. L., Syrdal, D. S., Dautenhahn, K., Te Boekhorst, R., and Koay, K. L. (2008). Avoiding the uncanny valley: robot appearance, personality and consistency of behavior in an attention-seeking home scenario for a robot companion. *Autonomous Robots*, 24(2):159–178.

Weiss, A. and Bartneck, C. (2015). Meta analysis of the usage of the godspeed questionnaire series. In *Robot and Human Interactive Communication (RO-MAN), 2015 24th IEEE International Symposium on*, pages 381–388. IEEE.

Weiss, A., Igelsbock, J., Pierro, P., Buchner, R., Balaguer, C., and Tscheligi, M. (2010). User perception of usability aspects in indirect HRI — A chain of translations. In *RO-MAN, 2010 IEEE*, pages 539–545. IEEE.

Wiltshire, T. J., Lobato, E. J., Wedell, A. V., Huang, W., Axelrod, B., and Fiore, S. M. (2013). Effects of robot gaze and proxemic behavior on perceived social presence during a hallway navigation scenario. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 57, pages 1273–1277. SAGE Publications.

Woods, S., Dautenhahn, K., Kaouri, C., Boekhorst, R., and Koay, K. L. (2005). Is this robot like me? Links between human and robot personality traits. In *Humanoid Robots, 2005 5th IEEE-RAS International Conference on*, pages 375–380. IEEE.

Woods, S. N., Walters, M. L., Koay, K. L., and Dautenhahn, K. (2006). Methodological issues in HRI: A comparison of live and video–based methods in robot to human approach direction trials. In *Robot and Human Interactive Communication, 2006. ROMAN 2006. The 15th IEEE International Symposium on*, pages 51–58. IEEE.

Xu, Q., Ng, J., Cheong, Y. L., Tan, O., Wong, J. B., Tay, T. C., and Park, T. (2012). Effect of scenario media on elder adults' evaluation of human-robot interaction. In *RO-MAN, 2012 IEEE*, pages 455–462. IEEE.

Yagoda, R. E. (2010). Development of the human robot interaction workload measurement tool (hri-wm). In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 54, pages 304–308. SAGE Publications.

Złotowski, J., Proudfoot, D., Yogeeswaran, K., and Bartneck, C. (2015). Anthropomorphism: opportunities and challenges in human–robot interaction. *International Journal of Social Robotics*, 7(3):347–360.

Chapter 8

Credits

Figure 1.1 RUR Image Poster for a stage performance of R.U.R. directed by Remo Bufano in New York, 1939, by the U.S. Works Project Administration (WPA). Work Projects Administration Federal Art Project, New York City - This image is available from the United States Library of Congress's Prints and Photographs division under the digital ID cph.3g05045, Public Domain - US.

Figure 1.1c Unimate image. Image published in Ballard et al. (2012), and credited to George Charles Devol, Jr.'s private collection. Reproduced without permission. Reproduction is fair dealing with a work with acknowledgement for the purposes of quotation, criticism or review under the Copyright, Designs and Patent Act 1988, Section 30.

Figure 1.1b Dust-jacket illustration by Ed Cartier. Reproduced without permission. Reproduction is fair dealing with a work with acknowledgement for the purposes of quotation, criticism or review under the Copyright, Designs and Patent Act 1988, Section 30.

Figure 6.4 was taken by Alex May at the robot house and posted on his twitter feed (@bigfug) after his visit. It is reproduced here without his per-

Appendices

Appendix A

Sharing Spaces With Robots

Syrdal, D. S., Dautenhahn, K., Walters, M. L., & Koay, K. L. (2008, July). Sharing Spaces with Robots in a Home Scenario-Anthropomorphic Attributions and their Effect on Proxemic Expectations and Evaluations in a Live HRI Trial. In *AAAI Fall Symposium: AI in Eldercare: New Solutions to Old Problems* (pp. 116-123).

Sharing Spaces with Robots in a Home Scenario – Anthropomorphic Attributions and their Effect on Proxemic Expectations and Evaluations in a Live HRI Trial

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Abstract

This paper presents results from an HRI study that involved participants interacting with robots of different appearances. The particular focus of this paper is how anthropomorphic attributions impacted the proxemic expectations of the robots' behaviour as well as the post-experimental evaluations of the robot. The results suggest that a higher degree of anthropomorphic attribution is linked to higher expectations of adherence to human proxemic norms. The post-experimental evaluation of the robots' violations of these expectations suggests an effect in which the reward-value of interacting with a robot which is considered more anthropomorphic counteracts the impact of the deviation from social expectation.

Introduction

Populations in the affluent industrialised nations are ageing rapidly, to the extent at that on a world wide basis, the relative number of over-60s is projected to double in the next 50 years (United Nations, 2002). This demographic shift poses serious challenges for the caring industries. Kovner et al (2002) highlight a number of issues that need to be addressed in geriatric care including that of further research into the organisation of care within health services providing care for the elderly

Such research considers the further implementation of technology to organise and deliver care to an ageing population. Robotics technology, utilising information technology along with the possibility of spatially and physically interacting with individual users in their environment and to deliver practical assistance as well as possible companionship, promises a wide range of possible ways to alleviate some of the challenges facing the workforce in the caring professions. Roy et al. (2000) argue that the falling cost of computational power as well as sensor technology brings the notion of widespread applications of assistive robotics in eldercare into the realms of feasibility. Tsui & Yanco (2007) outline some of these possible applications and attitudes towards them amongst members of the healthcare professions.

Drawing on the perspective of the user populations which may require assistance, Harmo et al. (2005) surveyed potential user groups for assistive robotics involving the elderly as well as carers, and relating the different needs expressed by these group to existing technology and technology which is currently being researched. Some of the needs presented by Harmo et al., such as security, the need for guidance in terms of navigation, dispensing medicine, mobility issues and cognitive prosthetics, can be met through the use of mobile robots with varying degrees of autonomy. Mobile robots can alleviate the need for movement, for example by assisting in fetch and carry tasks as exemplified in Hüttenrauch & Severinson-Eklundh (2002), as well as provide active guidance for users with vision impairment (Montemerlo et al., 2002) and remind users of tasks or events that they need to respond to (Roy et al., 2000). Mobile robots may also safeguard the health of its users by alerting carers of medical emergencies (Cesta et al., 2007; Roy et al., 2000).

However, mobility and perceived autonomy is not without its problems. Mobile robots have a physical and social embodiment due to their perceived autonomy and mobility that other assistive technological devices typically lack. The results from the fetch and carry study mentioned above (Hüttenrauch & Severinson Eklundh, 2002), specifically refer to the issue of space negotiation in its description of the impact of the mobile robot in a human-centred office environment. One can only assume that these issues will be even more pertinent in domestic environments, which are likely to be more cramped and cluttered than an office environment. Also, as noted in the social sciences, space negotiation is of paramount importance in human-human interactions (Hall, 1966;

Kendon, 1990). Violations of spatial preferences are often associated with feelings of discomfort (Aiello et al., 1977), even in short-term interactions. As such, care must be made when introducing mobile robots into home-environments so that they do not cause spatial discomfort of their users. This is of particular importance when the introduction of a technology into a domestic environment may not be initiated by the end user. The cost of assistive robotics may put it out of the reach of the private consumer, and as such, the decision to insert these technologies into the individual household may be based on the policy of healthcare authorities, rather than individual preferences (Swann, 2006). As such, this differs from adoption of other domestic robotics products as the Sony AIBO or the Roomba. Existing surveys (Sung et al., 2008; Friedman et al., 2003) regarding their adoption and use may not be applicable to assistive robotics. In particular, users of assistive robotics may be less 'forgiving' of changes in their everyday experience due to the introduction of new technology.

Spatial Comfort - Proxemics

In human-human interactions, the role of personal space and its negotiation is dependent on several factors (Albas, 1991; Burgoon & Walther, 1990; Gillespie & Leffler, 1983; Hartnett et al., 1970; Strube & Werner, 1984), including, but not limited to, threat, relative status and expectations related to situation and actors. Idiosyncratic factors such as personality and gender have also been reported to have an effect on proxemic expectations and perceptions of violations of these (Hartnett et al., 1970; Krail & Leventhal, 1976; Williams, 1971).

In our previous work we have considered the issue of human-robot proxemics, both in terms of specific scenarios (Koay et al., 2007; Walters et al., 2005) as well as in terms of individual differences (Syrdal et al., 2006; Syrdal et al., 2007; Walters et al., 2005). We have also reported some results on the role of robot appearance in proxemic preferences (Syrdal et al., 2007; Koay et al., 2007).

The role of robot appearance in HRI Proxemics

In human interactions, it is common for participants to form quick and lasting impressions of capabilities and personality traits of other humans with limited information available. Often such impressions are formed on the basis of appearance alone (Albright et al., 1988; Zebrowitz et al., 2002). While there are most certainly qualitative differences between how humans perceive other humans and how humans may perceive a robot companion, the appearance of a robot has been shown to be important with regard to how participants describe it, both in terms of their impressions of its capabilities as well as the attribution of anthropomorphic personalities to the robots (Lee & Kiesler, 2005; Walters et al., 2008).

Previously, we suggested that robot appearance may play an important role in human-robot proxemics (Syrdal et al., 2008). As suggested in (Gillespie & Leffler, 1983), human reactions to proxemic behaviour consists of two main mechanisms. The first is the formation of *expectations*, the second is an *evaluation* of the particular behaviour, both in light of previously held expectation as well as the reward or status of the originator of the behaviour.

According to Reeves and Nash (1996), there are similarities in how humans perceive and respond to computational artefacts and other types of technology and how they perceive and interact with other humans. This effect is referred to as 'the Media Equation'. It is therefore likely that expectations as to the proxemic behaviour of an autonomous robot will be based on expectations humans have of other humans in the same situation. However, the Media Equation is not a consistent effect across different interactions (Bartneck et al., 2005) or computational artefacts.

How participants perceive and form expectations regarding a particular robot may depend on several factors. Kiesler & Goetz (Kiesler & Goetz, 2002) suggest the framework of *mental models* to measure and understand how humans view robots. Mental models are collections of concepts which may be applied to robots and other computational artefacts. These mental models may incorporate aspects of anthropomorphic mental models, models which we use to perceive, interpret and predict human behaviour. The degree of anthropomorphism in a participant's mental model may thus influence the proxemic expectations of a robot. Kiesler & Goetz, showed an impact of robot appearance in terms of anthropomorphism in participants' mental models. A similar effect was also demonstrated in Hinds et al., 2004, in which participants responded more politely to a robot with a more human-like appearance than one who was more mechanical looking.

The results from these studies suggest that human users will form stronger expectations as to the proxemic behaviour of a human-looking robot, than that of a mechanical-looking one.

In terms of post-experimental evaluation of proxemic behaviour, our previous studies have shown an effect based on (1) the deviation from expected behaviour and (2) the reward of the behaviour (Syrdal et al. 2008). In this paper we investigate the hypothesis that anthropomorphic attributions towards a robot may mediate this effect.

Hinds et al (2004), as well as our previous studies (Walters et. al 2008), report that participants express more liking towards humanoid looking robots when compared to robots with a more mechanical appearance. This suggests that participants may enjoy interactions with a robot for which they have a more anthropomorphic mental model, than other robots. This enjoyment may add to the reward of the interaction and so mitigate the impact of violations of proxemic expectations.

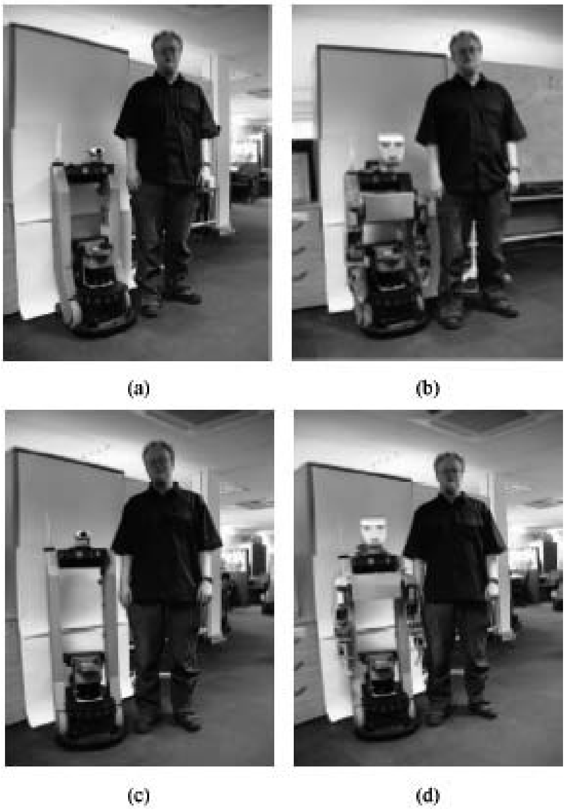


Figure 1 The different robot appearances. Shown here are (a) short mechanoid, (b) short humanoid, (c) tall mechanoid and (d) tall humanoid.

Towards this study

The purpose of this study was to investigate the role of anthropomorphic attributions in determining proxemic expectations in an experimental HRI study. We have previously examined anthropomorphic attributions of personality towards robots based on appearance in video studies (Walters et al., 2008). We have also demonstrated that robot appearance has an impact on both in-situ proxemic expectations (Koay, Syrdal et al., 2007) as well as on post-experimental evaluation of proxemic behaviour (Syrdal et al., 2008). However, the results from Walters et al. (2008) also suggest a need for consistency between appearance and behaviour. As such, the anthropomorphic attributions may be reduced due to similarity of behaviour. Secondly, if the expectations and evaluations of the robots' behaviour can be linked to the participants' mental models of the robots in terms of anthropomorphism, rather than the particular appearance of the robot used in this study, this will potentially increase the replicability of these results along a wider range of interactions with different robots.

Based on these issues, this study aims to answer whether or not expectations based on anthropomorphic attributions based on robot appearance are responsible for the differences in proxemic preferences.

Research Questions:

1. *Is the effect we have previously demonstrated in video studies for robot appearance in terms of anthropomorphic attribution, present in a live study?*

2. *Is there a direct link between these anthropomorphic attributions and in-situ proxemic preferences?*

3. *Is there a direct link between anthropomorphic attribution and post-experimental evaluation of robot proxemic behaviours?*

Method

Apparatus/ Setting

The robots used in this study were two Peoplebots[tm] (Commercially available from ActivMedia Robotics). One of the robots was modified so that its height was lower than the original model. Also, a set of removable arms as well as a head was constructed and attached to the robot in order to manipulate the human-likeness of the robots. Four different robot appearances were used: (a) short mechanical-looking (mechanoid), (b) short human-looking (humanoid), (c) tall mechanoid and (d) tall humanoid, see Figure 1 for the appearance and relative height of the robots.

In-situ proxemic preferences were recorded using the UH Subjective Feedback Device (UHSFD). The UHSFD is a small handheld device with a button. When pushed the device emits a signal to the robot. The participants were invited to try the UHSFD prior to the experiment.

Participants' evaluation of the robots' proxemic behaviour was investigated using a written questionnaire, using Likert scales to assess spatial comfort. The participants' impressions of the robots were also measured using a questionnaire. This questionnaire also included items regarding how much participants liked each robot's appearance, items measuring the 'Big Five' (Matthews et al., 2003) personality traits for each robot, as well as how human-like the participants viewed each robot (see Table 1).

Table 1 Items measuring anthropomorphic attribution

Aspect	Item
Humanlike	How Humanlike was the robot?
Extravert	How extravert/introvert was the robot?
Agreeableness	How interested/disinterested in people was the robot?
Conscientiousness	how organised & committed or disorganised/uncommitted was the robot?
Intelligence	how intelligent or unintelligent was the robot during its tasks?

The study took place in the UH 'Robot House', a private flat rented specifically for HRI studies and furnished in a manner typical for a British household, in order to create a more ecologically valid environment for participants in our studies.

Participants

33 participants took part in this study. These participants were recruited from Studynet, the University of Hertfordshire's Intranet, and were primarily students and staff at the university. Reflecting the typical population of a typical British university, they came from a variety of cultural backgrounds, including different European and Asian cultures as well as British.

Procedure

At arrival to the robot house, participants were given a brief standardised introduction to the experiment and a set of instructions. The experiment consisted of the robot approaching in 3 different scenarios, from two different directions and under two different robot control conditions. These different approach conditions were designed in order to account for a variety of use-scenarios as well as other conditions appropriate for an autonomous personal robot companion.

The three different scenarios were designed to reflect different interactions that a potential user of a personal robot may have, and were as follows:

No Interaction:

This interaction type was used in this experiment to give some insight as to how potential users may view the robots' proxemic behaviour when it is performing tasks that do not directly involve the user. In this particular scenario, the robot approached the participant before turning away.

Verbal Interaction:

This interaction type was being used to assess how potential users may respond to a robot's proxemic behaviour in interactions in which the robot and user engage in dialogue. The robot approached the user who would give the robot a series of instructions.

Physical Interaction:

This interaction type was being used to investigate the role of proxemics in interaction in which the user may need to manipulate parts of the robot, or pick up/manipulate objects carried by the robot. In this particular scenario, the robot approached the user in order for the user to pick a particular cube from its gripping tray.

There were also two different robot control conditions, reflecting situations in which the direct control a potential user might have on a robot companion might vary:

Human in Control(HiC):

In this condition the robot would approach the participant until the participant pressed the UHSFD, after which the robot would stop/turn away.

Robot in Control(RiC):

In this condition, the robot would approach the participant to its preset safety distance before stopping/turning away. The participants were still invited to use the UHSFD to indicate proxemic preference, and these responses were recorded.

Drawing on previous work on robot approach directions, which showed that participants prefer the robot to approach from the front or from an angle in full view of the participant (Woods et al., 2006) the robot approached from two different directions. It either approached directly from the front of the user, or from slightly to the right of the user.

Note, the programmes controlling the robots' behaviour were the same for the mechanoid and humanoid robot.

After participants interacted with the robot, they were invited to fill in the questionnaire evaluating the interaction, as well as the questionnaire regarding the appearance of the robots.

Research Question 1:

Research Question one was assessed using a t-test to test for differences between the robot's appearances. The results are presented in table 2 and Figure 2:

Table 2 T-tests results for anthropomorphic attribution

Aspect	Mean Diff	T-value	Significance
Humanlike	1.2	2.23(28)	**.03**
Extravert	.44	1.59(28)	**.12**
Agreeableness	.49	1.07(28)	.29
Conscientiousness	.13	.35(28)	.73
Intelligence	.77	.29(28)	.77

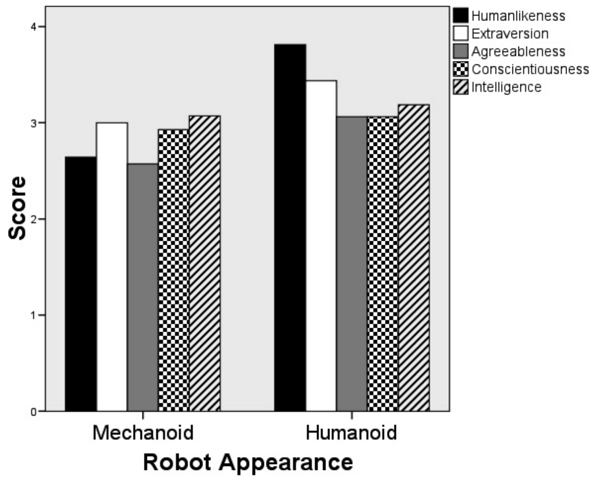


Figure 2 Mean scores for anthropomorphic attributions according to robot appearance

Table 2 and Figure 2 both suggest that the results from our previous video study could be replicated in the results from a live HRI study using the same robot appearance types. The results suggest the same trend as reported in our video study (Walters et al., 2008), namely that participants tended to rate the humanoid robot as scoring higher in both human-likeness as well as other personality traits. As in our previous paper, this result is more pronounced for Extraversion and Agreeableness, and less so for the other personality traits.

These results suggest that it is probable that participants' mental models of the robots were impacted by cues from their appearance, despite the high similarity of the robots' behaviour.

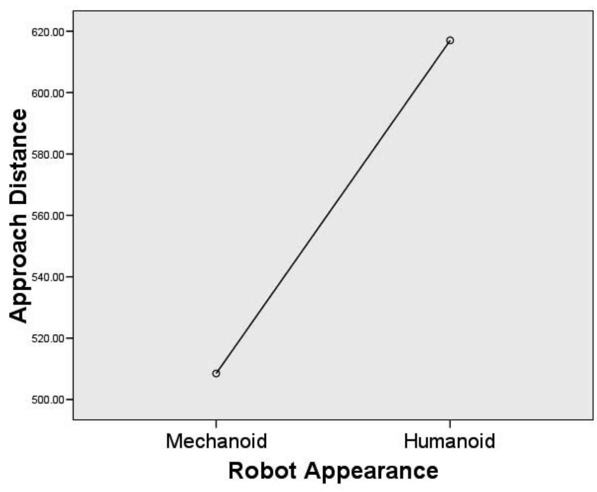


Figure 3 Approach Distances according to robot appearance.

Research Question 2:

Preliminary results from approach distance based on appearance were presented in Koay et al. (2008). For the sake of clarity, these results are summarised below. A repeated measures ANOVA found a significant main effect for robot appearance ($F(1,31)=11.61$, $p=.002$). The effect is described in Figure 3.

According to Figure 3, participants preferred the mechanoid robot to approach to a much closer distance. However, as the results from Research Question 1 show, some participants did rate the mechanoid robot appearance as humanlike, if to a lesser extent than the humanoid robot. In order to investigate Research Question 2, whether or not it was the anthropomorphic attributions rather than the particular appearance of the robot used in this study which was responsible for this effect, an ANOVA was performed, investigating the role of how human-like the robot was viewed and approach distances. We found a non-significant trend ($F(1,21)=1.0, p=.33$). The trend is described in Figure 4, and suggests that participants preferred robots which they viewed as more humanlike to keep a further distance.

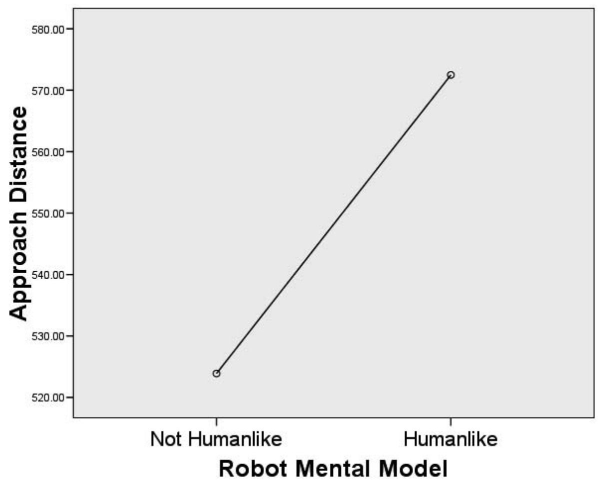
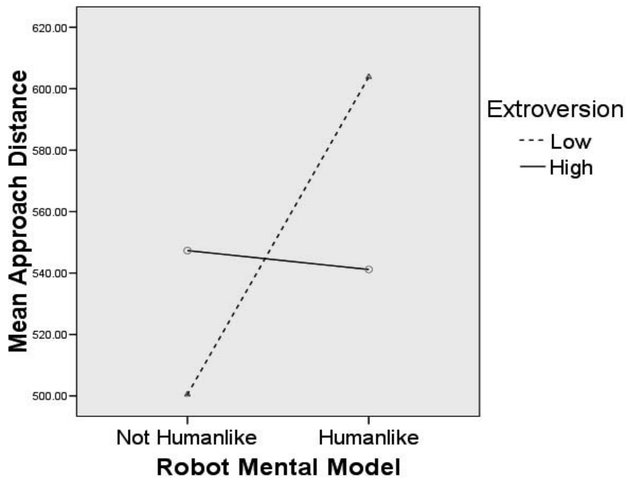


Figure 4 Approach Distances according to anthropomorphic attribution

In order to further investigate this trend, we included participants' extraversion scores into the model. As extraverts are more likely to use anthropomorphic heuristics (Luczak et al., 2003; Walters et al., 2008), and also show a greater tolerance to inappropriate proxemic behaviour (Syrdal et al., 2006), it is likely that these two effects counteracted the impact of anthropomorphic attribution on proxemic expectations. This analysis found a slightly larger effect which approached significance, ($F(1,21)=2.53$, $p=.13$) supporting this view. The effect is described in Figure 5, which shows that the impact of anthropomorphic attribution is much larger for introverts than extraverts.

Figure 5 Approach Distances according to anthropomorphic attribution and extraversion.



These results suggest that expectations as to robot proxemic behaviour within a given interaction behaviour is influenced by anthropomorphic attributions based on appearance.

Research Question 3:

Having established the link between anthropomorphic attribution and the formation of proxemic expectations, the next question pertains to how potential users may rate the proxemic behaviour of the robot in a post-experimental evaluation. To assess this, an ANOVA was run in the post-experimental evaluation of the *Robot in Control* condition as in this condition, the robot would ignore the participants' proxemic preferences, thus consistently violate their expectations. The ANOVA did not find a significant or salient effect for anthropomorphic attribution ($F(1,21)=.129$, $p=.73$), nor did a model controlling for extraversion find a salient or significant interaction effect ($F=(1,21)=.128$, $p=.74$).

Discussion

This paper presented trends and significant results suggesting that anthropomorphic attributions play an important role in determining proxemic expectations when participants interact with a robot. Robots with a more humanoid appearance are attributed to be more humanlike, and this attribution leads to higher expectations of conformity to social norms regarding proxemics.

However, previous studies have suggested that anthropomorphic attributions are also related to general liking of that particular robot. Thus a higher degree of anthropomorphism increases the reward value of interactions and seems to mediate the evaluation of the violations of the proxemic expectations in this particular experiment.

From a human-robot interaction research point of view, these results highlight the importance of paying attention to a wide range of data capture, and to the fact that in-situ behaviour may not always translate directly into how participants evaluate interactions and technology after an interaction. As such, these results support the assertion by Sabanovic et al. (Sabanovic et al., 2007) that these discrepancies need to be addressed within HRI research.

In this particular experiment, the reward-value correlated with anthropomorphic attributions to a large extent mediated the impact of increased expectations of conformity to social proxemic norms. This may not always be the case. This particular study was short-term and reflects an initial interaction with a robot. It very well possible that continued violations of such expectations as well as other inconsistencies between appearance and behaviour may (in long-term repeated interactions) lead to rejection of a robot by its user as suggested by Walters et al. (2008). If this is the case, the use of anthropomorphism in form may not be a good strategy to encourage interactions, as the social expectations to a robot with this form will be more difficult to adhere to for such a system. The role of expectations based on appearance and other cues of varying anthropomorphism, especially in long-term interactions, remains a salient field of study.

While the above interpretation of the study's results necessarily need to be tentative, we believe that a report of these findings is worthwhile to the research community studying human-robot interaction in assistive and eldercare scenarios. In particular, it is also important to note that the results regarding the impact of extroversion are consistent with our previous studies, both in regards to anthropomorphic attributions (Walters et al., 2008), as well as proxemic preferences (Syrdal et al., 2006), suggesting that these results may be robust across a wider range of interactions and robot types. Future work will further investigate these issues, including users from an elderly population in long-term studies, as part of our work in the new European project LIREC that develops and studies long term companionship with robots and other computational artifacts.

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References

Aiello, J. R.;DeRisi, D. T.;Epstein, Y. M.; & Karlin, R. A. 1977. Crowding and the Role of Interpersonal Distance Preference. *Sociometry* 40(3): 271-282.

Albas, C. 1991. Proxemic Behavior: A Study of Extrusion. *Journal of Social Psychology* 131(5): 697-702.

Albright, L.;Kenny, D. A.; & Malloy, T. E. 1988. Consensus in Personality Judgments at Zero Acquaintance. *Journal of Personality & Social Psychology* 55(3): 387-395.

Bartneck, C.;Chioke, R.;Menges, R.; & Deckers, I. 2005. *Robot Abuse - A Limitation of the Media Equation.* Paper presented at the Interact 2005 Workshop on Abuse, Rome.

Burgoon, J. K.; & Walther, J. B. 1990. Nonverbal Expectancies and the Evaluative Consequences of Violations. *Human Communication Research* 17(2): 232-265.

Cesta, A.;Cortellessa, G.;Giuliani, M. V.;Pecora, F.;Scopelliti, M.; & Tiberio, L. 2007. Psychological Implications of Domestic Assistive Technology for the Elderly. *PsychNology Journal* 5(3): 229-252.

Friedman, B., Kahn, P. H., and Hagman, J. 2003. Hardware companions?: what online AIBO discussion forums reveal about the human-robotic relationship. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Ft. Lauderdale, Florida, USA, April 05 - 10, 2003). CHI '03. ACM, New York, NY, 273-280.

Gillespie, D. L.; & Leffler, A. (1983). Theories of nonverbal behavior: A critical review of proxemics research. In *Sociological Theory Vol 1.* (pp. 120-154).

Hall, E. T. 1966. *The Hidden Dimension.* New York: Doubleday.

Harmo, P.;Taipalus, T.;Knuuttila, J.;Vallet, J.; & Halme, A. 2005. Needs and Solutions - Home Automation and Service Robots for the Elderly and Disabled. *IEEE/RSJ International Conference on Intelligent Robots and Systems, Edmonton Canada 2005*.

Hartnett, J. J.;Bailey, K. G.; & Gibson, F. W. 1970. Personal space as influenced by sex and type of movement. *Journal-of-Psychology:-Interdisciplinary-and-Applied. Vol. 76(2) Nov 1970, 139-144.*

Hinds, P. J.;Roberts, T. L.; & Jones, H. 2004. Whose Job Is It Anyway? A Study of Human-Robot Interaction in a Collaborative Task. *Human-Computer Interaction* 19(1): 151 - 181.

Hüttenrauch, H.; & Severinson Eklundh, K. 2002. Fetch-and-carry with CERO: Observations from a long-term user study with a service robot. *Proceeding of the 11th IEEE International Workshop on Robot and Human Interactive Interactive Communication(RO-MAN 2001), Berlin, Germany Sept 25-27, 2002*: 158-163.

Kendon, A. 1990. *Conducting interaction – Patterns of behavior in focused encounters. Studies in interactional sociolinguistics*. Cambridge, NY, USA: Press syndicate of the University of Cambridge.

Kiesler, S.; & Goetz, J. 2002. Mental Models and Cooperation with Robotic Assistants. *Proceedings of the ACM CHI'02 Conference on Human Factors in Computing Systems*: 576–577.

Koay, K. L.;Sisbot, E. A.;Syrdal, D. S.;Walters, M. L.;Dautenhahn, K.; & Alami, R. 2007. Exploratory Study of a Robot Approaching a Person in the Context of Handing Over an Object. *AAAI 2007 Spring Symposia - Technical Report SS-07-07, 26-28 March 2007*: 18-24.

Koay, K. L.;Syrdal, D. S.;Walters, M. L.; & Dautenhahn, K. 2007. Living with Robots: Investigating the Habituation Effect in Participants' Preferences during a Longitudinal Human-Robot Interaction Study. *IEEE International Symposium on Robot and Human Interactive Communication (Ro-man 2007), Jeju Island, Korea*: 564-569.

Kovner, C. T.;Mezey, M.; & Harrington, C. 2002. Who Cares For Older Adults? Workforce Implications Of An Aging Society. *Health Aff* 21(5): 78-89.

Krail, K. A.; & Leventhal, G. 1976. The Sex Variable in the Intrusion of Personal Space. *Sociometry* 39(2): 170-173.

Lee, S.; & Kiesler, S. 2005. Human mental models of humanoid robots. *In Proceedings of the 2005 international conference on robotics and automation (ICRA 05) (pp. 2767–2772), Barcelona, Spain*.

Luczak, H.;Roetting, M.; & Schmidt, L. 2003. Let's talk: anthropomorphization as means to cope with stress of interacting with technical devices. *Ergonomics* 46(13/14): 1361-1374.

Matthews, G.;Deary, I. J.; & Whiteman, M. C. 2003. *Personality Traits*. Cambridge, UK: Cambridge University Press.

Montemerlo, M.;Pineau, J.;Roy, N.;Thrun, S.; & Verma, V. 2002. Experience with a Mobile Robotic Guide for the Elderly. *National Conference on Artificial Intelligence, AAAI, August, 2002*.

Reeves, B.; & Nass, C. 1996. *The Media Equation: How people computers, television, and new media like real people and places.* Cambridge: Cambridge University Press.

Roy, N.;Baltus, G.;Fox, D.;Gemperle, F.;Goetz, J.;Hirsch, T., et al. 2000. Towards Personal Service Robots for the Elderly. *Workshop on Interactive Robots and Entertainment (WIRE 2000)*.

Sabanovic, S.;Michalowski, M. P.; & Caporael, L. R. 2007. Making Friends:Building Social Robots Through Interdisciplinary Collaboration. *Multidisciplinary Collaboration for Socially Assistive Robotics: Papers from the AAAI Spring Symposium -Technical Report SS-07-07*: 71-77.

Strube, M. J.; & Werner, C. 1984. Personal space claims as a function of interpersonal threat: The mediating role of need for control. *Journal of Nonverbal Behavior* 8(3): 195.

Sung, J., Grinter, R. E., Christensen, H. I., and Guo, L. 2008. Housewives or technophiles?: understanding domestic robot owners. In *Proceedings of the 3rd ACM/IEEE international Conference on Human Robot interaction* (Amsterdam, The Netherlands, March 12 - 15, 2008). HRI '08. ACM, New York, NY, 129-136.

Swann, J. 2006. Assistive equipment around the home: Tools for daily living. *International Journal of Therapy and Rehabilitation* 14(3), 135-138

Syrdal, D. S.;Dautenhahn, K.;Woods, S.;Walters, M. L.; & Koay, K. L. 2006. 'Doing the right thing wrong' – Personality and tolerance to uncomfortable robot approaches. *Proc. 15th IEEE International Workshop on Robot and Human Interactive Communication(RO-MAN 2006)*: 183-188.

Syrdal, D. S.;Koay, K.-L.;Walters, M. L.; & Dautenhahn, K. 2007. A personalised robot companion? The role of individual differences on spatial preferences in HRI scenarios. *IEEE International Symposium on Robot and Human Interactive Communication(Ro-man), Jeju Island, Korea*.

Syrdal, D. S.;Walters, M. L.;Koay, K. L.; & Dautenhahn, K. 2008. The role of autonomy and interaction type on spatial comfort in an HRI scenario. *Proceedings of Robotic Helpers: User Interaction, Interfaces and Companions in Assistive and Therapy Robotics. Full-day workshop at the third ACM/IEEE Human-Robot Interaction Conference (HRI08), 12-15 March 2008, Amsterdam, the Netherlands*.

Tsui, K. M.; & Yanco, H. A. 2007. Assistive, Surgical, and Rehabilitation Robots from the Perspective of Medical and Healthcare Professionals. *Proceedings of the AAAI Workshop on Human Implications of Human-Robot Interaction, July 2007.*

United-Nations. (2002). *World Population Ageing 1950–2050*: United Nations, New York: United Nations Population Division.

Walters, M.;Syrdal, D. S.;Dautenhahn, K.;Boekhorst, R. T.;Koay, K. L.; & Woods, S. 2008. Avoiding the Uncanny Valley – Robot Appearance, Personality and Consistency of Behavior in an Attention-Seeking Home Scenario for a Robot Companion. *Autonomous Robots* 24(2): 159-178.

Walters, M. L.;Dautenhahn, K.;Boekhorst, R. T.;Koay, K. L.;Kaouri, C.;Woods, S., et al. 2005. The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment. *Proc. 14th IEEE International Workshop On Robot And Human Interactive Communication (RO-MAN 2005)*: 347-352.

Walters, M. L.;Dautenhahn, K.;Koay, K. L.;Kaouri, C.;René te Boekhorst;Nehaniv, C., et al. 2005. Close Encounters: Spatial Distances between People and a Robot of Mechanistic Appearance. *Proceedings of 2005 5th IEEE-RAS International Conference on Humanoid Robots, Tsukuba, Japan*: 450-455.

Williams, J. L. 1971. Personal space and its relation to extraversion-introversion. *Canadian-Journal-of-Behavioural-Science* 3(2): 156-160.

Woods, S. N.;Walters, M. L.;Koay, K. L.; & Dautenhahn, K. 2006. Methodological Issues in HRI: A Comparison of Live and Video-Based Methods in Robot to Human Approach Direction Trials. *Proceedings, 15th IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN2006)* (51-58): 51-58.

Zebrowitz, L. A.;Hall, J. A.;Murphy, N. A.; & Rhodes, G. 2002. Looking smart and looking good: Facial cues to intelligence and their origins. *Personality and Social Psychology Bulletin* 28: 238–249.

Appendix B

Exploring Human Mental Models of Robots

Syrdal, D. S., Dautenhahn, K., Koay, K. L., Walters, M. L., & Otero, N. (2010). Exploring human mental models of robots through explicitation interviews. *In The 19th IEEE International Symposium on Robot and Human Interactive Communication-2010 RO-MAN (pp. 638-645).* IEEEXplore.

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Exploring Human Mental Models of Robots through Explicitation Interviews

Dag Sverre Syrdal, Kerstin Dautenhahn, Kheng Lee Koay Michael L. Walters, Kerstin Dautenhahn , and Nuno R. Otero

Abstract— **This paper presents the findings of a qualitative study exploring how mental models of a mechanoid robot using dog-inspired affective cues behaviour emerges and impacts the evaluation of the robot after the viewing of a video of an assistive robotics scenario interaction with the robot. It discusses this using contrasting case studies based on the analysis of explicitation interviews with three participants. The analysis suggests that while for some users zoomorphic cues may aid in initial interactions, they need to be framed in an authentic interaction, highlighting the actual capabilities of the robot as a technological artifact, and how these impact the everyday life and interests of the potential user.**

I. Introduction

This paper explores qualitatively the specifics of how a mental model of a robot is formed.

The term mental model is here derived from [1] and understood to be a process, wherein a mental model is constructed from mental representations of objects and process in the external world. This can then be used to predict outcomes of events and behaviour in the physical world. While the relationship between the representations contained in the model and their external world counterparts need not be one of direct correspondence (i.e. they may not accurately reflect reality), and the processes may not be consciously apparent to the individual at all given times, the contents of the model should be expressible through verbal and 'folk scientific' statements by the holder of the model. Mental models are important to human-robot interaction (HRI) since they act as a reasonable predictor of interactions with, and evaluations of, a given system. In order to investigate these issues an exploratory study into mental models in HRI has been performed.

Approaches in the literature to the study of human mental model of robots in HRI can be grouped in two rough categories:

The first is the study of 'low-level' mental models for human beliefs regarding very specific categories. For instance, Fischer and Lohse [2] describe an investigation into human mental models of a robot's situation awareness and suggest means of modifying such models to ones that are more in line with the robot's actual capabilities.

The other approach is looking at 'higher-level' mental models drawing on metaphor for their conception. In particular, several authors [3-5] have examined the role of anthropomorphic mental models where robots have been rated according to personality traits appropriate for humans as well as traits that are more appropriate for mental models that would see the robot as purely machine-like. Kiesler & Goetz [4] found a link between aspects of a participant's anthropomorphic mental model and their ability to cooperate with a robot. Syrdal et al. [6] found an effect in which attributions associated with a more anthropomorphic mental model of a robot had an impact on how participants responded to and evaluated the proxemic (social distances towards a human) behaviour of a robot. Furthermore, Andonova [7] examined how a high-level mental model of a wheelchair robot could be influenced and changed.

High-level mental models of robots, which incorporate anthropomorphic dimensions of interaction with robots, have been utilised in the design of robots (for instance,

Fig 1 Pioneer Robot used in the Video

Walters et al. [8] and Breazeal [9]). This use of anthropomorphic cues and interaction modes have been implemented for two main reasons: The first is to facilitate interactions that seem natural to the human interactants by drawing upon existing mental models of expected

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interaction, thus reducing the effort needed by the human interactant. Also, the ability to draw upon an existing body of knowledge is important, both in terms of “commonsense” as well as findings from the social sciences regarding mental models of expected behaviour in given interactions. In this sense, the use of anthropomorphic cues is no different from the practice in HCI (human-computer interaction) of incorporating features of popular existing software packages in new interfaces or conceptualizing interactions through the use of metaphors (the common example is the desktop metaphor [10]). However, pitfalls of the use of anthropomorphic cues have been highlighted. For example, if the appearance and cues of the robot seem to fit too well within a mental model in which the robot is understood as human-like, and if human behaviour within an HRI scenario based on such a model does not elicit the appropriate response from the robot, this may lead to a feeling of disillusionment and rejection of the robot for the user [11]. A reasonable conclusion here is that the appearance and cues displayed by the robot should be familiar enough to the user that the user is capable of discerning the intentions of the robot, while not engendering unrealistic assumptions of the anthropomorphic nature of the robot.

One method which has been applied is that of attempting to substitute anthropomorphic mental models with ones that are zoomorphic in origin. This has been the case for the entertainment robots such as Sony's AIBO and Ugobe’s Pleo, as well as the eldercare robot PARO [12]. Nicolescu and Mataric’ work with using dog-like cues to direct attention with a Pioneer robot is also an excellent example of this.[13] The increasingly widespread use of robots using zoomorphic appearance and cues warrants a re-examination of the higher-level mental models that interactants may have of robots. While there is evidence that personality attributions mainly associated with anthropomorphic mental models may be suitable for non-human animals [14, 15], and there are standardized ways of measuring such attributions for specific species [16], evidence suggests that human mental models of animal-inspired robots differ from those of the animal that the robot is based on [17].

II. Methodology

A. Aims

The above suggests that an in-depth investigation into how mental models are formed, shaped and then influence how participants evaluate a robot is a useful avenue of study which uses qualitative methods. This approach allows for an understanding of mental models that is data-driven, and could allow us to examine the participants' models on their own terms rather than the more narrow lenses that quantitative methods necessitate (for example the predefined semantic scales based on human personality traits in [3-6]). The study presented here aimed to examine and explore these issues in contrasting case studies, using interview transcripts from three participants. The case study approach has previously been used in HRI studies which have aimed for in-depth exploration of human perceptions of robots [18]. This methodology is not intended to replace quantitative methods, but rather aims to complement such methods, by allowing the researchers to get an in-depth understanding of the reasoning that leads to particular quantitative results as well as open up new avenues of investigations by raising new possible research questions.

B. The Transcripts and Video

The interview transcripts were obtained from a study performed for the purpose of evaluating the usefulness of affective cues inspired by dog-behaviour for wider use within the European LIREC project [19]. One of the purposes of these interviews was to pilot the display of the cues as well as to elicit responses that would allow the researchers to create a quantitative questionnaire based on the description of the participants. These results, along with the results from a quantitative pilot study are currently being written up for publication.

The video used in this study showed a user and a guest (named Anne and Mark) interacting with a robot that used affective non-verbal cues. The behavioural cues created to be exhibited by the robot were not identical to, but were inspired by, cues used by dogs interacting with humans in the same situations. The video was created at the University of Hertfordshire Robot House, with input from a group of ethologists from the Ethology Department at Eötvös Loránd University (Budapest). The motivation for the study was that if these cues were effective, they would elicit mental models of the robot and its behaviour that would draw upon existing mental models of dogs and dog-behaviour. As such, its use would allow us to investigate zoomorphic mental models in detail. An overview of the video follows in table 1.

Table 1 Timeline of the video

Scene No.	Brief Description
1	Robot/Dog is in dining room, Owner enters from outside, robot greets owner.
2	Robot/Dog is in dining room, Guest enters from outside, robot/dog greets guest and uses social referencing to interact with owner.
3	Robot/Dog follows owner to the kitchen and is loaded with items for tea and biscuits.
4	Robot/Dog attempts to gain guests attention for help in unloading.

5	Owner and Guest have tea and converse with robot /dog watching.
6	Guest leaves, robot/dog engages in "farewell" behaviour with guest.

The robot used in the video was a Pioneer[1] (see fig 1) which is mechanical-like in appearance, approximately the same size as a medium size dog, but in other respects was not particularly dog-like.

C. The Behaviours Used

The behaviours across this video were intended to be analogous of that of dogs, while taking into account the different modalities for sensing and communication. For instance, if a dog in a given situation would use its sense of smell to examine something, the robot would instead appear to be examining something by moving its camera.

The greeting behaviour for the owner consisted of the robot moving towards the owner as she entered, orienting its camera briefly towards the face of the owner and then moving away in the direction the owner would later move towards. This behaviour was intended to communicate enthusiasm both in terms of greeting the owner and aiding in the tasks the owner was later to perform.

The greeting behaviour for the guest was similar, however, here the robot spent more time on examining the guest, and immediately turned to the owner for the purposes of social referencing [20] by orienting its camera to the owner when the owner appeared..

The "farewell" behaviour towards the guest consisted of the robot orienting its body and camera towards the guest, observing him as he left the room. The "farewell" behaviour towards the owner consisted of the robot orienting its body towards the owner and then moving towards the owner as she walked to the door, following the owner to the door, only stopping as it reached the door.

The underlying "story arc" of the video was that of a friend visiting the owner of a robot who primarily used it as a moving platform for transporting objects from place to place. This task, like the behaviours, were inspired by actual tasks performed by helper-dogs for the disabled.

D. Participants

Three participants were used in this study. The participants were chosen primarily in order to highlight three different approaches to the robot's behaviour in the video.

Two of the participants used in this study were both male, in their mid-twenties and post-graduate education.

Participant BH1 comes from a science background working towards as PhD in one of the physical sciences and is highly proficient with computers, capable of coding programs for data collection and analysis within his field. His family has owned several dogs.

Participant TE1 comes from a computer science background, and is currently working towards a PhD in the subject and has experience with robotics. He does not own a dog, nor does his immediate family.

Participant NB1 is a female in her mid-forties. She is a stay-at-home mothers. And has suffered from debilitating arthritis since an early age While there may be a temptation to refer to her as technically naïve due to her lack of formal training in the use of computing equipment, she uses computers extensively in her day to day life, and before the interview made references to her experience of voice recognition software that she attempted to use as a substitute for typing, which can be painful due to the arthritis. She has previously interacted with a robot in a proxemics study similar to that reported in [21] She does not own a dog.

The interviews from these three participants were chosen from a larger pool of interviews which had been conducted to create a quantitative questionnaire for further use of the video. The two male participants were chosen due to their clear membership in the "early adopter" demographic for consumer electronics, like personal robots. This along with their different backgrounds in terms of technical experience of robots as well as differences in exposure to dogs, was hoped to illustrate different aspects of how mental models would form.

The third participant was chosen as a contrast to the previous two. She does not have their extensive experience of using computers, but have had experience in using particular technical aids for overcoming problems arising from her arthritis.

It was hoped that this combination of backgrounds would elicit and highlight salient issues in this investigation.

E. Method

The participants viewed the video and were then asked to participate in an explicitation interview exploring their experience while watching the video. This interview was unstructured, the dialogue mainly focused on a chronological account of the videos as well as requests from the interviewer for elaboration on statements from the participants attempting to draw out as much information regarding the issues raised by the participants, and care was taken not to mention the dog-inspired origin of the behaviour in order to assess the legibility of the cues. Also, while participants were prompted, towards the end of the interview, to compare the robot to something else, *this was not done until the end of the interview, and responses to this prompting was recorded and reported as such*. We previously used this interview technique in examining

[1] Commercially available robot platform from MobileRobots MobileRobots (http://www.activrobots.com/)

responses to HRI videos [22]. Explicitation interviews aim to evoke a revivification of the perceptual experience and one of the benefits of this is that it allows the construction of a narrative to be recorded rather than just the end-product narrative itself [23]. In this way, the technique allows us to examine how the participants describe their experiences and how these descriptions become the building blocks of a narrative in which the mental model of the robot emerges The transcripts were analysed in detail using the Grounded Theory approach in interacting with the data [24]. This approach was chosen as its open-ended, data-driven nature was deemed suitable for the exploratory nature of this investigation.

The initial open coding focused on identifying and coding themes relating to how the participants described the behaviour of the robot and the robot itself. Early on in this process, the salient themes became those relating to attribution of agency, emotive descriptions, referencing of personal experience, descriptions of robot behaviour, and the use of metaphor in describing the robot. This was followed by axial coding, in which the initial themes, and their relationships with each other, were examined across the transcripts of the participants.

III. RESULTS:

A. The main dimensions

Organising these themes into dimensions yielded two primary dimensions in which the two transcripts differed; that of describing the robot using the dog metaphor and understanding the robot as a malleable, customizable, technological artefact. The way that these two dimensions interacted to form the particulars of the two participants' mental models of the robot and subsequent evaluation of the robot, became the focus of the analysis.

B. Describing the robot – Dog metaphor and the robot's mechanical nature:

BH1, when describing the robot's behaviour clearly identifies its behaviour as doglike and frames this behaviour directly within his own personal experience of dogs:

> **BH1:** *It acts a bit like a dog, actually, and goes up to investigate who comes through the door.*
> **E**: *You say it acts a bit like a dog, can you elaborate?*
> **BH1:** *I got a couple of dogs at home, and as soon as I come through the door or as anybody comes through the door they get up and investigate who comes into the door by walking up to the person and have a look.*

This is quite important for the development of the rest of the interview, as this participant continues to frame the behaviour of the robot within interactions that have taken place within his own everyday experience. Of particular interest is the following discussion of the robot's attention seeking behaviour:

> **BH1**: *I suppose because it needs to grab his attention and to assess how it should grab his attention, I suppose if it moved fast it would be very useful to grab his attention, although it would hurt him. And as it does not seem to be able to talk or make any sounds at all, it has to sort of assess that it is gonna have to collide with him to grab his attention…*
> **E:** *...What do you think of the way the robot tried to grab his attention?*
> **BH1***: Well, obviously it assessed that the guest was paying no attention to the robot and then decided that the best course of action would be to sort of gently grab his attention by driving into his foot rather slowly. I would say that was quite acceptable.*

This exchange seems to suggest that BH1 sees the robot as having an agency defined by its task, and the ability to use the modalities provided by its form to compensate for its lack of verbal ability.

NB1, on the other hand, describes the robot in quite mechanical terms. She focuses primarily on low-level descriptions of the behaviours as well as the practical issues for the user:

> **NB1:***It is quite small, whiteish coloured, and it had a small camera, which could move up and down, but it [the robot] was quite short. It followed her to the kitchen, wheeled at a steady pace keeping up with her. Then it stopped. It must have decided that it knew where she was going, and so stopped as it knew where Anne was if she needed it.*
> **NB1**: *When Mark came in, it moved its camera up and down slowly as if measuring him, maybe, I think, to get a picture of him so that he could be recognized more quickly the next time he was visiting.*

These statements indicate a mental model of the robot as a purely mechanical entity, whose function defines its behaviour and motivation. The behaviours are descriped in low-level terms and explained in terms of their utility to perform subsequent tasks. Moving on from this, she highlights the actual task the robot was used for.

> **NB1**: *It [the robot] follows her to the kitchen and she loads it with the plates and cutlery and things. I think it's ok, but for that kitchen I think it is a bit too close, She needs to bend over too much when loading it at that angle, I think I would want it a bit further away, if I was to use it.*

The robot's behaviour here is critiqued purely in terms of how they meet the users needs in terms of the practical performance of the task.

This is continued in her description of the attention seeking sequence:

NB1:*I am not sure if I liked the way that it acted when Mark was reading his paper and not noticing the owner. I think maybe it shouldn't have bumped into him, maybe used a beep or something to alert him…On the other hand, Mark didn't seem to mind, and since he was allright with it, maybe it doesn't need to be changed.*

NB1 here highlights an episode where the robot is acting in a manner that she thinks may be problematic. What is interesting here is that after drawing up possible solutions, using sound based communication, she concludes that the behaviour of the robot was appropriate due to the acceptance of it by the user, another example of her focus on the practical aspect of adopting such a technology.

TE1 in contrast, seems to incorporate aspects of both the above participants, models of the previous participants. When asked to describe the behaviour of the robot, the following exchange occurs:

TE1: *Ok, sure, I believe she comes into the room, the robot sees her, and she says something like "Hello Robot", and the robot seems to respond by looking at her but not really responding in… in any other way.*

E: *OK, could you think back to the way Anne and the robot move in that particular sequence. Could you describe the way the robot moves?*

TE1: *Ehm...the robot seems to direct himself towards her, going to towards her and seems to focus his camera on her.*

Participant TE1 here draws on his particular technical background to deconstruct the overall behaviour of the robot into a set of sub-behaviours, which are determined by how it uses its camera and movement. However, TE1 still references more high level communicative functions by noting their absence e.g. "*...not really responding".*

This reference to the absence of behaviour is repeated in his description of the robot meeting the guest, the robot is described as constrained by its abilities.

TE1: *It seems like he does greet him a little bit, but he doesn't have the power to actually go and do some interaction with Mark*

When describing the attention seeking behaviour, TE1, like BH1 and NB1 highlights the lack of verbal/auditory communication modalities for the robot.

TE1: *Given how its capabilities were that he couldn't make a noise or something, I would say that is the only way he could get his attention.*

The responses of the three participants indicate an underlying difference in how the robot is viewed. BH1 has framed the robot and its behaviour within that of his own experience through the similarities with dog-behaviour. Thus, he seems to regard the behaviour of the robot in the attention seeking sequence as an active adaptation on the basis of actively pursuing a task. NB1 proceeds to frame this behaviour within the interactions with and reactions from the users. Interestingly, the more technically minded TE1, however, sees the situation more clearly from the robot's perspective with the constraints as limiting and the robot as being forced into a set of actions.

C. The possibility of 'bettering' the robot.

These limitations are a continuing theme in TE1's considerations of the robot behaviours:

TE1*: It seems like acting a little bit socially, but not too much. Most of the time it acted just like a tool for the owner. And...sometimes it did seem try to kind of find a connection with the people, but I don't think...it didn't seem like it succeeded in that.*

Here, the robot is described as trying to find a connection to people as it did in the initial discussion of the greeting sequence, but is unable to transcend the constraints of its hardware, by means of particular sounds or verbal utterances, to make this connection. While the affective dimension of TE1's description of the robot is not explicit in the above statement, this dimension is made so along with an acknowledgement of the utility of such a n affective connection, despite its lack of authenticity later on:

TE1: *I think so, yeah...if somehow he would seem a little bit attached to me. He would have a reason to help, it would be nice, he would be more than a tool. Then sometimes he is maybe in the way, if you have the feeling that he is doing that because of attachment you would be more lenient with that.*

TE1: *Yes, I am fully aware that it is really easy to project emotion or something on something that doesn't have it. But still in daily life you don't consider it. With pets for instance you easily project intelligence or emotions on them. It just happens even though you know when you are talking to it, it doesn't understand it. But it is still comforting to project it on it.*

Here, the participant references anthropomorphic aspects of interactions with other non-human entities, and while acknowledging that these aspects are one-sided, still confesses to being not only susceptible to them, but also the possibility of drawing emotional support from them. As such, there is a similarity with one of the case studies reported in human-AIBO interactions by Turkle [18], where the human interactant saw the robot not only as a creature with the possibility to have emotions, but also representing an avenue through which she could fulfill her need to nurture another being. Similarly, TE1 sees the possibility of the robot being able to act emotionally, but sees this possibility undermined by the constraints of its current capabilities. Interestingly, TE1 also seems to argue that the robot as well is struggling against these constraints. TE1's reasoning implies that it is possible to remove these constraints, and this removal is mutually beneficial both for the robot (which succeeds in its attempts to '*...find a connection.*', and '*..become more than a tool.*'), and the user which will be comforted by the robot. In this sense, TE1's sentiments echoes Turkle's Melanie in the need to nurture the robot, albeit through different modalities and a more reasoned approach, not necessarily based on emotional needs, but more likely based on a greater sense of the efficacy of creating a technical solution to aid the robot. It is also interesting to note that when pressed to compare the robot's behaviour to a non-robot entity, TE1 refers to children as well as dogs in his description:

TE1: *It reminds me a bit like children. If you don't give them attention, they get busy and run around until you look at them and give them attention.*

TE1*: …* *like children if the mother leaves there is more attachment. The same with dogs if the owner leaves there is more display of this behaviour than with random people.*

In contrast, BH1 focuses less on the robot itself, but rather on its role in the interactions when considering its behaviour:

BH1: *It seemed very socially capable really. It reminded me of an animal, particularly a dog in that it wanted to be near its master. Follows its master around the house, it obeyed every command, seemed to understand every command, particularly when Mark walked in and Anne introduced Mark to the robot and the robot to Mark it seemed to acknowledge him. And then just acted normally.*

Again, there is a grounding in the participant's experience with dogs to understand the robot as dog-like, which here leads to a favourable assessment of the robot's behaviour. By emulating a dog, the robot allows itself to be slotted into the participant's expectations of possible interactions within domestic settings, and so the robot is considered much more socially capable as it conforms to these pre-existing expectations. As such, the need for nurturing through increased modalities is not present for BH1.

When considering the social aspect of the interaction. NB1 draws from her own experience with assistive technologies:

NB1: *It seemed to understand what they were saying to it really easily. I remember trying to use voice-recognition software a couple of years ago, so I wouldn't have to type so much, you know, because of my arthritis, but I don't think it worked that well. I remember thinking it was easier just to type a bit more slowly.*

This cements the notion that for NB1 the robot's potential is primarily as a tool to use in particular situations that she may find difficult.

D. Evaluating the Robot's role in the Situation

However, when assessing the usefulness of the robot within the scenario presented there is another difference between the three participants:

TE1: *I would think so, yeah. It definitely could help carrying stuff like that. It shows enough intelligence to follow people and bring stuff, and I would say that is useful yeah.*

NB1: *Yes, I could see a use for it. I remember when I broke my leg and had problems walking. I couldn't make myself a cup of tea, and had to wait for my daughter or husband to come home to help me with that. It makes you feel a bit helpless you know. Maybe we could get these on the NHS*[2]*?*

BH1: *Not particularly* [useful]*, she loaded it with a couple of things, and brought the rest in herself and it seemed like a pointless exercise. She could have done it all herself...I don't think you could have a relationship with it [the robot] the way you could with a dog, cause a dog has a personality, while for a robot, the personality is just a couple of subroutines…*

This divergence of opinion can most easily be understood through the perceptions that the participants have displayed throughout the earlier parts of the interview. TE1, having described the robot as constantly being 'frustrated' by its constraints in its efforts to connect with the humans in the scenario, here highlights the one function that the robot seems to be able to perform without such 'frustration'. This leads him to consider the robot's ability on the robot's own terms.

NB1 relates the robot to her own needs and sees it as a potentially useful aid in her everyday life, highlighting an episode where it could have been of use. This is consistent with her situating the robot within the tasks and interactions that previously emerged in the interview.

BH1's comments on the other hand, reflects his ability to insert the robot into what he considers a plausible social scenario. For him, the robot seems capable of functioning in existing interactions, which leads him to focus on how the robot can bring added value to these interactions, a function that the robot fails to perform.

E. Summary

The analysis of the interview transcripts suggests that BH1 and TE1 took an interest in and interpreted the zoomorphic cues as communicating emotive information and both referred to dog behaviour when attempting to describe them. The participants differed, however, in how dog-like they saw them. Participant BH1 repeatedly referenced his own rich experience of dog-behaviour when describing and reasoning about the cues and their purpose, while participant TE1, on the other hand, while referencing dogs, also referenced children as well as attempting to reconcile a more technical deconstruction of the robot's behaviour with the affective dimension of the cues.

[2] A reference to the British National Health Service.

This divergence became more apparent as the narrative was constructed within the interview. In the later stages of the interview, the utility of the BH1's dog-based mental model while useful for understanding the robot, also seems to have led him to unfavourable evaluation of the robot and its utility especially when this rich mental model of “the robot as a dog” led to a direct comparison of the robot with a dog.

TE1, on the other hand, while interpreted the robot's behaviour successfully using a mental model still containing dog metaphors, incorporated other aspects into this model, which allowed him to look for means for the robot to overcome its lack of sophistication.

NB1, in contrast to both the other participants, did not consider the affective communication aspect of the interaction in her descriptions, choosing instead to focus on the task related aspects of the video, and when considering interactions, focused on ease of use as well as acceptability. She also referenced her own experiences with assistive technologies as well as specific instances where the robot as being portrayed in the video would be of use.

IV. Conclusions

The responses from these participants highlight important issues in dealing with the robot portrayed in the scenario:

One the one hand, there is the approach exemplified by BH1. In this approach the behaviour of the robot is not only taken as offered by the scenario, but is easily incorporated into this participant’s own experiences and expectations. The robot is understood more in terms of its role as a “dog”, or even possibly as a dog-substitute. While initially this approach seems to make the participant more appreciative and accepting of the robot, the placement of the robot in this role, also puts demands on the robot, both socially and emotionally, as well as in terms of usefulness. In this case, the robot fails to live up to some of these expectations.

NB1’s mental model of the robot, is not so much considering the robot as a separate entity, but rather focuses on how the presence of the robot impacts her mental models on how tasks are performed. The robot is represented mainly as the sum of its functions. The affective communication aspect of the interaction was completely overshadowed by the use-possiblities that this participant envisaged.

TE1, on the other hand exemplifies an approach in which the robot is considered to occupy a paradoxical position. On one hand, it is seen as a tool, and this approach explicitly acknowledges its ‘mechanical’, non-human nature. However, it is also imbued with what could be described agency, a purpose to transcend the constraints of its current form. This approach opens up the possibility of a more active user, who sees the robot more of a hobby, a project in which there is a reciprocal relationship between the robot who is given further modalities in which it can communicate and connect with its user, and the user who will enjoy and be comforted by the robot’s increasing ability to interact.

The contrast between NB1 and TE1 provide an interesting illustration of the two demographics highlighted in Sung et al [25] where many users who don’t fit into the early adopter stereotype acquire consumer robots to perform particular tasks, while some users purchase consumer robots in order to improve and customise them. The perspectives of these users allow for an understanding of how views on the robot in itself as well as their impact on their environment are formed.

While it is certainly easy to argue that it may be difficult to make strong claims about the generalisability of the participants’ reasoning to a wider group of users, it is important to note that what this method allows for, however, is to present an in-depth account of how these participants reasoning, attitudes and feelings towards the robot emerge. As such, it provides insights that irrespective of participant numbers can be used in the design of robot technologies, For instance results such as these are very valuable for developing “user personas” in an Interaction Design approach like the one described in [26]. They also raise issues that may be studied further, both qualitatively and quantitatively, for instance, studies such as [27] rely on a highly detailed and sophisticated user profile, which in turn opens the door for customization and personalization of artifacts.

In terms of lessons for further research on the use of zoomorphic and anthropomorphic cues to regulate interactions and emergent relationships, these interviews highlight salient differences in how the nature of companionship with a robot is interpreted and understood by different people and how these interpretations arise and develop. Implications of this work include:

Firstly, anthropomorphic and mechanical reasoning regarding the robot are not necessarily antagonistic to each other, and as the appearance of the robot in this study was not doglike at all, does not necessarily rely on appearance.. This is exemplified by TE1’s reasoning regarding the robot incorporates both a sophisticated interpretation of the robot’s behaviour which explicitly and knowingly utilises his own anthropomorphic biases while still retaining a core understanding of the robot as a machine. This is reminiscent of the phenomena of Joint Pretense discussed by Clark [4] in regards to interactions with virtual partners, or the Performed Beliefs reported in Pleo blogs by Jacobsson [28]. These conflicting notions of the robot’s nature are complementary, and it is telling that in TE1’s responses, the anthropomorphic aspects of his reasoning about the robot are most apparent when he considers its technical limitations as a robot.

Secondly, it is important to consider the highly important role of personal experience when reasoning about the robot. Dog ownership seems to form the core around which BH1's perception of the robot is constructed, while the experience of being disabled allows NB1 to situate the robot very clearly in her everyday life. The Computer Science background of TE1 seems to create a focus on the specific technical problems that the robot has in performing the social aspects of its tasks. This suggests that while zoomorphic cues may aid in initial interactions for some users, they need to be framed in an authentic interaction, highlighting the actual capabilities of the robot, and how the individual user may relate to and utilise it within their own everyday experience.

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VI. References

[1] P. N. Johnson-Laird, "Mental Models, Deductive Reasoning, and the Brain," in *The Cognitive Neurosciences*, M. S. Gazzaniga, Ed. Cambridge, MA: MIT Press, 1994.

[2] K. Fischer and M. Lohse, "Shaping Naive Users' Models of Robots' Situation Awareness," *IEEE International Symposium on Robot and Human Interactive Communication (Ro-man 2007), Jeju Island, Korea*, pp. 534-539, 2007.

[3] S. R. Fussell, S. B. Kiesler, L. D. Setlock, and V. Y. H. 145-152, "How people anthropomorphize robots.," *The Third ACM/IEEE Human-Robot Interaction Conference (HRI08), 12-15 March 2008, Amsterdam, the Netherlands*, pp. 145-152, 2008.

[4] S. Kiesler and J. Goetz, "Mental Models and Cooperation with Robotic Assistants," *Proceedings of the ACM CHI'02 Conference on Human Factors in Computing Systems*, pp. 576–577., 2002.

[5] S. Lee and S. Kiesler, " Human mental models of humanoid robots," *In Proceedings of the 2005 international conference on robotics and automation (ICRA 05) (pp. 2767–2772), Barcelona, Spain*, 2005.

[6] D. S. Syrdal, K. Dautenhahn, M. L. Walters, and K. L. Koay, "Sharing Spaces with Robots in a Home Scenario – Anthropomorphic Attributions and their Effect on Proxemic Expectations and Evaluations in a Live HRI Trial," *Proc. AAAI Fall 2008 Symposium "AI in Eldercare: New Solutions to Old Problems" November 7-9, Washington, DC, USA*, 2008.

[7] E. Andonova, "Changing Mental Models of a Wheelchair Robot," *Proceedings of the Workshop on How People Talk to Computers, Robots,and other Artificial Communication Partners, Bremen 2006, pp. 131-139*, 2006.

[8] M. Walters, D. S. Syrdal, K. Dautenhahn, R. T. Boekhorst, K. L. Koay, and S. Woods, "Avoiding the Uncanny Valley – Robot Appearance, Personality and Consistency of Behavior in an Attention-Seeking Home Scenario for a Robot Companion," *Autonomous Robots*, vol. 24, pp. 159-178, 2008.

[9] C. L. Breazal, *Designing Sociable Robots*. Cambridge, Massachusetts: MIT Press, 2002.

[10] J. M. Carroll and J. C. Thomas, "Metaphor and the Cognitive Representation of Computing Systems," *IEEE Transactions on Systems, Man, and Cybernetics*, vol. 12, pp. 107-116, 1982.

[11] K. Dautenhahn, "Design spaces and niche spaces of believable social robots," *Proceedings of the 11th IEEE International Workshop on Robot and Human Interactive Interactive Communication(RO-MAN 2002), Berlin, Germany Sept 25-27, 2002*, 2002.

[12] T. Shibata, K. Wada, T. Saito, and K. Tanie, " Human interactive robot for psychological enrichment and therapy.," *Proceedings of the AISB '05 Symposium on Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction Hertfordshire, England, April 12-15, 2005). Hertfordshire, England: University of Hertfordshire, 2005, 98-109.*, 2005.

[13] N. Nicolescu, and M. J. Mataric, "Linking Perception and Action in a Control Architecture for Human-Robot Domains," *Proceedings Thirty-Sixth Hawaii International Conference on System Sciences, HICSS-36, Hawaii, USA, January 6-9, 2003.* 2003.

[14] S. D. Gosling and O. P. John, " Personality Dimensions in Nonhuman Animals: A Cross-Species Review," *Current Directions in Psychological Science*, vol. 8, pp. 69-75(7), 1999.

[15] S. D. Gosling, V. S. Y. Kwan, and O. P. John, "A dog's got personality: A cross-species comparative Approach to personality judgments in dogs and humans.," *Journal of Personality & Social Psychology*, vol. 85, pp. 1161-1169., 2003.

[16] E. Kubinyi, B. Turcsan, and Á. Miklósi, "Dog and owner demographic characteristics and dog personality trait associations," *Behavioural Processes*, vol. 81, pp. 392–401, 2009.

[17] B. Friedman, P. H. Kahn, and J. Hagman, "Hardware companions?—What online AIBO discussion forums reveal about the human–robotic relationship," *Proceedings of the CHI 2003 Conference on Human Factors in Computing Systems. New York: ACM*, 2003.

[18] S. Turkle, W. Taggart, C. D. Kidd, and O. Dasté, "Relational artifacts with children and elders: the complexities of cybercompanionship," *Connection Science*, vol. 18, pp. 347-361, 2006.

[19] LIREC, *http://www.lirec.org*, 2008.

[20] M. D. Klinnert, R. N. Emde, P. Butterfield, and J. J. Campos, "Social referencing: The infant's use of emotional signals from a friendly adult with mother present.," *Developmental Psychology*, vol. 22, pp. 427-432, 1986.

[22] K.L. Koay , D. S. Syrdal , M.L. Walters , and K. Dautenhahn . Living with Robots: Investigating the Habituation Effect in Participants? Preferences during a Longitudinal Human-Robot Interaction. *Proceedings of the IEEE International Symposium on Robot and Human Interactive Communication (Ro-Man 2078,* Jeju Island, Korea, 26-29 August 200, 564-569.

[22] D. S. Syrdal, N. R. Otero, and K. Dautenhahn, "Video Prototyping in Human-Robot Interaction: Results from a Qualitative Study," *Proceedings of the 2008 European Conference on Cognitive Ergonomics*, 2008.

[23] A. Light, "Adding method to meaning: A Technique for exploring peoples' experiences with technology," *Behaviour & Information Technology*, vol. 25, pp. 175-187, 2006.

[24] N. Pidgeon and K. Henwood, "Using grounded theory in psychological research," in *Doing Qualitative Analysis in Psychology*, N. Hayes, Ed. London: Psychology Press, 1997, pp. 245-274.

[25] J.-Y. Sung, R. E. Grinter, H. I. Christensen, and L. Guo, "Housewives or technophiles? understanding domestic robot owners," in *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction*. Amsterdam, The Netherlands: ACM, 2008.

[26] Grudin, J. & Pruitt, J . Personas, participatory design, and product development: An infrastructure for engagement. *Proc. PDC 2002,* 144—161, 2002

[27] A.R. Chatley, K.Dautenhahn, M.L. Walters, D.S. Syrdal and B. Christianson. Theatre as a discussion tool in human-hobot interaction experiments. *Proceedings The Third International Conference on Advances in Computer-Human Interactions ACHI 2010, February 10-16, 2010 - St. Maarten, Netherlands Antilles, IEEE Press, pages 73 – 78,* 2010

[28] M. Jacobsson, "Play, Belief and Stories about Robots: A Case Study of a Pleo Blogging Community," *Proceedings of the IEEE International Symposium on Robot and Human Interactive Communication (Ro-Man 2009)*, 2009.