LIVING WITH ROBOTS

INVESTIGATING THE USER ACCEPTANCE OF SOCIAL ROBOTS IN DOMESTIC ENVIRONMENTS

Maartje de Graaf

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by

Maartje Margaretha Allegonda de Graaf

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DISSERTATION

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Maartje Margaretha Allegonda de Graaf

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in Gouda, The Netherlands

This dissertation has been approved by promotor **prof. dr. J.A.G.M. van Dijk** and assistant promotor **dr. S. Ben Allouch**.

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PART I

GENERAL INTRODUCTION

1

INTRODUCTION

"All glory comes from daring to begin. Let's do just that."

— Eugene F. Ware —

When you are at work, a robot does your laundry, vacuums your living room, and prepares dinner for your family. It picks up your children from school and takes care of them until you come home. Although this may sound like science fiction, such scenarios are become increasingly more realistic as we speak. Many sources indicate that, today, people have busier lives than ever before with increasingly less time to spend with family and friends (e.g., Lin, 2011; Pelletier & Laska, 2012). Social robots that take over certain household chores could especially relieve families where both parents are working. However, the development of the increasing presence of robots in our everyday lives will not simply be accepted without reservation on the part of human users. Research in robotics suggests that the mere presence of robots in everyday life does not automatically increase the acceptance of these robots and the willingness to interact with them (Bartneck et al., 2005). A challenge for the success of social robots is their acceptance by future users. Furthermore, the inclusion of future users at the early stages of design is important for developing socially robust, rather than merely acceptable, robotic technologies (Sabanovic, 2010). The question is: Are people willing to accept social robots to live within their personal home environments?

1.1 THE RISE OF SOCIAL ROBOTS

The field of robotics is rapidly advancing. In 2013, approximately 4 million service robots for personal and domestic use were sold worldwide, and the number is expected to increase to 31 million units by the end of 2017 (International Federation of Robotics, 2014). The economic prospects for robotics markets are rapidly expanding. Internationally, success stories are seen at the US enterprise iRobot, which, in addition to the introduction of the successful Roomba vacuum cleaner, is applying various robot technologies for service and defense. Bill Gates (2007) has observed that, with robots becoming pervasive in our society, the field of robotics stands at the precipice of the same emergence that the personal computer business did at the end of the last century. As a key architect in the computer industry, his prediction carries special weight, and his vision is believed to be shared by many experts in the field of robotics (Lin, Abney, & Bekey, 2012). In a few decades, robots in society will be as ubiquitous as personal computers are today. These predictions raise both scientific and technological challenges as well as economic opportunities for our society.

There are a growing number of different types of robots, and their roles within society are expanding. Currently, robots are mostly used for tasks that are perceived by humans as dirty, dangerous or dull (Takayama, Ju, & Nass, 2008). Automated machines are already welding car parts in factories, harvesting lettuce on farms, exploring space, and saving lives as search-and-rescue robots. Not only are robots becoming capable of taking on more delicate and intricate tasks, but they are also increasingly adaptable and capable of operating in chaotic conditions and working alongside humans. Simultaneously, the cost of robots is declining. As the capabilities of robots develop, the possibility arises that they will be able to perform more and more difficult tasks and become our full-fledged team members, assistants, guides, and companions in the not-so-distant future.

Already today, there are some commercially available social robots for home applications, such as Paro, Pleo and Autom. Paro, the baby seal robot, comforts its (mainly older) users by responding to petting and cuddling and even by responding to its name. Pleo, the baby dinosaur robot, elicits nurturance from its users by means of its need to be taken care of while it matures. Finally, Autom is a conversational health coach that helps its users to lose weight. However, the diffusion of social robots in society to date is at its very earliest stages.

Yet, why should technologies interact socially with us? A common belief in human-robot interaction research is that natural and fluent interactions with robots increase their acceptance by human users (Breazeal, 2002). However, the level of sociability needed depends on the specific application domain, in addition to its requirements for social skills and the nature and frequency of contact with human users (Dautenhahn, 2003). Social robots are important for domains in which robots must exhibit social interaction skills, such as the home environment (Fong, Nourbakhsh, & Dautenhahn, 2003), or when aiming for long-term interactions (Castellano et al., 2009). This is either because, in the case of so-called socially assistive robots, such social skills are required for the execution of specific tasks or because, in the case of so-called companion robots, the primary function of the robot is to interact socially with people. Rather than forcing people to learn a programming language to control technologies, these technologies could learn to understand our language or interaction behavior instead. This will make it possible for everyone to use these technologies for numerous tasks.

1.2 THE RELEVANCE OF COMMUNICATION SCIENCE FOR HUMAN-ROBOT INTERACTION RESEARCH

Human-robot interaction is a research field that addresses the manner in which people can work, play and generally interact with robots and how robots can be best enabled to work together with humans in an acceptable manner. With the rise of social robots, where their presence in our everyday society continues to be more evident, it is increasingly important to understand the psychology of human-robot interactions by studying the perceptions and acceptance of these robots in natural environments. Designing robots to act socially means understanding ourselves and thus understanding how people interact socially with each other. Communication science is a research field that studies human-human interactions and behaviors. Social robots are being designed to satisfy different human needs as our servants and assistants, performing tasks that up to now were reserved for humans (Levy, 2008). Studying human-robot interactions from a communication science perspective helps robotics designers to improve robots' social interactions and increase their acceptance by potential future users.

Reviews on current human-robot interaction research reveal that there are shortcomings in the way that most studies are conducted. The lack of standard approaches to conducting reliable and valid studies makes it difficult to accumulate scientific results and build a strong research field. Most human-robot interaction studies draw conclusions from relatively small sample sizes, which may affect the results (Bethel & Murphy, 2010) due to the possibility of suffering from sample group selection bias and the lack of statistical power (Broekens et al., 2009). Larger sample sizes enable the discovery of smaller effects with significance. Thus, determining the appropriate sample size required to obtain statistically significant results is desired.

Furthermore, a standard approach to address issues in human-robot interaction research is to conduct experiments. However, most of the experimental designs in human-robot interaction often lack control groups (Broekens et al., 2009), which are necessary to interpret the effects of the stimulus. Additionally, most human-robot interaction studies only use self-assessment as the method of research (Bethel & Murphy, 2010). However, there are more appropriate methods available, such as qualitative measures, behavioral measures, psychophysiological measures, and task performance metrics, for studying human-robot interaction and the acceptance of robots by users. Furthermore, these short-term experiments often seem to focus on testing the technical operation of (parts of) the robotic system without investigating whether potential users actually want the technical features that are being tested. In conclusion, the fields of human-robot interaction research should be enriched with a wider variety of research methods or even a triangulation of methods, which is a more common approach in communication science.

Human-robot interaction studies are often short-term studies. Long-term studies are still scarce because almost all studies are typically no longer than one day (e.g., Bartneck et al., 2007a; Bartneck, Reichenbach, & Carpenter, 2008; Heerink et al., 2007; Nomura et al., 2008; Wada & Shibata, 2006). As a consequence, not much is currently known about the factors that influence the acceptance and continued use of social robots in everyday life (Oydele, Hong, & Minor, 2007). Yet, people's perceptions of technologies are likely to change over time as they develop experiences with those technologies and their usage skills develop (Fink et al., 2013; Sung et al., 2009; Venkatesh & Davis, 2000). Thus, longitudinal studies are necessary to investigate how users' perceptions towards robots, their behaviors and their experiences change over time.

Finally, there seems to be a strong focus on performing research on new and undiscovered research angles (Broekens et al., 2009). However, replication studies are needed before a finding can be accepted as well-established. Findings obtained in one study may not hold true in another study involving different researchers, new participants, and other contexts. Replication studies are vital for any field of science because they help make it a self-correcting system.

I argue that evaluating peoples' perceptions and behaviors in the process of the long-term user acceptance of social robots in real-world contexts is necessary for assessing and intertwining the various social, scientific and technological concerns that are relevant for designing acceptable social robots for domestic purposes. The ultimate test of robots consists of showing their capacities in an open social environment in which robots must work constantly and autonomously. Through understanding how people perceive and accept social robots in their own private social and physical environments, it will be possible to design socially interactive robots (Fong, Nourbakhsh, & Dautenhahn, 2003) for which social interaction plays a key role in peer-to-peer human-robot interaction. Evaluations of people's perceptions and acceptance of social robots can be utilized to create new theoretical and practical models of appropriate social robot behavior and design.

1.3 BUILDING UPON THE SERA PROJECT

The research in this dissertation aims to further build on the findings from the EU-funded Social Engagement with Robots and Agents (SERA) project, which was carried out between 2009 and 2011. Its aim was to advance science in the field of the social acceptability of verbally interactive robots and agents, with a view to their applications, especially in assistive technologies, such as robot companions and virtual assistants. To achieve this goal, the project undertook a field study with three ten-day iterations to collect data on real-life interactions with robotic devices within people's own homes. The three iterations tested the different conditions (functionalities) of the equipment, which consisted of a computer, sensors and a simple robotic device (the Nabaztag) as the front-end for conversational interaction. The scenario of the field study was based on health- and fitness-related applications.

The interviews obtained during the SERA project showed that social robot acceptance somewhat follows the process indicated by domestication theory (Silverstone & Haddon, 1996). However, it was concluded that not all participants completely reached a state of sustained use, in which a technology is integrated into a person's everyday life and the initial adoption is reaffirmed. It could be that the successful acceptance of social robots depends on the user's perception of these robots (Young et al., 2007). Another explanation is that the separate iterations in the SERA project did not provide enough time for the participants to reach a state of sustained use. Some roboticists argue that longitudinal studies need to last for at least two months when one aims to observe sustained use beyond the novelty effect (Sung et al., 2009). Therefore, the research in this dissertation aims to investigate the existence of different phases of technology acceptance and to determine whether and how a longer, uninterrupted period of use of a social robot in a domestic environment affects the long-term acceptance of social robots.

Furthermore, the participants in the SERA project evaluated the robot more positively after each iteration. This is called a mere-exposure effect, which is the tendency to evaluate novel stimuli more positively after repeated exposure. When people use technologies for a longer period of time, they are more willing to ignore the shortcomings of that technology because of factors such as habitual use and familiarity (Silverstone & Haddon, 1996). Therefore, the research in this dissertation aims to investigate when, how and why users' evaluations of social robots change over time during their use in the home.

Additionally, the results from the SERA project indicated that hedonic social interactions seem to be the most important for the acceptance of social robots in the home. This finding is contrary to most former technology acceptance research, which stresses the central role of usefulness as determining user acceptance (Lee, Kozar, & Larson, 2003). One explanation could be that usefulness does not have the same function as in earlier technology acceptance research where the investigated technologies are of a utilitarian nature. When the purpose of the robot is to be social, it could be that people tend to focus on other aspects of the robot. Another explanation could be that the participants talked more about the social capabilities of the robot, instead of its usefulness, simply because social interactions are a more interesting topic to talk about. Nonetheless, despite the greater attention to the hedonic factors, the utilitarian factor of usefulness seems to be a fundamental basis for engaging in long-term use with a social robot. The importance of practical utility is also stressed by Fink et al. (2013), who reported that people who did not perceive the robot to be useful stopped using it after some initial trials. Therefore, this dissertation focuses on both the utilitarian and the hedonic variables that can influence social robot acceptance.

Furthermore, the stories of participants from the SERA project indicated that the importance of the use context increased over time, with a special focus on the increase of social influence and situational factors. In addition, evaluations of contextual factors of privacy, trust, and perceived behavioral control seem to influence the continued use of social robots. The older adults in this study who evaluated these contextual factors negatively would not have continued the use of the social robot after our study if they had been allowed. It also seems that these variables could be related to each other. Participants who evaluated one of these aspects as negative were more likely to evaluate the other aspects as negative as well. Thus, in addition to variables related to the robot, the research undertaken in this dissertation also addresses the use context and aims to further deepen our understanding of the influence of these contextual aspects on the long-term acceptance of social robots.

Finally, the SERA project pointed to the possibility of establishing human-robot relationships. The results indicated that hedonic factors exert greater influence than utilitarian factors on whether people build a relationship with social robots. Perceiving a social presence while interacting with the robot and appreciating the sociability of the robot especially seemed to explain whether participants treated the robot as a companion. An earlier study also reported that a higher appreciation of robot sociability resulted in more intense social responses towards it (Baddoura & Venture, 2013). Given that research into human-robot relationships is a fairly new field, this dissertation aims to provide some initial further insights into this phenomenon.

1.4 SCOPE OF THE DISSERTATION

It is important to make a distinction between the concepts of technology adoption and technology acceptance. Here, technology adoption is regarded as the initial decision to buy and start using a technology. In contrast, technology acceptance is a process that starts with an individual becoming aware of a technology and, ideally, ends with that individual embracing the technology and incorporating its use in his or her everyday life. This dissertation provides a framework for the process of technology acceptance and defines six phases for this long-term process in chapter 6.

The studies presented in this dissertation adopt a user-centered perspective. Although we acknowledge that the behavior and appearance of the robot affects the user's experience, this dissertation focuses on how people react to and interpret a robot's appearance and behavior, regardless of what the robot's behavior or the cognitive processes inside the robot entail. Especially during the 1990s, the role of users has been increasingly addressed within the technology acceptance literature, which argues for the recognition of active users and important actors in shaping technology (Silverstone & Hirsch, 1992; Lie & Sørenson, 1996). By including the user, an attempt is made to overcome the problems associated with approaches that focus on the actors who produce the technologies, such as scientists, engineers, politicians, financers and marketers (Wyatt, Thomas, & Terranova, 2002). It is vital to involve prospective users as active testers in the design process. Their opinions and perceptions help researchers, designers, and engineers to create social robots that fit the special needs and demands of potential future users.

The research undertaken for this dissertation is conducted in home environments. The home environment is defined as any place where people reside in their everyday lives, including living rooms, kitchens and gardens (Iocchi, Ruiz-del-Solar, & van der Zant, 2012). Although social robots are also expected to appear in other contexts, such as health care and education, these contexts are beyond the scope of this dissertation. With the rise of social robots in society and the growing number of commercially available robots for domestic purposes, it becomes increasingly important to study how and why people accept these robots into their personal home environments. Yet, systematic research on human-robot interactions within home settings, especially long-term studies, is still scarce. Therefore, this dissertation focuses on the long-term use of social robots in home environments.

Despite our focus on social robot acceptance in the home, which may imply the collective acceptance of the complete household, the starting point of this dissertation is the acceptance behavior of the individual user. Nevertheless, as will be discussed in part II and part III, this dissertation considers the social context of acceptance behavior by including normative beliefs. However, the evaluation of these normative beliefs is viewed from the perspective of the individual user.

Finally, although addressing such issues in a thorough manner is beyond the scope of this dissertation, robotics researchers need to address legal, societal and ethical issues before robots become widespread within our society. Not only should researchers focus on preventing ‘bad’ things from happening, but they also need to investigate the social roles that robots can (not) or should (not) perform in the future according to the opinions of potential future users. When ordinary people start using autonomous technologies, such as robots, in their everyday lives, robotics researchers need to map all possible interaction scenarios and their potential consequences for both individual users and society as a whole. If the rise of robotics is similar to that of personal computers a few decades ago, we can expect some important legal, societal and ethical issues to emerge from robotics as well. Therefore, robotics researchers need to attend to these issues if we want to anticipate the potential (negative) consequences of the ubiquitous use of robots in our society.

However, addressing these legal, societal and ethical issues cannot be done thoroughly without real empirical data on the relationship between human users and robots. The common presumption is that robots will become ubiquitous in our societies and that it is inevitable that everyone will be using a social robot in their own homes within the not-so-distant future (Gates, 2007; Lin, Abney, & Bekey, 2012). Yet, will people readily accept social robots in their everyday lives? Are they prepared to handle social robots on a daily basis? Are they capable of establishing social relationships with social robots? Research on people's interactions with and social reactions towards social robots is necessary to shape the ethical perspectives on these issues. By understanding people's acceptance of robots and their potential roles in society, robotics researchers can more effectively address their research efforts towards the successful introduction of robots into our society.

1.5 GOAL, RESEARCH QUESTIONS AND OUTLINE

This dissertation addresses the long-term user acceptance of social robots in domestic environments. The starting point of the research presented here is building further on the findings from the EU-funded Social Engagement with Robots and Agents (SERA) project. The results of the SERA project have indicated that there are multiple variables related to robots and the use context that may affect the acceptance of social robots, and their influence seems to fluctuate over time. Furthermore, the results have shown that there may be different phases in the process of acceptance but that the separate iterations may have disturbed that process for the participants. Finally, the results of the SERA project point to the possibility for users to establish some type of relationship with robots. To further build on these findings, two main research questions are formulated for the current research in this dissertation:

RQ_a: *Which acceptance variables in which phase of acceptance are the most Important determinants of social robot acceptance in domestic environments?*

RQ_b: *How do users assess their willingness to treat robots as companions before and after the adoption of a social robot?*

Together, these two research questions shape the research presented in this dissertation and resulted in the following goal of this dissertation, which is threefold: (1) providing insight into which variables mostly influence the acceptance of social robots in domestic environments; (2) investigating how people's user experiences with a social robot develop over time; and (3) presenting some first insights into the variables that explain why some people are willing to treat robots as companions. To achieve these three goals and guide the research process, this dissertation is divided into five parts, with the associated underlying research questions. The contents of these five parts and the underlying research questions are discussed below.

The present part (part I) contains the general introduction to this dissertation. In addition to introducing the research background, the rationale and the outline of this dissertation (this chapter), chapter 2 provides a definition for social robots. Before further investigating this topic, the conceptualization of social robots should be clear. This requires a comparison of the existing terminology used in the literature to demonstrate the existing common ground shared by these definitions and indicate what type of characteristics make a robot become social. Chapter 2 addresses RQ_1 and provides a definition for social robots based on both the literature and user descriptions, and argues that social robots are a new technological genre.

RQ_1: *How can social robots be defined conceptually?*

Part II of this dissertation is called adoption because it ends with testing a conceptual model of the anticipated acceptance of social robots. To have a proper understanding of social robot acceptance, one needs insights into the potential underlying factors regarding users' technology acceptance behavior. Therefore, chapter 3 takes the broader view of the full process of acceptance and addresses RQ_2 by providing an overview of existing theories on human behavior in general and technology acceptance in particular to gain insight into the concepts related to social robot acceptance.

RQ_2: *What theoretical insights can be derived from a review of the existing variables, from a user's perspective, that influence the process of social robot acceptance in domestic environments?*

Drawing upon the theoretical foundation established in chapter 3, chapter 4 provides a comprehensive overview of the acceptance variables from multiple research disciplines that have been shown to play a role in the acceptance of technology generally and robots or virtual agents specifically. These acceptance variables are presented as a conceptual model of social robot acceptance guided by RQ_3.

RQ_3: *Which variables, from a user's perspective, influence the initial adoption and sustained use of social robots in domestic environments, and how can these be modeled in a conceptual model of social robot acceptance?*

As a final chapter in Part II, chapter 5 empirically tests the conceptual model of social robot acceptance as addressed by RQ_4. Given that the diffusion of social robots within society only exists in its very earliest stages to date, an online survey was administered to investigate the anticipated acceptance of social robots in domestic environments based on three possible future use scenarios of social robots in home environments.

RQ_4: *Which variables from the conceptual model of social robot acceptance are most important in the anticipated acceptance of social robots in domestic environments, and how do these variables relate to each other?*

Part III of this dissertation focuses on the process of long-term acceptance, which starts with an individual becoming aware of a technology and, ideally, ends with that individual embracing the technology and incorporating its use in his or her everyday life. Chapter 6 defines the different phases in the process of long-term acceptance and denotes that acceptance is a broader concept than adoption, which is considered to be a phase within the broader process of acceptance. Chapter 6 ends with an outline of the research design of the long-term home study. Following the defined acceptance phases, chapter 7 presents the qualitative results of the acceptance experiences in each phase from the participants in the long-term home study, including the experiences from both users and non-users. These insights provide an answer to RQ_5.

RQ_5: *How do people's user experiences with a social robot in their own homes evolve in a process of long-term acceptance?*

Chapter 8 completes part III by addressing RQ_{6a} and RQ_{6b} with the presentation of the participants' evaluations of the acceptance variables over time and the fluctuations of the influences of these acceptance variables on social robot acceptance from phase to phase.

RQ_{6a}: *How does the assessment of the acceptance variables for a social robot evolve in a process of long-term acceptance in the context of domestic use?*

RQ_{6b}: *How does the influence of the acceptance variables for a social robot evolve in a process of long-term acceptance in the context of domestic use?*

Part IV focuses on the bonding and attachment effects that result from using a social robot in home environments. In the future, robots are expected to serve humans in various social roles, such as companions, coaches, educators, nurses, and user interfaces for smart homes. The socially interactive components of these social robots, in addition to their functional requirements, may foster the formation of human-robot relationships. Chapter 9 provides an answer to RQ_7, exploring the foundations of the human need to socially connect with others and providing insights into the one-sided relationships people can build with television personas (i.e., parasocial relationships) and objects as well as robots.

RQ_7: *What can the existing scientific knowledge on human friendship formation, attachment to objects and parasocial relationships tell us about the possibility of establishing human-robot relationships?*

Scientific evidence shows that people respond to robots in a way that is similar to how they respond to other people. Given that the exploration of human-robot relationships is a fairly new field of research, Chapter 10 attempts to provide some initial insights into the influential variables for human-robot relationships based on the existing knowledge on human-human friendship formation, which provides an answer to RQ_8.

RQ_8: *Which influential variables for human friendship formation may explain people's willingness to treat social robots as companions?*

This dissertation concludes with two chapters (i.e., chapter 11 and 12) that form part V and constitute the main conclusions and general discussion of the overall results gathered in this dissertation.

1.6 METHODOLOGICAL CONSIDERATIONS

The aforementioned research questions and goals are addressed by conducting several studies of different types and using a variety of methods and techniques. The specific research methods and designs are presented before discussing the results of the respective studies. The following table (table 1.1) provides an overview of the studies presented in this dissertation.

Table 1.1: Overview of the studies presented in this dissertation

Study	Used Robot	Setting	Duration	Methods	Participants	Focus
Robotic Appearances Study	Several	Virtual	30 minutes	Questionnaire	Prospective users (n= 175)	Evaluation of robot appearances
Acceptance Survey	Several	Virtual	20 minutes	Questionnaire	Dutch population	Anticipated acceptance
Karotz Home Study	Karotz	Domestic	6 months	Questionnaire	168 people in 70 households	Long-term acceptance
				Interviews		User experiences
Pleo Study	Pleo	Laboratory	30 minutes	Questionnaire	Students (n= 86)	Human-robot relationships

2

DEFINING SOCIAL ROBOTS

"Robots are a new form of living glue between our physical world and the digital universe we have created."
– Illah Reza Nourbakhsh –

The aim of social robotics research is to build a robot that can engage in social interaction scenarios with humans in a natural, familiar, efficient, and above all intuitive manner. Robots build for the domestic environment can be used for household chores, assistance purposes, security tasks, entertainment functions, and educational goals. The manner in which people interact with robots appear to be fundamentally different from how they interact with most other technologies. People tend to ascribe a level of intelligence and sociability to robots that influences their perceptions of how the interactions should proceed. This chapter will provide a definition of social robots, based on both literature and user descriptions, and will further determine social robots as a new technological genre. Parts of the results presented in section 2.4 have been published before in:

Graaf, M.M.A. de, & Ben Allouch, S. (2014). Users' preferences of robots for domestic use. *Poster presented at the International Conference on Human-Robot Interaction, Bielefeld, Germany*.

2.1 DEFINITIONS OF SOCIAL ROBOTS

Although the development of robotic technology has started in the mid-20th century, robot-like behavior and its implications for humans have been around for centuries in religion, mythology, philosophy, and fiction (Goodrich & Schultz, 2007). The word 'robot' originates from the Czechoslovakian word 'robota' which means 'work' (Webster's Dictionary). The multidisciplinary field of human-robot interaction started to emerge in the mid-1990s and early years of the 21th century, however, the niche of social robotics and the involvement of the user's perspective into the evaluation of these robots have been initiated much later (Goodrich & Schultz, 2007). Only recently, robots have become robust enough to be introduced into the user's domestic environment (Ferneaus et al., 2010), which is the user context this dissertation is focusing on. Young, Hawkins, Sharlin, and Igarashi (2007) define a domestic robot as "a machine that (a) is designed to work with individuals and groups in their personal and public spaces, (b) has a dynamic spatial presence in those spaces, and (c) can ‘intelligently’ interpret its environment and interact physically with it” (p. 5). This definition does not require robots to resemble humans, to be mobile, or to communicate using natural verbal language. However, this definition leaves potential social interaction with human users unspecified, which allows the inclusion of non-sociable robots such as robot vacuum cleaners. But what are social robots exactly?

Examining the different definitions provided in the literature, there seems to be consensus that social robots are those robots capable of socially communicating in a humanlike manner (Breazeal, 2002; Dautenhahn, 2002; Duffy, 2003; Kirby, Forlizzi, & Simmons, 2010; Leite, Martinho, Pereira, & Paiva, 2008; Looije, Neerinckx, & de Lange, 2008). However, a description of what communicating in a ‘humanlike manner’ means often remains unspecified. Bartneck and Forlizzi (2004a) have given a more encompassing definition and specify that social robots interact socially by following the rules of behaviors expected by those people with whom the robot is designed to interact with. However, social robots existing today are still far away from being capable to incorporate human social behavior (see section 2.2 for a more detailed discussion on this topic). It is believed here that it actually are the human users who apply the social rules of human behaviors in their interactions with robots, and not the other way around as suggested by the definition of Bartneck and Forlizzi (2004a).

Another definition is given by Lee, Park and Song (2005) who state that social robots are designed to evoke meaningful social interaction through commands of natural verbal and nonverbal communication modalities (e.g., speech, gestures and artificial intelligence), and interact with users who actually manifest certain types of social responses (e.g., bonding with robots, ontological perception of robots as social actors, and expectations and applications of complicated social rules in human-robot interaction). This definition of Lee, Park and Song (2005) not only specifies several ways of social interaction, but also acknowledges that robots are essentially not social by speaking in terms of ‘evoking meaningful interactions’.

This dissertation combines parts of the definitions of Lee, Park and Song (2005) and Bartneck and Forlizzi (2004a) by defining social robots as those robots that simulate social interactions because they are programmed in such a manner to stimulate the human users to apply social rules of human behavior in the interactions.

Because social robots among themselves can be quite different from each other, the following sections provide three tools which can be used to distinguish social robots based on either their social intelligence, their appearance or their functional clarity. When making general conclusions and discuss their implications, this dissertation will mainly focus on the classifications of appearance combined with the classification of social intelligence.

CLASSIFICATION BASED ON SOCIAL INTELLIGENCE

Breazeal (2003) makes classifications of social robots in terms of: (1) how well the robot can support the social model that is ascribed to it; and (2) the complexity of the interaction scenario that can be supported. She defines four classes of robots. Socially evocative robots rely on the human tendency to anthropomorphize and capitalize on feelings evoked when humans nurture, care, or get involved with objects. Social interface robots provide a 'natural' interface by employing humanlike social cues and communicate modalities, whereas the social behavior only occurs at the interface level resulting in shallow models of social cognition. Socially receptive robots can learn from interaction by imitation, requiring deeper models of human social competencies. Sociable robots engage pro-actively with humans in order to satisfy internal social aims, requiring deep models of social cognition. Fong, Nourbakhsh, & Dautenhahn (2003) add three complementary classes to this list. Socially situated robots perceive and react to their social environment, enabling them to distinguish between other social agents and various objects in the environment. Socially embedded robots interact with their environment and other agents and humans, are structurally coupled with their social environment, and are at least partially aware of human interactional structures. Socially intelligent robots show aspects of human style social intelligence, based on deep models of human cognition and social competence.

DOMAINS OF HUMAN-ROBOT INTERACTION RESEARCH

The above list shows the diversity of the classification of a robot's social intelligence which depends on the particular research domain. Approaches to social interactions with robots can be grouped into three, not mutually exclusive, domains of human-robot interaction: robot-centered, human-centered and robot cognition-centered domain (Dautenhahn, 2007). Robot-centered human-robot interaction perceives robots as autonomous entities that are pursuing their own goals based on their motivations, drivers and emotions, whereby interaction with people serves to fulfill some of its 'needs' (as identified by the robot designer and modeled by the internal control architecture). Research in this domain is focused on the social needs to be fulfilled in the interaction itself, such as surviving the environment and fulfilling internal needs. Robot cognition-centered human-robot interaction sees robots as intelligent systems that make decisions on their own. Robots solve encountered problems as part of the tasks they must perform in a particular application domain. Research in this domain focuses on the development of cognitive robot architectures, machine learning and problem solving. Human-centered human-robot interaction concerns how robots can fulfill their tasks in an acceptable and comfortable for their human users. Research in this domain is focused on how people react to and interpret a robot's appearance and behavior, no matter what the robot's behavior or cognitive processes inside the robot entails.

Dautenhahn (2007) has placed Breazeal's (2003) classifications of social robots within the domain triangle of human-robot interaction research (see figure 2.1). Socially evocative robots (A) are placed at the extreme end of the human-centered domain where robots are defined by the responses they elicit from their human users. Here, the robot's appearance or behavior is irrelevant as long as it elicits certain human responses. Socially situated robots (B) are related to the robot-centered view, but less than the sociable robots. Although these robots are able to interact with their social environment, they do not must possess any model of social intelligence. Here, the robot's social interactions emerge from the robot being situated in and responding to its environment. Sociable robots (C) are placed in the extreme end of the robot-centered domain where robots are defined as sociable machine that engages in interactions for the purpose of fulfilling its own internal needs, and cognitive skills and human responses are determined by the robot's needs and goals (Breazeal 2004). Socially intelligent robots (D) require all three domains of human-robot interaction because its models of social cognition and interaction competence are inspired by human-human interpersonal interactions by simulating human social intelligence. These types of robots behave, communicate and interact similarly to humans, and the manner in which humans users perceive and respond to these robots is as equally important as its modalities are similar to humans. Socially interactive robots (E) are placed at the extreme end of the robot-cognitive domain where robots are defined by the variety of interaction skills guided by the appropriate control and cognitive architecture. Although internal motivations and the response of the human user is important, here the main emphasis lies on the robot's ability to engage in social interactions.

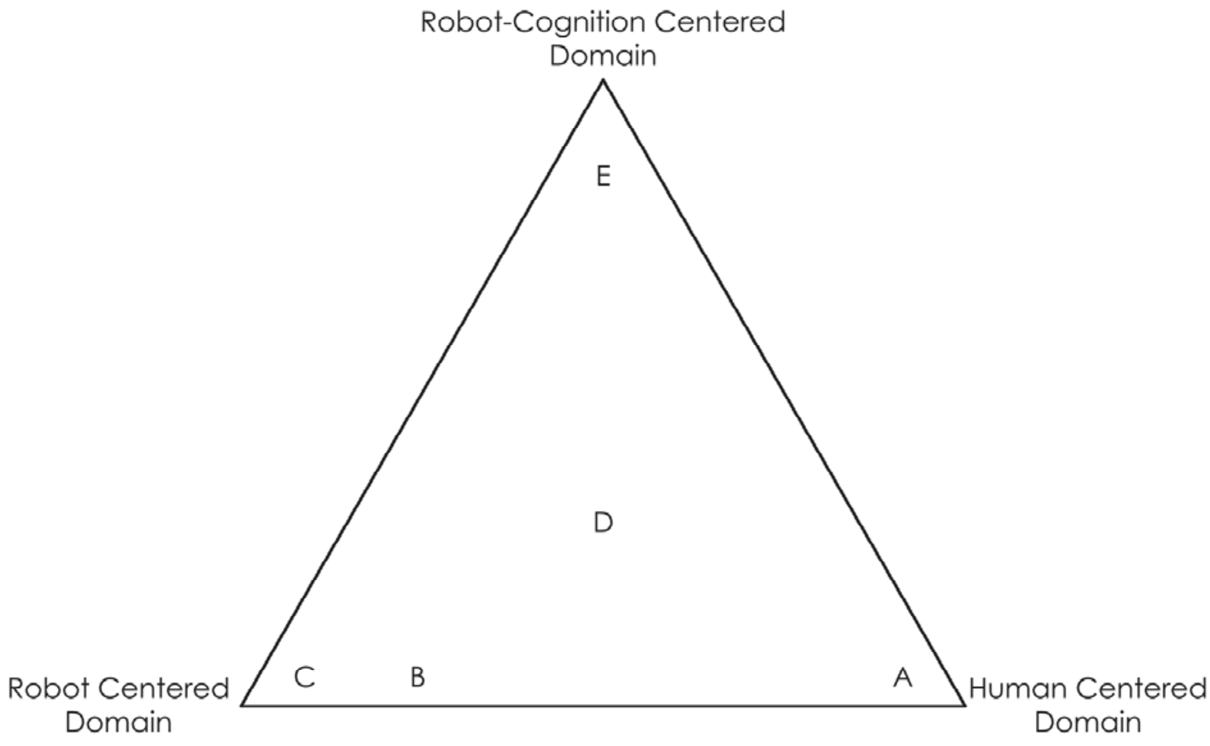

Figure 2.1: The domain triangle of HRI research (adopted from Dautenhahn, 2007)
Note: A= socially evocative robots; B= socially situated robots;
C= sociable robots; D= socially intelligent robots; E= socially interactive robots

This dissertation takes the human centered view on social robotics. Although it is acknowledged that the appearance and functionality of a robot influences its evaluation by human users, the several studies reported in this dissertation emphasize on people's reactions to and evaluations of social robots without focusing on robot's behavior or cognitive processes inside the robot. Similar to how the definition of social robots addressed in this dissertation, social robots are defined by the evoked responses from the human users.

CLASSIFICATION BASED ON APPEARANCE

Another classification of social robot has been done based on the robot's appearance in four broad categories: anthropomorphic, zoomorphic, caricatured, and functional (Fong, Nourbakhsh, & Dautenhahn, 2003).

HUMANOID ROBOTS

Anthropomorphic robots are in fact humanoid or human-shaped robots. Anthropomorphism is based on what developmental psychologists call the "Theory of Mind", which is the human ability to impute a mental state to others (Whiten, 1991). Anthropomorphism is a tendency to regard and describe objects, animals, and even natural phenomenon in human terms, attributing human characteristics to them with the intention of rationalizing their actions (Duffy, 2003). By anthropomorphizing natural phenomenon, we simplifying the world around us to make sense of our environment by projecting a host of expectations about human life onto aspects of that environment (Persson et al., 2000). Earlier finding have shown that people are not only anthropomorphizing humanlike robots (e.g., Kuchenbrandt et al., 2011; Salem et al., 2011), but also non-humanoid robots (e.g., Friedman, Kahn, & Hagman, 2003; Kerepesi et al., 2006) and other kinds of autonomously moving objects and phenomenon such as computers (e.g., Nass & Moon, 2000), religious figures such as god (e.g., Barrett & Keil, 1996), and geometric shapes (e.g., Heider & Simmel, 1944). Therefore, the category of anthropomorphic robots defined by Fong, Nourbakhsh, & Dautenhahn, 2003) will therefore labeled in this dissertation as humanoid robots. Having a humanoid appearance is often argued for as a necessity for meaningful social interaction by other researchers (Fong, et al., 2003). Main argument is that for interaction with humans based on their interaction modalities robots must be structured, function and behave similar to humans. Examples of humanoid robots are very realistic Geminoid robots (Dougherty & Scharfe, 2011; Nishio, Ishiguro, & Hagita, 2007), iCub (Sandini, Metta, & Vernon, 2004), Jules from Hanson Robotics, and Albert Hubo (Oh et al., 2006).

ZOOMORPHIC ROBOTS

Zoomorphic robots exhibit characteristics that users associate with domestic animals and are designed to imitate living creatures (Fong, et al., 2003). Such robots may benefit from the mechanisms behind the establishment of human-creature or owner-pet relationships, because people te behave similarly around zoomorphic robots like they do around pets (Friedman, Kahn, & Hagman, 2003; Kerepesi et al., 2006). Moreover, it will be easier to avoid the uncanny valley (i.e., the eeriness experienced by human users when a robot looks and behaves almost, but not exactly, as human beings), because human-creature relationships are simpler than human-human relationships and the users' expectations of what constitutes 'realistic' animal morphology tends to be lower than those of human morphology (Fong, Nourbakhsh, & Dautenhahn, 2003). Examples of zoomorphic robots are Paro (Kidd, Taggart, & Turkle, 2006; Shibata et al., 2012; Wada & Shibata, 2006; Wada & Shibata, 2007), iCat (van Breemen, Yan, & Meerbeek, 2005; Leite et al., 2014), AIBO (Bartneck, Reichenbach, & Carpenter, 2008; Banks, Willoughby, & Banks, 2008; Friedman, Kahn, & Hagman, 2003; Weiss, Wurhofer, & Tscheligi, 2009), Sparky (Scheeff et al., 2002), Nabaztag and its successor Karotz (Eimler, Krämer, & von der Pütten, 2011; de Graaf, Ben Allouch, & Klamer, 2015; de Graaf, Ben Allouch, & van Dijk, 2014; Klamer, Ben Allouch, & Heylen, 2010), and Pleo (de Graaf & Ben Allouch, 2014; Fernaeus et al., 2010; Jacobsson, 2009; Rosenthal - von der Pütten et al., 2013). The studies reported in this dissertation are mainly conducted using a zoomorphic robot.

CARICATURED ROBOTS

Caricatured robots are not realistically human-shaped robots. Animators have long shown that cartoon characters do not necessarily must appear realistic in order to be believable (Thomas & Johnston, 1981). Similar rules may apply to robots as well and the application of techniques from traditional animation for robotic design have already been discussed (Scheef et al., 2002). Caricatured robots can be used to create desired interaction biases and to specifically focus attention on, or distract attention from specific robot features (Fong, Nourbakhsh, & Dautenhahn, 2003). Examples of caricatured robots are Keepon (Kozima & Michalowski, 2009), Papero (Osada, Ohnaka, & Sato, 2006), Pearl and its preliminary model FLO (Baltus, et al., 2000; Goetz, Kiesler, & Powers, 2003; Montemerlo et al., 2002; Pineau et al., 2002), Robovie (Ishiguro et al., 2001; Kahn et al., 2012; Kanda et al., 2004), Robota (Robins et al., 2004), ASIMO (Mutlu, Forlizzi, & Hodgins, 2006), and Kobian (Endo et al., 2008; Zecca et al., 2008).

FUNCTIONAL ROBOTS

In the case of functional robots, the appearance of a robot reflects the tasks it is intended to perform (Fong, Nourbakhsh, & Dautenhahn, 2003). The choice and design of physical features is thus guided purely by the role the robot has to fulfill. Examples of functional robots are Roomba (Forlizzi & DiSalvo, 2006; Jones, Lawson, & Mills, 2008; Sung et al., 2009), Packbot (Yamaughi, 2004), Cheetah (Rutishauser et al., 2008), PeopleBot (Dautenhahn et al., 2006; Woods et al., 2005), Lucas the library robot (Behan & O'Keeffee, 2008), and Roball (Salter, Werry, & Michaud, 2008). Although a robot's shape has an impact on the interactions with human users, all shapes have their own potentials.

CLASSIFICATION BASED ON FUNCTIONAL CLARITY

Another approach to classify robots is the toolset of classification ease. For the social acceptance of robots it is important for people to be able to easily classify these robots. Riek and Robinson (2008) hypothesize that when users can easily classify a robot's type, role, and behavioral function, they are more apt to feel comfortable with it, and thus will be more accepting of it. Classification ease is consistent with one of the core ideas in human-centered design, that technology acceptance is directly related to consistency with the users' mental models (Norman, 1988). It is also motivated by the cognitive dimensions framework (Green, 1989), with type classification corresponding with the perceptual mapping dimension (what the robot's physical appearance conveys), role classification with the role-expressiveness dimension (what role the robot presents), and behavioral classification with the closeness of mapping dimension (how the robot's behavior maps to its type and role).

2.2 WHAT MAKES A ROBOT SOCIAL?

Robots designed for purposes in domestic environments must operate in spaces specifically designed for humans. To ease the communication with its users, robots are designed to evoke social interactions following the rules of human social interaction behaviors. The common underlying assumption is that people prefer to interact with machines in a similar manner because they do with other human beings (Fong, Nourbakhsh, & Dautenhahn, 2003). According to Breazeal (2002), an ideal social robot is capable of communicating and interacting in a sociable way so that its users can understand the robot in the same social terms, to be able to relate to it and to empathize with it. Robotic researchers strive for the development of such sociable machines by making use of models and techniques generally used in human-human communication.

Yet, the social capabilities of today's robots are still limited. Simple human social skills can be quite challenging to program into the robot's software. Although a lot of research on the social behaviors of robots has been performed, they have not yet produced a complete set of robotic social behaviors for optimal social interaction with humans (Joosse, Sardar, Lohse, & Evers, 2013). However, an abundance of literature suggests the following critical social characteristics for robots to be perceived by their users as socially interactive: social learning and imitation, dialog, learning and developing social competencies, exhibit distinctive personality, establishing and maintaining social relationships (Fong, Nourbakhsh, & Dautenhahn, 2003; Mutlu, 2011).

This list of critical social characteristics is a list with characteristics of primitive simulation which social robots should ideally possess. Though, social robot prototypes existing today still lack important social skills and display only limited socially acceptable behaviors, which prevents these robots from engaging in truly natural interactions with their users (Castellano et al., 2009). Only when all of these criteria can be met, we can truly speak of social robots.

In the following sections, I will address these robotic capacities and explain what this means for optimal human social interaction with robots. However, I would like to point to the fact that robots themselves are not social. Robots can only simulate social behavior or behave in such a manner that is perceived by human users as social. The descriptions of the social behavior of robots provided by social robotics researchers in the upcoming sections assume that all the knowledge about human behavior and human emotions is already known. Yet, (social) psychology and communication science do not have full knowledge about all the aspects of how people behave, think and react. Empirically and theoretically, they are young disciplines of science. Therefore, in the following descriptions of social capacities I will observe actual behavior of social robots and where the social interpretations of the robot's behavior by the human user begins which are necessary for successful social interactions.

SOCIAL LEARNING AND IMITATION

For robots to behave socially, they must interpret and simulate human behavior. In social situated learning, one interacts with his social environment to acquire new competencies (Galef, 1988). Using socially situated learning, a robot is supposed to learn from its environment with which it interacts, including transferring skills, tasks and information, and imitation (Fong, Nourbakhsh, & Dautenhahn, 2003). In the future, robots could use socially situated learning to improve their communication, to facilitate interaction, and to share knowledge (Klingspor, Demiris, & Kaiser, 1997). However, it is almost impossible to program robots in such a manner, because socially situated learning presumes a high human cognition.

To overcome possible differences in sensing and perception between the robot and the human user, certain social robotics researchers suggest imitation. Imitation is an important mechanism for learning behaviors socially in primates and other animal species, which for robots depends upon having perceptual, cognitive, and motor capabilities (Dautenhahn & Nehaniv, 2001). For real-time body imitation a robot must simultaneously maintain its balance and imitate the motion demonstrated by a human (Gams, van den Kieboom, Dzeladini, Use, & IJspeert, accepted). Robots today are already capable of recognizing motions made by humans, learning this motion when unfamiliar with it and imitate the instructed motion by modifying a learned motion (Okuzawa, Kato, Kanoh, & Itoh, 2011; Theofilif, Nehaniv, & Dautenhahn, 2014). Thus, today, social robots are capable of imitating and simulating human behaviors.

HUMAN MENTAL MODELS

Ideally, social robots must learn and recognize other people's mental models (Multu, 2011). For meaningful interaction with people, robots must be able to perceive the world similar to the manner in which humans perceive the world. They must sense and interpret the same phenomena, which means they must possess perceptual abilities similar to people (Fong, Nourbakhsh, & Dautenhahn, 2003). To interact naturally with people, a robot must be able to perceive human social behavior (Breazeal, 2005). However, in fact, we are far away from developing social robots that possess the ability to perceive similar perceptions requires more than similar sensors.

Moreover, in an ideal world, social robots also must learn about the dynamics of social relationships between individuals, groups and communities and should consider the needs of these people. Some researchers postulate that through the integration of robotics and social network analysis, robots today are presumed to analyze this data to determine the innovators of a social network (Lee, Kaloutsakis, & Couch, 2009), and expected to perceive the different types of relations between users and a group of others who interact with that user (Chu et al., 2014). However, the ability to 'read' the social world is even difficult for certain groups of people, such as those diagnosed with autism (Baron-Cohen, 1995; Sodian, 1991), yet alone that robots could have a theory of mind similar to those of humans. Nevertheless, this does not imply that human users are incapable of projecting a theory of mind onto the robots they interact with.

USER MODELING

To acknowledge robots as having full social behavior, robots and people must find the same types of stimuli salient (Breazeal & Scassellati, 1999). A robot needs to detect and recognize human action, for which communication provides a good starting point, but more important is the capability to interpret and react to human behavior (Fong, Nourbakhsh, & Dautenhahn, 2003). A key mechanism for performing this behavior is user modeling. User modeling helps the robot understand human behavior and dialog, shapes and controls feedback given to the user, and enables the robot to adapt its behavior to accommodate different types of users (Fong, Nourbakhsh, & Dautenhahn, 2003). User modeling should contain information about preferences, interests and cognitive characteristics (Aizpurua et al., 2013), and helps a socially intelligent system to adapt to the users' behaviors by constantly monitoring it and by continuously collecting their direct and indirect feedback (De Carolis et al., 2013).

Today, several socially intelligent systems have already been build that can monitor physiological data in real time (Predinger et al., 2005) and reduce the users' negative affective state by showing empathy (Klein et al., 2009). More recently, Conati and Maclaren (2010) have demonstrated the integration of the output of physical sensors in a more complex model. Similarly, Arroyo et al. (2009) have combined evidence about multiple channels of physical behavior (e.g., facial expressions, skin conductivity, posture and pressure) with contextual features in tutoring environments. Additionally, robots today are endowed with techniques to analyze the level of attention from users and personalize its interruption strategies accordingly (Chiang et al., 2014). However, it should be denoted that the monitoring capabilities of robots are still superficial compared to human abilities in similar situations, and robots today still have a long way to go in this matter.

MIMICKING

To readily be understood by its users, a robot may must mimic how human perception works by having similar visual motor control as humans (Breazeal, 2005; Breazeal & Fitzpatrick, 2000; Breazeal et al., 2001). In research studies involving social interactions between humans and robots, it is shown that human users also use this strategy in their communications with robots. People mimic the robot by waving back, greeting the robot (von der Pütten et al., 2011), and talk to robots similar manner as they would do to children (Breazeeal & Scassellati, 1999). Thus, human users not only respond socially to the behaviors of robots but also make concessions to smoothen the social interactions.

Although the development of techniques to build socially aware robots increases, today it is not possible for robots to perceive more complex social signals such as respective face directions or vocal cues (Chu et al., 2014). And communication science learns us that nonverbal channels of communication, such as body signals and intonation of spoken words, transmit thirteen times the impact of the verbal channel in interpersonal communication (Mehrabian, 1972). Thus the social situated learning and awareness of robot technology is still considered superficial and primitive.

DIALOG

Human-human interaction comprises both verbal and nonverbal communication. Dialog is a joint process of human-human communication, and people make use of a variety of paralinguistic social cues, such as facial displays and gestures, to control the flow of dialog (Lansdale & Ormerod, 1994). These social cues are also useful for regulating human-robot interactions (Breazeal, 2003). It is considered that there are three primary forms of human-robot communication (Fong, Nourbakhsh, & Dautenhahn, 2003): low-level, nonverbal, and natural language.

LOW-LEVEL COMMUNICATION

Low-level communication occurs insight the robot hardware and software which makes it understand and interpret human communication signals. To employ social interaction with humans, a robot must convey intentionality in that it must accomplish that humans consider the robot to have beliefs, desires and intentions (Dautenhahn, 1997). Computer technology have learned to use natural language processing to read and partially understand human language (Luger &

Stubblefield, 2004). Today, robots can only understand spoken commands that are preprogrammed into its systems (Mubin et al., 2012), or when the robot is trained to recognize the unique characteristics of a single user's voice (Pai et al., 2014). The current limitations in speech interaction for natural language is a major obstacle for human-robot interaction trough speech (Mubin et al., 2012). Moreover, in human-computer interaction one or more parts of the communication process (e.g., the sender, the message, the medium, the channel or the receiver) is shaped technically and the intentions and meanings behind human language is only partially understood (van Dijk, 2012). Therefore, it is incorrect to say that computer technologies, such as robots, can really communicate and have actual dialog with their human users.

NONVERBAL COMMUNICATION

Nonverbal communication has many forms, including body positioning, gesturing, and physical action. In that most robots today still have limited capacities for recognizing and producing speech (Mubin et al., 2012), nonverbal communication is a valuable alternative (Fong, Nourbakhsh, & Dautenhahn, 2003). Robots that use nonverbal social cues (i.e., gaze and gestures) in addition to verbal communication are evaluated as more engaging than robots that use only speech (Sandygulova et al., 2013). Human-human communication is enabled by a number of embodied cues, with or without intent, that form or shape the content of messages.

An overview has been provided of nine embodied communicative cues that human communication researchers have indicated over the years and which can be considered as key design variables for effective dialog with robots (Mutlu, 2011). Verbal cues, which involves spoken language, enable coordinated actions toward achieving common ground (Walker, 1997) and indirectly shape the social interaction (Goffman, 1969) between communication partners. The communication cue of spoken language will be further addressed in the next section on natural language dialog.

Vocal cues, which involve intonation and tone, facilitate processing and understanding of spoken words, syntactic structure, and discourse structure (Cutler, Dahan, & Van Donselaar, 1997) and communicate affect, attitudes, and intentions (Scherer, Ladd, & Silverman, 1984). Today, speech recognition technologies are at the beginning of interpreting acoustic and phonetic properties of emotive speech such as pitch (peak, value and range), the intensity of the speech, the formants and the speech rate to successful recognize the basic emotions of human users in most of the cases (Rabiel & Gasparetto, 2014).

Gaze comprises of the orientations of the eyes, head and body, communicate direction of attention (Frischen, Bayliss, & Tipper, 2007) and facilitate a number of communicative processes including joint and shared attention (Emery, 2000). Robots today are supposed to be capable to support their communication goals with gaze behavior (Huang & Mutlu, 2013).

Gestures include arm, hand and head movements, embody particular symbolic meanings (McNeill, 2005). Robots today are presumed to interpret the meaning of human upper body gestures with acceptable accuracy in real time interactions and express itself using a combination of body movements, facial expressions and verbal language (Yang et al., 2014).

Proximity, which conveys the social use of space (Severson-Eklund, Green, & Hüttenrauch, 2003), serves as a salient embodied cues (Hall, 1966) and varies based on the relative orientation between the people involved (Hayduk, 1981). Hall’s proxemics (Hall, 1966) have been proposed for robotic systems as a social signal to estimate the nature of the social relationship between users (Amoka et al., 2009).

Facial expressions, which are emotional and other internal states through movements of the face, shape other people’s perceptions of the initiator (Ekman, 1993). For example, social smile, which is the smile expressing understanding and agreement, serves as a backchannel and improves conversational efficiency (Brunner, 1979). Robots that succeed to incorporate the facial action coding system (FACS) of Ekman and Frieser (Ekman & Frieser, 1982) should be able to detect the seven basic human emotions from real time posed facial expression by human users (Zhang et al., 2013).

Social touch, which involves physical interaction between communication partners, serves as a uniquely embodied and potent communication cues (Gallace & Spence, 2010). There is only a limited number of research that investigates the physical interactions between humans and robots (Aydin, Arghavani, & Basdogan, 2014). However, because social robots are expected to perform in several social roles such as caregiving roles, physical interaction is likely to be part of the complete interaction spectrum. Research shows that people respond differently to robot touch depending on how the person interprets the intention of the robot. People who thought the robot touched them to clean their arm reacted more positively than people who thought the robot touched them to comfort them, even though the manipulated behavior of the robot was the same (Chen et al., 2014). More research is necessary to investigate what kind of physical interactions and under which circumstances are appropriate according to human users.

The last embodied communicative cue is that of posture. Posture involves cues such as openness of arms and legs, arms-akimbo position, and trunk relaxation. These type cues provide information on the attitudes and status relationships between communication partners (Mehrabian, 1969) and shape how they perceive each other (Osborn, 1996). Today, robots can use trunk, head and arm movements to display emotions recognizable for human users (McColl & Nejat, 2014).

NATURAL LANGUAGE DIALOG

Natural language dialog or speech is affected by several factors ranging from the physical and perceptual capabilities of the interaction partner to the social and cultural context of the dialog (Fong, Nourbakhsh, & Dautenhahn, 2003). Ideally, social robots must track the state of the interaction and must integrate the interpretations of the users' spoken input to select the next communicative action (Belpaeme et al., 2012). Making use of voice information, agents have had some success in reacting and adapting to a user's behavior (Bauer et al., 2013) and detect the state of a meeting and the roles of the meeting partners (Banerjee & Rudnicky, 2004). To be social in speech, robots should be able to vary in their speech frequency, speech rate and speech volume (Banse & Scherer, 1996). Robots today can use modern speech synthesizers to convey emotion with their speech that is recognizable for human users (Crumpton & Bethel, 2014), most of the times.

LEARNING AND DEVELOPING SOCIAL COMPETENCES

As social robots are designed for social interaction, they should possess a considerable amount of social skills. The sociability of a robot shapes not only the manner in which people interact with it but also how that robot is evaluated. In observing human-human interactions, there are several characteristics that make certain people more likeable in the eyes of others. These characteristics are conceptually combined as social competence (Rubin & Martin, 1994). Social competence or sociability for robots is defined as the users' belief that the robot possesses the social, emotional, and cognitive skills required for successful social adaptation.

EMOTIONAL EXPRESSION

Emotions are a major part of human social behavior. Recognizing and expressing emotions is a capability that should be programmed into any robot that is intended to be empathic (Levy, 2008). Artificial emotions can be incorporated in the design of social robots to facilitate believable human-robot interaction (Cañamero & Fredslund, 2001; Ogata & Sugano, 2000), to provide feedback to the user such as indicating the robot's internal state and intentions (Bartneck & Okada, 2001; Breazeal, 2003; Kozima & Yano, 2001), and to act as a control mechanism to drive the user's behavior and reflecting on how the robot is affected by, and adapts to, different factors over time (Cañamero, 1997; Michaud et al., 2000; Velasquez, 1998).

A highly effective method to express emotions is through speech. The emotional content of speech primary governs loudness, pitch (level, variation, and range), and prosody. The utterances produced by robots today sound monotonous, unnatural and unfriendly, because their text-to-speech systems are not build for communication but for text-reading (Sugiura et al., 2014). Yet, first attempts to create emotional speech have been made. For example, Kim (2013) has developed a program for expressing emotions through speech by controlling pitch contour, acoustic energy, vocal tract features and speech energy. However, the effectiveness of this technique was not investigated in that study.

Another method of expressing emotion is through facial expression with the primal components being used are mouth, cheeks, eyes, eyebrows, and forehead. Most robots exhibit emotional expression in compliance with the FACS system of Ekman and Frieser (Ekman & Frieser, 1982). Emotions are better recognized when robot's express them by facial expression than by postural expression (Clavel et al., 2009). However, when robots use postural expression and complement these with facial expressions, than the recognition of their emotions increases even further (Zecca et al., 2009). Yet, most research today that employ robots that express emotions in real time interaction are still not fully autonomous, and the researchers use the Wizard-of-Oz technique to study the effects of emotional expressions of the robot in human-robot interactions (e.g., Tielman, Neerincx, Meyer, & Looije, 2014; Wang et al., 2014). The Wizzard-of-Ozz technique comprises of an human-robot interaction scenario in which the human believes to be interacting with an autonomous robot, but which is actually operated or partially operated by an unseen human being. Nevertheless, the emotions expressed by robots in these studies are easily recognized by human users and have positive effects on the user's interaction experience.

Finally, people communicate emotions through body language. Non-verbal communication is often transmitted through gestures and body movement, and most gestures occur during interaction with others and provide needless information (Krauss, Morrel-Samuels, & Colassante, 1991; McNeill, 1992). Research has shown that human body language can be interpreted accurately without facial or vocal cues (Beck et al., 2012; de Gelder, 2006; Kleinsmith, De Silva, & Biachi-Berthouze, 2006). Based on Cassell (2000) and

Vinayagamoorthy et al. (2006), Beck et al. (2013) robot body language can be classified into three different areas broadly used in the literature: posture, movement and proxemics. Body posture are specific positions a body takes at a certain point in time. Body movement entails the movements themselves as well as the manner in which they are performed (i.e., movement speed, dynamics, curvature, etcetera). Proxemics refers to the distance between individuals during social interaction. Several humanoid robots can already express recognizable emotions using sounds, body movement and body posture (Beck et al., 2013; Haring, Bee, & Andre, 2011; Itoh et al., 2004; Searbeck & Bartneck, 2010). Yet, researchers must agree that robots actually do not have real emotions but act as if they have emotions by showing caricatured verbal and nonverbal expressions recognized and interpreted by humans as real emotions.

EMPATHIC RESPONSES

Robots in social roles are supposed to be able to behave sensitively and supportively to its user's needs. Thus, besides the capability to express emotions, a robot should be able to not only recognize our human emotions but also respond empathically. Although robots cannot feel empathy, they can respond to humans in such a manner that is recognized by human users as empathic behavior (Kwak et al., 2013). People tend to show natural social responses to a robot when such a robot seems to recognize their emotional states and responds empathically through various verbal and non-verbal cues (Breazeal, 2002; Breazeal, 2003). This sounds logical, given that the human ability to recognize and manifest emotions is critical for successful social integration (Lee, et al., 2005), and it is thus critical in social robots as well (Breazeal, 2003). If future robots are going to merge into our everyday lives, they should be able to respond to our emotions in an empathic manner (Leite et al., 2014).

Various modalities can be utilized to recognize the emotions of the human users (Breazeal & Aryananda, 2002; Littlewort et al., 2004). A large body of research on affect-detection based on speech and vision called social signal processing has been done by Pantic and colleagues (Pantic & Rothkrantz, 2003; Zeng, Roisman, & Huang, 2009). But the techniques for artificial social intelligence and socially aware computing still have a long journey ahead (Vinciarelli, Pantic, & Bourlard, 2009).

Physiology is yet another method to estimate the emotional state of human users. By measuring certain components of the human nervous system such as measuring electrical conductance of the skin (Carlson, 2013), computer systems are already capable of distinguishing a few basic human emotions. In psychophysiology, it is common knowledge that emotions and physiology are closely related to each other (Russell, 2003) Although the application of the techniques for artificial social intelligence and socially aware computing is still in its infancy (Vinciarelli, Pantic, & Bourlard, 2009), research into affective wearables or wearable computing (Ashford, 2014; Picard, 2014; Starner, 2014) provides a promising future of unobtrusively monitoring our vital signals.

To be perceived as empathic, robots today are being developed to follow Reis and Patrick's (1996) theoretical model of responsiveness which includes understanding, validation and caring. Understanding means active listening, showing attention, interest in the conversation, and understanding of the discloser's words. The purpose of validation is to make the conversation partner feel respected and to reinforce their self-views, including behaviors that acknowledge the significance of the described events. Caring contains expressions of love, care about the other's well-being, and showing a joint stake in the issues discussed. Hofman et al. (2014) translated these responsive behaviors into the human-robot domain and successfully tested some basic translations of responsive behavior in human-robot interactions. The authors propose that, for the expression understanding, a robot could nod, provide backchannel signals, direct gaze attention, and summarize human speech. For the expression of validation, a robot could relate events to the resulting feelings and affirm the user's positive traits. For the expression of caring, a robot could touch the user affectively and affirm emotional caring verbally. The robot's social responses on its users communication are expected to affect numerous personal and interpersonal outcomes, because it does in human interpersonal communication (Clark & Lemay, 2010; Maisel, Gable, & Strachman, 2008; Reis, 2007; Reis & Shaver, 1988). However, again, researchers should be aware that, although such empathic interactions are respectable achievements in social robotics, the empathic responses of robots are just simulations of human behavior that users interpret as empathic responses and actual empathic abilities of robots are still quite limited with respect to human abilities.

EXHIBIT DISTINCTIVE PERSONALITY

Personality may provide users a way to model and understand the robot's behavior (Fong, Nourbakhsh, & Dautenhahn, 2003). Although, obviously, a robot cannot have a personality, it can present a series of behaviors interpreted by their human users as a personality. Personality is a key determinant in human social interactions (Tapus et al., 2008). In psychology, personality is defined as a set of unique qualities that distinguish individuals (Engler, 2009; Michel, Shoda, & Smith, 2004).

Certain human-robot interaction researchers believe that people would be more willing to interact with a robot if it possesses a compelling personality (Breazeal, 2005). A robot can express its personality through emotions, embodiment, motion, manner of communication, and the tasks it performs (Fong, Nourbakhsh, & Dautenhahn, 2003; Severson-Eklund, Green, & Hüttenrauch, 2003; Yoon et al., 2000). The emotional responses and communication styles of a robot can affect the personality of that robot as perceived by its users (Lee et al., 2005). The studies of Meerbeek et al. (2009) and Woods et al. (2005) include a robot with a personality largely based on trait theory. These theories focus on habitual patterns of thought, emotion and behavior and the personality of a person by a limited number of such traits being stable over time (Matthews, Deary, & Whiteman, 2009). Humans have a multiplicity of selves (James, 1890; Baldwin, 1897). This creates both plurality and unity, which extends the current work on designing robot personalities in human-robot interaction studies (Ruckert, 2010). Designers focusing on robot personalities could improve their work by switching from simple traits to multiple personalities (Ruckert et al., 2013), as different users might prefer different interaction modalities.

Some studies have argued that the personality of a robot should match with that of the human user (Nakajima et al., 2003), whilst others indicated that a robot's personality should match with his design purpose (Woods, 2006). Goetz and Kiesler (2002) found that humans find more enjoyment in the interaction with a happy robot, but they would rather comply with specific instructions when the robot had a more serious personality. Other results show that certain people try to match and project their own personality characteristics and styles onto the robot with whom they are interacting (Woods et al., 2005). Additionally, research findings suggest that people also prefer to interact with robots that have a similar personality (Bernier & Scassellati, 2010; Park et al., 2012). This can be explained by the similarity-attraction hypothesis which states that people prefer to interact with others who possess personality traits similar to those of themselves (Byrne et al., 1986; Isbister & Nass, 2000). So it seems that people prefer to establish and maintain engaging interactions with robots that gives them a familiar feeling.

People naturally pick up a robot's personality from its design characteristics (Syrdal et al., 2007). This perceived personality invokes specific emotions in humans that are interacting with the robot (Hwang, Park, & Hwang, 2013). Robotic designers should carefully consider a robot's personality when it is interacting with humans because this influences the user experience during its performance. Therefore, developing a clear, consistent and appealing robot personality is of major importance for meaningful human-robot interaction. However, because the scientific community of psychology doesn't hold a complete grasp on what a human's personality contains, it remains quite difficult to program a full personality into a robot.

ESTABLISH AND MAINTAIN SOCIAL RELATIONSHIPS

Robots have a great potential to become human companions due to their physical embodiment. The form and structure of a robot supports the establishment of social expectations. A robotic pet will be treated differently than a robot with a humanlike appearance (Fong, Nourbakhsh, & Dautenhahn, 2003). Besides its embodiment, also a companion robot's social abilities contribute to its acceptance (Heerink et al., 2010; de Ruyter et al., 2005). To maintain social relationships with humans, besides the several sociable behaviors described above, some social roboticists argue that robots should at the same time be empathic and trustworthy (Hancock et al., 2011; Lee, 2006).

EMPATHY FOR HUMAN-ROBOT RELATIONSHIPS

Empathic robots are perceived as better companions (Leite et al., 2010), as empathic robots are evaluated as more caring, more likeable, and more trustworthy than agents without empathic capabilities (Bickmore & Picard, 2005; Brave, Nass, & Hutchinson, 2005; Paiva, Dias, Sobral, Aylett, Sobreperez, Woods, Zoll, & Hall, 2004). Additionally, empathic agents are respected more (Bickmore & Picard, 2005), and improve the user's attention and willingness to interact (Nguyen & Masthoff, 2009). Moreover, non-empathic agents can lead to negative user experiences because the users create certain expectations when interacting with a system.

To be perceived as empathic, a robot should be capable of recognizing emotional states of its human interaction partner, processing and expressing its own emotions, and communicating with other humans and perspective taking (Tapus, & Mataric, 2007). More information on the role of expressing and recognizing emotions in human-robot interaction has been dealt with in the section 'learning and developing social competence'. The first virtual agent that used, among other strategies, empathic dialog as a means to establish relationships with humans is Laura, developed by Bickmore and Picard (2005). In the relational condition, Laura used scripted interaction dialogs including social dialog, empathy dialog meta-relational communication, humor, continuity behaviors and appropriate form of address and politeness strategies. Besides these speech modalities, in the relational condition, Laura also used a range of nonverbal behaviors such as hand gestures, body posture shifts, gaze behavior, facial expressions, nodding and walking on and off the screen. In the non-relational condition, both the relationship inducing speech and nonverbal behaviors were kept to a minimum. After a month of daily interaction, the relational version of Laura was respected more, liked more, trusted more, and the participants had higher intention to continue to interact with Laura. Another series of research has been done by Leite et al. (2010, 2014) who programmed empathic behaviors into Philips iCat based on the characteristics of empathic teachers described in Cooper et al. (1999). Leite et al.'s iCat used both facial expressions and verbal responses as empathic behaviors. Using its face, the iCat used a lot of eye-contact and expressed its affective state using proper facial expressions. In the verbal responses, the iCat was empathic by responding to the users affective state or to encourage the user. The participants in their study felt more companionship towards the empathic robot and trusted this version of the robot more. Another study showed that being empathic might also include a white lie in certain circumstances (Cramer, Goddijn, Wielinga, & Evers, 2010). In case of a negative valence condition (i.e., losing the game), a robot that lied by responding positively was perceived as more empathic than a robot that responded honestly by pointing out the negative emotion of the user. However, the lying robot was not trusted more than the honest robot.

TRUSTWORTINESS FOR HUMAN-ROBOT RELATIONSHIPS

Besides being empathic, according to Hancock et al. (2011) and Lee (2006), a robot designed for companionship should also be trustworthy. A meta-analysis on factors affecting trust in human-robot interaction has shown that factors related to the robot performance were the greatest contributors to trust, environmental factors were moderately associated with trust, and user-related factors had minimal effects on trust (Hancock et al., 2011). Thus, the behavior of the robot has the most impact on whether or not it is perceived as trustworthy by its human users. Robots enabled with nonverbal cues are perceived as more trustworthy (DeSteno et al., 2012). For instance, a robot's motion fluency, hesitation and gaze behavior influence its users' level of trustworthiness (van den Brule et al., 2014). Additionally, team-related and task-related factors seem to have an effect on trustworthiness (Biros, Daly, & Gunsch, 2004; Evers et al., 2008; Li, Rau, Li, 2010; Wang et al., 2010). However, due to the insufficient number of empirically codable studies, limited evidence could be found in the meta-analysis for team-related and task-related effects on trustworthiness as well as other user related factors (Hancock et al., 2011), which indicates a strong need for future research on the role of trustworthiness in human-robot interaction.

2.3 SOCIAL ROBOTS AS A NEW TECHNOLOGICAL GENRE

Researchers in the field of human-computer interaction have produced and studied various theories on the user acceptance and use of technology. Although building autonomous robots that interact with people may share certain design challenges with computer interfaces, both systems are profoundly different technologies in important ways (Breazeal, 2004). Theories from neighboring fields, such as psychology and human-computer interaction, might not work for human-robot interaction due to unique features of robots (Kanda et al., 2008). Before applying those existing theories to the field of human-robot interaction, we must emphasize the similarities and differences between social robots and other common domestic applications and technologies.

PHYSICAL PRESENCE

Robotic systems are different from other technologies, because robots are embodied technologies and perform their tasks in the personal spaces of their human users. Although new media is also advancing the integration of their communication modes (e.g., images, sounds, text and data in a single medium) (van Dijk, 2012), robotic devices hold even richer communication modes as they add nonverbal communication and higher social presence to their interaction capabilities. Because robots are part of our physical environment, they share our world with us (Breazeal, 2004). The physical embodiment enables robots to exist in the same physical world as their human users. Having a physical body enables robots to perturb and be perturbed by the environment, which creates a stronger social presence (Lee, 2004; Lee et al., 2006) and affects the users' perceptions and interactions with these robots (Breazeal et al., 2005; Walters et al., 2007; Wang et al., 2006). Artificial creatures have their own distinct individuality, which manifests itself in the robot's design and behavior configuration, in the same way that people and other living beings differ from each other by various parameter, such as weight and height, behavioral reactions and character, emotions and cognition, abilities and coping strategies (Libin & Libin, 2003). This introduces interesting benefits as well as possible risks (Breazeal, 2004).

SENSING OUR ENVIRONMENT

Moreover, robots are different from other technologies as they must survive in our human world. Robots must be able to perform their actions in our social and physical environment. And our human world is not easily simplified without the implementation of potentially unacceptable restrictions for their users (Breazeal, 2004). Robots are able to perceive naturally offered cues of their users using cameras or microphones. Although certain other interactive media have the same affordance, it is clearly more limited for a screen character than for a robot whose sensors can move with it and can remain compelling eye contact. Humans are exquisitely perceptive of gaze direction and eye contact, which is an ability with a powerful impact on a person's sense of being engaged on a personal and direct level (Breazeal, 2004). A robot is part of the physical environment sharing our spaces with us. The opportunity for frequent interaction over an extended period of time, and the opportunity to establish a long-term relationship, poses some additional significant design challenges for robots (Breazeal, 2004). Because of these characteristics robots differ from other interactive technologies.

SOCIAL RESPONSES TO ROBOTS

Due to the strong social and emotional component caused by their physical presence in our personal spaces and their ability to sense our environments, the experience of interacting with robots appears to be different from how people interact with most other technologies. People behave as if they are interacting with another person when interacting with robots or screen agents (Bartneck & Forlizzi, 2004b), especially when robots behave unpredictable (Eyssel, Kuchenbrandt, & Bobinger, 2011), and when users perceive the robot as an ingroup member (Eyssel & Kuchenbrandt, 2012). However, this finding was already discovered in human-computer interactions. A large number of experimental studies indicate that technological objects such as computers are often evaluated as social entities, a phenomenon known as the media equation (Reeves & Nass, 1996). Yet, if computers are already perceived as social actors, android interfaces, which clearly emulate human facial expressions, social interaction, voice and overall appearance, will most likely generate empathic inclinations from humans (Bartneck, Reichenbach, & Carpenter, 2008). Very machine-like robots were treated in a similar way as people treat computers and humans, but robots scoring very high on anthropomorphism were praised more and punished less (Bartneck, Reichenbach, & Carpenter, 2008). By testing the media equation theory of Reeves and Nass (1996) on human-robot interaction, the study of Lee, et al. (2005) expands the applicability of the media equation to human interaction with embodied social actors. Additionally, research shows that robotic objects can elicit empathic responses from their human users (Kahn et al., 2006; Kwak et al., 2013; Rosenthal - von der Pütten et al., 2013).

It is being argued that a social interface may be a truly universal interface given that humans have evolved to be experts in social interaction (Reeves and Nass, 1996), assuming that attempts to foster human-robot relationships will be accepted by a majority of people if the robot displays rich social behavior (Breazeal, 2004). People tend to ascribe a level of intelligence and sociability to robots which influences their perceptions of how the interaction should proceed. Robots capable of natural language dialog raise users' expectations not only with respect to the natural language, but also regarded to the intentionality of both verbal and nonverbal behaviors, the robot's autonomy, and its awareness of the sociocultural context (Simmons et al., 2011). It is likely that robots, which are enabled with sociable interaction features such as familiar humanlike gestures or facial expressions in their designs, will further encourage people to interact socially with them in a fundamentally unique way. Moreover, the autonomous behaviors of robots are likely to be associated with intentionality, which induces and strengthens a sense of agency in robots. Agency refers to the capacity to act and carries the notion of intentionality (Dewey, 1980). It is being argued that robots, being physically embedded and enabled with sociable interaction, creates a unique and affect-charged sense of active agency similar to that of living entities (Young et al., 2011). This might cause human-robot interaction, in a sense, to be more like one is interacting with another living entity than it is like interacting with a machine. It could thus be that human interactions with robots follow the principles of inter-human communication rather than the principles of human-machine interaction.

A NEW ONTOLOGICAL CATEGORY

Additionally, social robots could be interpreted as both animate and inanimate. Animate, because they move and talk. On the other hand they are inanimate as they are programmed machines. So it seems like a new ontological category is about to emerge through the creation of social robots and this process magnifies when robots become increasingly persuasive (Kahn et al., 2011). This line of work suggests that social robots should be perceived as a new technological genre, something that has been argued by other robotic researchers as well (Young et al., 2007).

A first evidence for this new category can be found in the notion that young children cannot easily distinguish robots from alive or not alive (Bernstein & Crowley, 2008; Jipson & Gelman, 2007), even though they consistently classify other living and nonliving entities as distinct from another in terms of biological, psychological and perceptual properties from the age of five (Inagaki & Hatano, 2002). So it seems that children do not show similar patterns of attribution of aliveness to robots as they do with other canonical entities. To further address this issues, Kahn and colleagues executed a line of research to assess social and moral relationships with robotics others. Chat room analysis (Friedman, Kahn, & Hagman, 2003) indicates that people (n= 182) become psychologically engaged with the robotic dog AIBO by ascribing essence (presence of biological or animatic underpinning), agency (presence of mental states such as intentions, feelings, and psychological states), and social standing (engagement of AIBO in communications, connections, and companionship) to their AIBOs (Friedman, Kahn, & Hagman, 2003). However, moral standing (worthy of moral regard or responsibility, having rights, or deserving respect) was much less assigned to AIBO. Two follow-up studies from Kahn and colleagues (Kahn et al., 2006; Melson et al., 2009) investigated children's social and moral relationships with the robotic dog AIBO. Together, these three AIBO studies provide evidence that children and adults often establish meaningful social conceptualizations with robotic others even though they recognize them as a technology. Thus robotic technologies seem to challenge traditional ontological categories between animate and inanimate (Kahn et al., 2006), which might impose some additional challenges for the evaluation of social robot acceptance.

2.4 USER STUDIES TO CONCEPTUALIZE SOCIAL ROBOTS

In addition to look at the academic definitions of (social) robots, also the opinions from ordinary people were investigated. Only a few studies incorporating a user-centered approach have focused on people's perceptions of robots. For example, in an interview study, people had no tendencies for a specific design, but that the design should match its purpose and that one should be able to personalize the appearance such as color, form and material (Kahn, 1998). In the same study, the participants specified that verbal communication with a robot is preferred by most people, and feedback from the robot is essential as part of the communication with the robot (Kahn, 1998). A large scale survey study including more than 2000 people in which more than two-third could imagine living with robots on a daily basis, but almost half of the participants would not like to have a humanoid robot (Arras & Cerqui, 2005). These findings are supported by an exploratory study in which the participants explained that they would desired humanlike communication modalities, but that humanlike behavior and appearance was less essential (Dautenhahn, 2005). A qualitative study investigated what the word robot evoked among 240 attendees of the home and art of living exhibition in Switserland (Ray, Mondana, & Siegwart, 2008). Their results indicated that the majority associated robots with positive or neutral aspects such as useful help, science fiction, and future technology, and only 4% of the participants associated robots with negative effects such as job loss, danger, lack of trust and inhumanity.

In this section, people's conceptualization and perceptions of robot for domestic purposes will be explored to contribute to the limited knowledge on this topic. First, people's perceptions of and associations with robots will be presented. Second, insights will be provided into what capabilities are necessary for robots to become social according to ordinary people. A third contribution will be made with a discussion on people's overall evaluation of robot appearances.

PEOPLE'S PERCEPTIONS OF AND ASSOCIATIONS WITH ROBOTS

During a set of interviews, I asked participants (*n*= 21) what a robot is for them. The participants (7 males, 14 females) were selected to participate in the Karotz Home Study, a long-term user study being held in The Netherlands between October 2012 and May 2013. More details on the procedure of this study can be found in chapter 6. At the time of these interviews, the participants had not been provided with the details of the Karotz Home Study, nor the type of robot that would be used. The participants were selected based on their living situation and age, with eight singles (5 young, 3 older), five couples (3 young, 2 older), five families (3 with young children, 2 with teenagers), and three students living in a dorm. When I asked them what came across their minds when hearing of or thinking about robots, their descriptions entailed wordings that can be categorized into three main categories (Cohen's Kappa = .73): appearance characteristics (e.g., what it looks like), utility characteristics (e.g., what kind of tasks they could perform), and other characteristics (e.g., not belonging to the other two main categories). The overall frequency distribution of the main categories are presented in table 2.1. In the following three sections, I will further zoom in on these three main categories and clarify their meaning with some quotes from the interviews.

Table 2.1: Frequency distribution of main characteristics to describe robots

Characteristics	**Count**	**%**
Appearance	115	35
Utility	132	41
Other characteristics	78	24
Total	325	100

APPEARANCE CHARACTERISTICS

When talking about the appearance, some of the participants' descriptions could be divided into the four robotic appearance groups as formulated by Fong et al. (2003), namely humanoid (or anthropomorphic), zoomorphic, caricatured or functional. The remaining descriptions of the robot's appearance were categorized as other appearance descriptions. The results of the categories of the participants'' descriptions are presented in table 2.2.

Table 2.2: Frequency distribution of appearance characteristics to describe robots

Appearance Characteristics	Count	%
Humanoid	34	30
Zoomorphic	3	3
Caricatured	27	23
Functional	8	7
Other	43	37
Total	115	100

When talking about the appearance, more than half of described features were related to a humanlike appearance (e.g., humanoid and caricatured). Most of the participants started to described robots a creatures with a humanlike shape (e.g., humanoid appearance), such as have a body and a head with eyes so it could see where it is going.

> "When I think purely about robots, then I see a robot with a humanlike shape." - female, 19, living in student dorm
>
> "Basically, it comes down to me wanting it to have a humanlike body." - female, 26, living with young family

However, when stimulating the participants to further elaborate on these humanlike shapes, most participants explained that they would not want a robot in their homes that looks all too humanlike. They expressed their desire for robots that looked not all too humanlike (e.g., caricatured appearance).

> "No, not really with a human head, not that. A little bit funny, a little doll-like." - female, 57, living alone
>
> "I image a certain type of puppet, but not really very much a human being." - female, 27, living with spouse

A lot less, the participants discussed that the appearance should be matched with a specific task (e.g., functional appearance). For example, a participant explained that it would be practical for a robot to have a (touch) screen for interaction purposes. Other participants explicitly pointed to specific tasks that robots could perform and should be shaped in a way that supports that purpose.

"With a touch screen for the interaction." - female, 32, living with young family
"I recon something from Discovery [Channel] with robots assembling things.." - male, 24, living alone
"For example a robot vacuum cleaner." - male, 38, living with young family

Only a few participants noted that robots could have an animal shape (e.g., zoomorphic appearance), just like having a pet around.

"In the shape of a pet, I would like that." - female, 33, living alone

UTILITY CHARACTERISTICS

Another category of characteristics to describe robots were in terms of a robot's utility. These descriptions could be divided into the purpose of assistant, companion, information source, entertainment, gadget or other purposes (see table 2.3).

Table 2.3: Frequency distribution of utility characteristics to describe robots

Utility Characteristics	**Count**	**%**
Assistant	56	43
Companion	16	12
Information Source	20	15
Entertainment	25	19
Gadget	4	3
Other characteristics	11	8
Total	132	100.0

The participants described several tasks domestic robots could perform. Most of the times the participants referred to robots as assistants. Especially the performance of several household chores would be warmly embraced by most of them, although some participants thought that this scenario would only exist in a far future.

"That [the robot] takes care of my household chores." - female, 57, living alone
"A robot should be doing all kinds of household chores. Vacuum cleaning, clean up." - male, 30, living with spouse
"That you can tell [the robot] to get the vacuum cleaner and go vacuum cleaning, go get the lawn mower and go mowing. Go get my slippers. Make come coffee." - male, 38, living with young family

Though the younger participants were only thinking of household chores, it were especially the older participants that came up with other assistance tasks domestic robots could perform. The wished for assistance with other tasks varied, from fetching objects to helping with remember things.

> "A machine that takes over task from humans. … that he walks to the corridor to pick up the newspaper." - female, 57, living alone
>
> "A robot that helps you remember things… things you might forget." - male, 64, living with spouse

Although, for almost all participants, the butler functionalities were noted first, some additional purposes the participants described were more fun orientated. Especially the younger participants suggested that domestic robots could be used for entertainment purposes, such as listening to your favorite music or movies, or playing games with or on it.

> "To listen music with… and that it repeats songs because it knows what kind of songs I like." - female, 22, living in student dorm
>
> "I would appreciate it if there is a screen on [the robot], so I can see things on it … such as emails or movies. And that it has a good sound quality." - male, 30, living with spouse

Another purpose for domestic robots was its use as an information source. The participants assumed that robots would be connected to the internet and could thus provide them with all the information available on the web.

> "A nice walking encyclopedia that can look up stuff, like recipes which he could read out loud." - male, 32, living alone
>
> "Such as looking up the weather forecast… or the current news events. At least a lot of stuff that can be found on the internet." - female, 33, living alone

Some of the participants even brought up the role of companion for domestic robots. Especially those participants who were living alone stated that a robot could complement to their social lives, such as watching television together or to serve as a conversational partner when coming home from work.

> "When you are watching television in the evenings, that you and [the robot] are watching together and that he comments on the television shows." - female, 57, living alone
>
> "It would be nice that when you come home that there is someone, that you can talk to [the robot]." - female, 27, living with spouse
>
> "I resist the fact that when [my children] come home and there is nobody there, … quiet and deathlike. If there is something there to talk to, that would be better than nothing." - female, 38, living with mature family

One participant also described domestic robots as a gadget or a toy. However, this was done in addition to describing such robots as assistants.

OTHER CHARACTERISTICS

Besides the appearance and utility of robots, some other topics occurred in the participants' descriptions of domestic robots. These descriptions were grouped into a third category called 'other characteristics' (see table 2.4).

Table 2.4: Frequency distribution of other characteristics to describe robots

Other Characteristics	**Count**	**%**
Capability	22	28
Cost	25	32
Moral Standing	5	7
Natural Language	26	33
Total	78	100

The participants described robots in terms of what they can or should be able to do (e.g., capabilities). Most of these description included the robot having sensors to become aware of its environment and socially interact with it.

> "With sensors. That [robots] can sense if something is in their way, that they will walk around it… or turn around." - female, 22, living in student dorm
>
> "That [the robot] can distinguish family member with facial detection, and that he can sense their emotions." - female, 24, living with mature family
>
> "Everything a normal person is capable of doing if [the robot] has enough grip." - female, 19, living in student dorm

Moreover, the participants discussed robots possessing the ability to talk to us (e.g., natural language). For most of the participants, talking to robots is for the purpose to give robots instruction, however, some participants indicated that they would just to talk to the robot to have a conversation with it.

> "May be including a language package. That I can say certain words to [the robot] and that he goes off to do something." – female, 22, living in student dorm
>
> "[The robot] needs to be voice activated… he needs to do what I tell him to do." – male, 30, living with spouse
>
> "When you wake up in the morning, could it greet you then?." – female, 57, living alone

Additionally, the participants spoke about prizes of future robots (e.g., cost). Some participants discussed paying a larger amount of money at once, some other participants explained that they would pay a monthly fee.

> "What I would be willing to pay for [a robot] depends on what it can do. I don't need it at the moment. But if you become more dependent on it, let's say 5000 euros." – female, 55, living with spouse
>
> "If [the robot] could do all those household chores? I would pay at least a couple of thousand euros, because I never have to iron anymore." – female, 38, living with mature family

Only a few participants suggested that robots deserve rights and ethical treatment (e.g., moral standing), and that a robot should be treated equally to humans.

> "I think it is absurd to consider [robots] as some type of slaves. That is just weird. Once you get a robot to really do tasks around the house, then I think you should provide it with, not emotions, but some type of consciousness. To sense that it is here and it has to do all kinds of stuff. And other people don't have to do all that. That would be weird, such a difference. That would feel like abuse." – female, 19, living in student dorm

ROBOTIC CREATIONS MADE BY THE PARTICIPANTS

After their own descriptions and definitions of robots, I provided the participants with different robot magazines, pencils, markers and colored paper. Then I asked them to potter their own creation of a future domestic robot focusing on both its appearance and purpose while thinking out loud in the process. This approach is inspired by a participatory design approach, which is a general design approach that perceives technologies as part of an actor network that combines technology, human abilities and organizational practices in such a way that it improves both social and technological aspects of the user's experience (Latour & Weibel, 2005). Participatory design helps users to express their ideas about complex robotic technologies without relying on stereotyped notions of robots, and help researchers to better understand the meanings and roles users attribute to robots in their own homes as well as the possible uses and designs for robots used in home environments (Lee, Šabanović, & Hakken, 2013). The process of pottering their own future robot for domestic use is meant to inspire the participants' imagination, and help them verbalize their ideas and needs.

With the exception of one, all participants composed a human-shaped robot. During the think aloud process, they all explained that a humanoid appearance would feel familiar and would be more convenient as our natural environments are accustomed to humans. Moreover, a humanoid appearance is just what people envision when thinking of robots, so it was most logically to them to compose a human shaped robot. A few participants further explained their preference for a humanlike appearance by saying that they would feel eerie if they had something machinelike in their home that can think for itself. They would feel more comfortable if a autonomously acting and thinking machine looks humanlike. However, when further deepening into the human shaped creations, the participants stated that they would not want a robot in their homes that resembles the appearance of a human. This result is in line with Walters et al. (2012) who's respondents also indicated that they would not want a very humanlike robot, but would prefer to own a robot with certain humanlike attributes and capabilities.

The most preferred task for the robot was for it to perform several household tasks. This result is in line with an earlier study that indicated that people would prefer robots to perform household chores (Dautenhahn et al., 2005). Almost all participants preferred natural language to instruct the robot, which is similar findings from an online survey in which people indicated to favor speech as an interaction modus for robots (Ray, Mondana, & Siegwart, 2008). Moreover, they wanted a robot that could adapt to personal preferences, such as installing your own applications and determining the robot's appearance. Two participants wished for a robot that could also serve as a vehicle.

In terms of cost, the participants were divided in three groups. One group of participants (*n*= 10) would pay over 5000 euros for their ideal domestic robot, some participants (*n*= 4) suggested a prize for their ideal robot between 1000 and 5000 euros, and another group of participants (*n*= 7) said that their ideal domestic robot was not worth more than 1000 euros. There seems to be a link between the pricing and the type of tasks people would like their ideal domestic robot to perform. Those participants that wished for more complicated tasks are also willing to pay more for those robots.

ESSENTIAL SOCIAL ABILITIES FOR ROBOTS ACCORDING TO USERS

The same 21 participants interviewed above from the Karotz Home Study were followed in their experiences of using the Karotz robot (www.karotz.com) for over six months. During the several interviews (*n*= 97) conducted in this study, a number of questions were asked about the possibility to build social relationships with robots in general. Based on their experiences with the Karotz robot, the participants disclosed several characteristics of human relationships and certain specific features domestic robots should possess before they could seriously consider robots as social companions (see table 2.5). In the following sections, I will clarify their meaning with some quotes.

Table 2.5: Frequency distribution of social characteristics for a robot companions

Social characteristics	**Count**	**%**
Autonomy	20	7
Coziness	15	5
Mutual Respect	7	2
Similarity	9	3
Social Awareness	40	14
Social Support	22	8
Thoughts and Feelings	57	20
Two-way Interaction	119	41
Total	289	100

TWO-WAY INTERACTION

The far most noted topic was two-way interaction, which constitutes speaking to the robot and for it to respond to what has been said. Above all, people should be able to freely interact with robots in a natural humanlike manner. This is not surprising, because human cognition requires language to communicate with other people for mutual understanding (van Dijk, 2012). Some participants had expected to be able to do this with the current robot and were somewhat disappointed when they found out that the Karotz robot could only understand preprogrammed commands.

> "He doesn't communicate with you. You have to push a button and then you could give [the robot] commands. Sometimes he answers, sometimes he doesn't." - female, 57, living alone
>
> "[For the robot to be perceived as a social companion] he needs to interpret the things I say. He basically needs to continuously receive things and send out without needing to push the button." - male, 32, living alone

THOUGHTS AND FEELINGS

Another frequently noted topic was thoughts and feelings. Robots should be embedded with thoughts and feelings. Robots should be able to think for itself and act upon it. In addition, a robot be able to display humanlike emotions.

> "[The robot] can't laugh or cry or look sad… If he wants to be a full-fleshed interaction partner, he needs to be able to shows his emotions." - male, 32, living alone
>
> "That [the robot] can signify his emotions. So instead of a printed face, you could have a mouth. That he can laugh or cry… That he can signify with his face what is going on." - female, 19, living in student dorm
>
> "When such a device becomes intuitive, gets more emotions, becomes more intelligent or something. Than it will be different… Then you will treat it differently too." - male, 31, living alone

SOCIAL AWARENESS

The participants also indicated that robots should be aware of their social environment. Robots must be able to sense our presence and our moods to be able to be perceived as companions.

> "[The robot] doesn't respond to noise, except when you push that button. So he needs to permanently distinguish sounds and interpret and react upon them. That is when you could be speaking of contact." – male, 32, living alone
>
> "[The robot] should react better to what he does… That his ears turn when you come in… That would make you perceive it more as something alive." – female, 27, living with spouse

SOCIAL SUPPORT

Another topic noted to elicit human-robot companionship, though much less discussed, was social support. With social support, the participants referred to their friends being there for them to support them when needed and sharing life experiences with each other. For the possibility perceive robots as companions, there should be a trust relationship between a human and a robot and knowing that you can always count on it to be there for you.

> "That you share stuff. That you have the feeling you can count on each other." – female, 57, living alone
>
> "To share stuff. I have different friends for different purposes. With one friend I talk about superficial stuff and with another friend I can share more serious stuff when something is bothering me… And sports friends. And in that way I have for my different needs several people around me." – female, 27, living with spouse

AUTONOMY

Also much less noted was the topic of autonomy. With autonomy, the participants particularly referred to the fact that the robot used for this study was standing still. For a robot to be perceived as a companion, the participants need that robot to be able to move around independently and behave unpredictably and spontaneously and not only have pre-programmed behaviors. Increase the robot's presence would let it be perceived as more animate or alive. With autonomy, the participants indicated that they would want the robot to act on its own.

> "It needs to be a completely movable robot. More in the direction of humans instead of something static. Then it would be more suitable for companionship." – male, 24, living alone
>
> "If [the robot] could move more, it would be more alive… For example driving around… or some more degrees of freedom, so not just moving its ears." – male, 32, living alone

COZINESS

The topic of coziness was noted a few times by the participants as a characteristic for human-robot companionship. With coziness, the participants discussed to their experiences hanging around with their friend just for the sake of being together. That feeling of companionableness is something the participants would miss when in the company of a robot. Coziness or companionableness seems to be a predecessor of intensive social interactions.

> "For me companionableness is important. I like it to be surrounded by a group of people to talk to." – female, 22, living in student dorm
>
> "Coziness off course. Just to talk to each other and have some drinks." – female, 19, living in student dorm

SIMILARITY

Similarity as a characteristic for human-robot companionship was also much less noted. Related to the topic of similarity, a few participants said that their friends are their friends because they share similar personalities or similar interests with them which makes is easier and more pleasant to interact with.

> "What I like about people is that they talk and have feeling that are similar to mine." – female, 22, living in student dorm
>
> "Having resemblances with people. And to talk about that with each other, and to brainstorm with someone who has the same interests. That is nice to that to. I think that is important" – male, 38, living with young family

MUTUAL RESPECT

Another topic noted only a few times was mutual respect. A few participants explained that the way they spook to the robot was different from how they interact with other people. They were quite rude and blunt to the robot, because they knew that the robot would not respond to that behavior. So in order for them to perceive robots as a companions, they should perceive the robot as a higher form of intelligence which would make them feel obligated to treat the robot with respect.

> "You are rude [to the robot], because you think that the robot doesn't have any feelings." – male, 32, living alone
>
> "[The robot] is defenseless, so he can't say anything back. I also think you make shorter sentences, or even talk to him in stop words. Because he doesn't understand it anyway." – female, 19, living in student dorm
>
> "When [the robot] begins to speak, I say 'shhh, what is it saying?'. So maybe you don't really speak to him, but you do talk about him. – female, 38, living with mature family

Now that more is known about people's perceptions of robots and their recommended characteristics for social behavior, the next section discusses people's evaluations of robot appearances.

EVALUATING ROBOT APPEARANCES

A growing number of robotics researchers believe that robots will come to live with us as assistants and companions. To make the diffusion of social robots a success, it is important to study the users' design preferences of domestic robots in an early stage of their development process, so that future social robots can be adapted to their desires and requirements. As discussed section 2.1, four different robotic appearances have been defined by Fong, Nourbakhsh, and Dautenhahn (2003): humanoid robots with a humanlike appearance, zoomorphic robots with an animal-shaped appearance, caricatured robots with only an immediate association with an existing animal or human, and functional robots for which its shape is determined by its function. Although humanoid and caricatured robots seem to be dominant in human-robot interaction (HRI) studies, there is little research done on the users' preferences for either of the four robotics designs. Most HRI researchers use either humanoid or caricatured robots in their studies (Hwang, Park, & Hwang, 2013; von der Putten & Krämer, 2012). By including all four types of robotics appearances in the evaluation, this study could provide a more comprehensive insight into people's preferences for robotic appearances. Additionally, people's feelings towards robots influence their opinions towards robots (Nomura et al., 2008). People's negative attitudes and anxiety towards robots are thus an important factor to include when evaluation design preferences.

PARTICIPANTS

The Robotic Appearances Study, an online survey that has been conducted in May 2013, investigated people's evaluations of domestic robot appearances. The target population consisted of people between 25 and 45 years old living in The Netherlands. People in this age range are most likely to represent the innovators and early adopters who can effort newly introduced products on the market (Rogers, 2003). A total of 200 people were asked personally via Facebook to participate in the study with the question to also ask at least one other person in their own network (i.e., snowball method). In total, 266 people started the online survey of which 81 (30,5%) dropped out. In the end, a total of 175 people, 76 males and 99 females, between 25 and 45 years old (M= 29.10, SD= 5.29), completed the online survey.

PROCEDURE

A pre-test was conducted to select representative pictures that represent the four robot categories (i.e., humanoid, zoomorphic, caricatured and functional). First, 38 different robots pictures were chosen which included robots that (1) have not been in a movie, (2) are real embodied robots and not sketches, and (3) have neutral backgrounds. Second, these 38 robot pictures were presented to 11 (6 males, 5 females) participants representing the target group together with a brief description of the four robotic appearance categories of Fong, Nourbakhsh and Dautenhahn (2003). In the pre-test, the participants were asked to create four piles of the robot pictures based on these descriptions. Last, the four pictures for each category that were most frequently chosen by these participants were selected for the final version of the online survey.

In the final version of the online survey, the participants were asked to rate the 16 selected robot pictures (4x humanoid, 4x zoomorphic, 4x caricatured, and 4x functional appearance). The used robot pictures are displayed in figure 2.2 on the next page. The presentation order of the 16 robot pictures were randomized.

Humanoid appearances

Zoomorphic appearances

Caricatured appearances

Functional appearances

Figure 2.2: Pictures of robotic appearances used in the study

Table 2.6: Descriptive statistics of the variables

Variable	**M**	**SD**	**Cronbach's α**
Anthropomorphism	2.90	0.76	.87
Animacy	3.24	0.82	.87
Likeability	4.12	0.76	.90
Intelligence	3.53	0.83	.81
Safety	4.60	0.96	.82
Sociability	3.81	0.92	.90
Negative attitude towards robots	4.54	0.91	.69
Anxiety towards robots	3.72	0.96	.79

MEASUREMENTS

The participants rated all the pictures with the Godspeed scales of Bartneck et al. (2009). These scales are often used to evaluate robots, and includes the variables of anthropomorphism, animacy, likeability, intelligence and safety. Other studies investigating the domestic use of social robots indicate that the robot's sociability affects the users' satisfaction with such robots (Bartneck et al., 2004; Kirby et al., 2010; Woods, 2006). Therefore, Heerink et al.'s (2008) sociability measure was added to the evaluation. All items were presented on 7-point semantic differentiates. Because people's feelings towards robots may influence their evaluations of robots (Nomura et al., 2008), the participants' negative attitudes and anxiety towards robots were also administered in the online survey using the scales from Nomura et al. (2008). These items were presented on 7-point Likert scales. Table 2.6 on the previous page shows the descriptive statistics of the variables in the Robotic Appearances Study. The questionnaire concluded with asking the participants' age and gender.

RESULTS

A repeated measures ANOVA was conducted for all the evaluation factors separately between the four types of robotic appearances (see table 2.7). Humanoid robots were significantly more positively evaluated than all other robotic appearances on anthropomorphism ($F(3,171)= 424.79$, $p > .001$), animacy ($F(3,171)= 351.03$, $p > .001$), likeability ($F(3,171)= 274.04$, $p > .001$), intelligence ($F(3,171)= 318.66$, $p > .001$), and sociability ($F(3,171)= 138.49$, $p > .001$). Only for safety, the zoomorphic design was rated most positively ($F(3,171)= 119.81$, $p > .001$). All evaluations differed significantly from each other ($p < .05$), with an exception for the difference in likeability between caricatured and functional robots, the difference in safety between zoomorphic and functional robots, and the difference in sociability between zoomorphic and caricatured robots.

Additionally, the effect of the participants' negative attitudes and anxiety toward robots on their evaluations of the robotic appearances were investigated with regression analyses. The results showed that negative attitude toward robots has an effect on the scores of anthropomorphism ($R^2= .03$; $F(1,182)= 5.02$, $\beta= -.16$, $p= .026$), animacy ($R^2= .04$; $F(1,182)= 6.72$, $\beta= -.19$, $p= .01$), likeability

(R^2= .08; F(1,182)= 15.41, β= -.28, p < .001), intelligence (R^2= .06; F(1,182)= 11.59, β= -.25, p < .001), safety (R^2= .21; F(1,182)= 49.08, β= -.46, p < .001), and sociability (R^2= .08; F(1,182)= 16.45, β= -.29, p < .001). In addition, anxiety towards has an effect on the scores of intelligence (R^2= .04; F(1,182)= 4.44, β= -.15, p= .037), and safety (R^2= .14; F(1,182)= 30.94, β= -.38, p < .001). The other regressions with anthropomorphism, animacy, likeability, and sociability were non-significant.

Table 2.7: Evaluations of the four types of robotic appearances

	Robotic Appearance								**ANOVA**	
	Humanoid		Zoomorphic		Caricatured		Functional			
Evaluation Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	F(3, 171)	*p*
Anthropomorphism	3.95^{abc}	0.88	3.02^{ade}	0.77	2.41^{bdf}	0.76	2.22^{cef}	0.64	424.79	.000
Animacy	4.12^{abc}	0.90	3.52^{ade}	0.93	2.82^{bdf}	0.81	2.48^{cef}	0.63	351.03	.000
Likeability	4.70^{bc}	0.74	4.82^{de}	0.87	3.40^{bdf}	0.75	5.54^{cef}	0.78	274.04	.000
Intelligence	4.47^{abc}	0.94	2.77^{ade}	0.77	3.71^{bdf}	0.92	3.15^{cef}	0.68	318.66	.000
Safety	4.46^{abc}	0.99	5.10^{ade}	0.91	3.91^{bdf}	1.02	4.92^{cef}	0.92	119.81	.000
Sociability	4.58^{abc}	0.92	3.60^{ae}	0.80	3.68^{bf}	0.88	3.48^{cef}	0.74	138.49	.000

Bonferoni significance between two conditions at p < .05

^{a}= between humanoid and zoomorphic
^{b}= between humanoid and caricatured
^{c}= between humanoid and functional
^{d}= between zoomorphic and caricatured
^{e}= between zoomorphic and functional
^{f}= between caricatured and functional

2.5 CONCLUDING REMARKS

Roboticists must acknowledge that social robots are essentially not social themselves. Social robots are machines programmed in such a manner that their behavior is perceived by users as social which, in turn, evokes social responses from users. In other words, the robot's sociability lives in the interpretation of the user. This dissertation combined the descriptions of social robots from other scholars (e.g., Bartneck & Forlizzi, 2004; Breazeal, 2002; Lee, Park, & Song, 2005) and defined social robots as robots that elicit social responses from their human users because they follow the rules of behavior expected by their human users. However, given that the technology will inevitably change in the future, the definition of social robots may similarly change. Yet, the core of all the definitions of social robots in the literature, which is interacting socially in a humanlike way, will most likely remain.

ESSENTIAL SOCIAL ABILITIES FOR SOCIAL ROBOTS

It is interesting to see that potential users mention similar essential social behavior for future robots because social roboticists already pursue in their creations (Fong, Nourbakhsh, & Dautenhahn, 2003; Multu, 2012). The fact that the participants indicated two-way interaction as the most essential social skill is much related to social characteristic of dialog, which describes that robots should be capable to verbally communicate with us. Furthermore, participants indicated that robots should possess thoughts, feelings and emotions, and should be capable to sense their social environment. These characteristics show overlap with the social characteristic of learning and developing social competences, exhibit distinctive personality, and social learning. Learning and developing social competences describes that robots should possess a considerable amount of social skills to interact with their human counterparts. Exhibiting distinctive personality entails that robot should have a compelling personality (Breazeal, 2005), which can be expressed through emotions, embodiment, motion, manner of communication, and the tasks it performs (Fong, Nourbakhsh, & Dautenhahn, 2003; Severson-Eklund, Green, & Hüttenrauch, 2003; Yoon et al., 2000). Social learning and imitation partly entails the robot's ability to understand human mental models (Multu, 2011).

Much less reported were social support, autonomy, coziness, similarity and mutual respect. Social support, coziness and mutual respect could be included in the social characteristic of establish and maintain social relationships. Although these three behaviors are not explicitly noted under that characteristic, two features in this category, empathy and trust, together elicit social support and coziness to the human user. Moreover, the participants explained that the lack of mutual respect impedes intensive social interaction with a robot. Last, autonomy could be aligned under the social characteristic of exhibiting distinctive personality, which entails a personification of the robot. Similarity is in line with the social characteristic of social learning and imitation, which includes mimicking and imitating human social behaviors. Although we can conclude that robots are not even close to behaving socially in an ideal manner, this is not fully necessary because the creative human mind will restore these shortcomings with the subconscious process of the media equation.

UTILITARIAN AND HEDONIC ELEMENTS OF HUMAN-ROBOT INTERACTION

Examining what is outlined in this chapter, it is shown that, although social robots are utilitarian and productivity-orientated systems, they also are hedonic and pleasure-orientated systems trying to engage us by simulating human social rules. Results from various research studies imply that social robots are a new technological genre that might challenge traditional ontological categories between animate and inanimate (Kahn et al., 2006). This new technological genre comprises artifacts that are autonomous (e.g., initiating action), adaptive (e.g., act in response to their physical and social environment), personified (e.g., convey an animal or human persona), and embodied (e.g., the computation is embedded in the artifacts rather than just in desktop computers or peripherals). Thus, the suitability of the human-computer interaction question whether something is alive or not might be at stake, and what may be needed is a more nuanced psychology of human-robotic interaction that can reveal emergent categories in peoples' understanding of and relationships with this new technological genre. Therefore, researcher should be cautious when generalizing existing technology acceptance theories to social robots, even though the technologies have similar characteristics, because the comparability with regular technologies might be more complex than initially assumed (Karahanna & Limayem, 2000). To be able to obtain a complete view on the user acceptance of social robots, a model is needed that explores the acceptance of social robots in a broader holistic way including both the utilitarian and the hedonic elements of social robot interaction. Consequently, this approach allows for a dual perception on social robots as functional products as well as conversational partners with which some kind of relationship is possible (Heerink et al., 2010). The next chapter will critically review a variety of existing theories on technology acceptance and human behavior in their suitability for social robot acceptance.

PART II

ADOPTION

3

GENERAL THEORIES OF TECHNOLOGY ACCEPTANCE

"Technology has to be invented or adopted."
– Jared Diamond –

The previous chapter provided a definition of social robots based on the human-robot interaction literature as well as from a users' perspective and concluded with the notion that social robots are a new technological genre. This chapter will explore the relevant theories on human behavior and technology acceptance from different scientific backgrounds. The goal of this dissertation is to explain how and why people (would) use social robots in their own homes. This emphasizes the focus on technology use and acceptance behavior as the outcome variable. Therefore, this chapter includes only those theories that focus on predicting human (technology use) behaviors as their outcome variable and excludes theories where behavior is the starting point of explaining why and how people behave as they do, such as the cognitive dissonance theory (Festinger, 1957) or the social judgment theory (Hovland & Sherif, 1980).

Moreover, acceptance is not static decision, but acknowledged here as an ongoing evaluation and reevaluation of the adoption decision. Therefore, this chapter will make a first attempt to place existing human behavior and technology acceptance theories within a framework of the long-term technology acceptance process. In doing so, this chapter will start with an introduction to the different 'neutral' stages of the process of long-term technology acceptance. Thereafter, existing theories of technology adoption and human behavior, coming from the disciplines of psychology, sociology and communication science, will be described that provide useful insights for explaining social robot acceptance. For each theory, it will be discussed where in the acceptance process it will be most fruitful for research. Finally, this chapter concludes with the theoretical basis for a model of social robot acceptance.

3.1 TECHNOLOGY ACCEPTANCE AS A CONTINUOUS PROCESS

Technology acceptance is regarded from different perspectives in the literature. Moreover, most technology acceptance theories and models do not acknowledge the fact that technology acceptance needs to be considered as a long-term decision-making process. However, every theory has a specific stage to which it should be linked. Because there haven't been any descriptions formulated yet about neutral stages of technology acceptance, this section will take this first step in describing these stages. This framework of neutral acceptance stages will then be used in the following sections to connect existing general theories of technology acceptance to these stages, as it is presumed here that every technology acceptance theories has a main focus on one of these stages.

Acceptance begins with so so-called initial causes. Before people even think about buying a technology, they are already exposed to (images and stories of) that technology. In the case of robots, people have already seen movies or documentaries of robots. Or maybe your neighbor is very tech-savvy and already owns a few high-end technological devices with which you have come in contact with. Today, several households around the world have already adopted a robot vacuum cleaner. These stories about robots influence people's attitudinal and affective responses to robots. When all these external influences have a positive effect, a person might actually consider to use that technology in the future. This is called behavioral intention, which is in case of robots the readiness of a person to use a robot. After the behavior intention follows the start of the actual behavior, which is in case technology use the adoption. Adoption is the decision that leads to the acceptance (or rejection) of a technology. This is where people actually start using the technology and gain their first serious user experiences with the technology. The period that follows after the adoption is called initial use. This is when people are trying out the different functionalities of the technology to get familiar with it. They are exploring what purposes of the technology fits their own needs. This is a process of trial and error in which frustrations are not uncommon. After this period of exploration, people have had the time to figure out whether or not the technology offers an advantage and the next period of sustained use is about to begin. People are now completely familiar with the technology. When people have discovered how a technology can be of use, people incorporate the technology into their everyday lives. They create routines of use which might even become use habits.

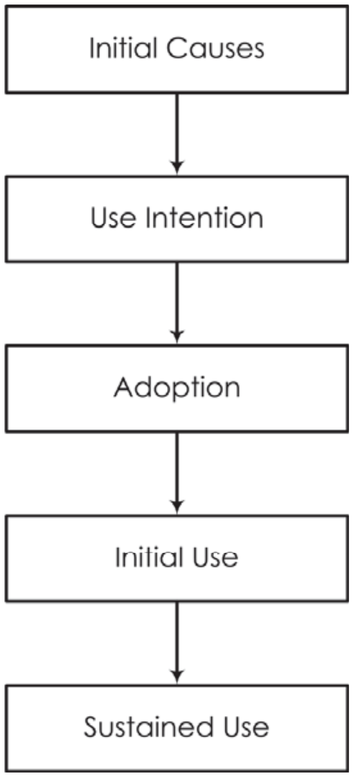

Figure 3.1: Stages of technology acceptance

Thus, the full decision-making process of technology acceptance involves several stages (see figure 3.1). And although there are many theories that focus on technology acceptance, none of them really acknowledge these different stages in the acceptance process nor do they indicate in which of these stage their theory could be most useful. In the following sections, some theories that provide insight into technology acceptance are presented and simultaneously linked to a stage within the decision making process of technology acceptance.

3.2 INSIGHTS FROM A PSYCHOLOGICAL PERSPECTIVE

THEORY OF PLANNED BEHAVIOR

The theory of planned behavior, which is an extension of the theory of reasoned action (Ajzen & Fishbein, 1980), has been one of the most influential, well-researched theories in explaining and predicting behavior across a variety of settings (Manstead & Parker, 1995). As a general model, it is intended to provide a parsimonious explanation of informational and motivational influences on most human behavior and can therefore be used to predict and understand human behavior (Ajzen, 1991). The approach of the theory of planned behavior is embedded in expectancy-value models of attitudes and decision-making, with an underlying logic that the expected personal and social outcomes of a particular action influences the intention to behave in a certain way (Manstead & Parker, 1995). According to the theory of planned behavior, the main determinant of a behavior is a behavioral intention, which in turn is determined by attitude, subjective norm, and perceived behavioral control. Attitude captures an individual’s overall evaluation of performing the behavior, whereas subjective norm refers to an individual’s perception of the expectations of important others about the specific behavior. Because the achievement of behavioral goals is not always completely under volitional control, Ajzen (1991) has added a third concept to the prediction of behavior with perceived behavior control. Perceived behavioral control is an individual's perceived ease or difficulty of performing the particular behavior and is conceptually related to Bandura’s (1977) self-efficacy. The concept of perceived behavioral control may encompass both internal (e.g., skills, knowledge, adequate planning) and external (e.g., facilitating conditions, availability of resources) factors. The model is displayed in figure 3.2.

Although the theory includes the actual behavior in its model, the application of this model comes to its full advantage in the stage of use intention. The explanatory power of most independent variables end at behavioral intention. Moreover, according to Taylor & Todd (1995), who reviewed several technology acceptance models, the theory of planned behavior excels at explaining use intention compared to other technology acceptance models, especially when it is decomposed to a specific technology.

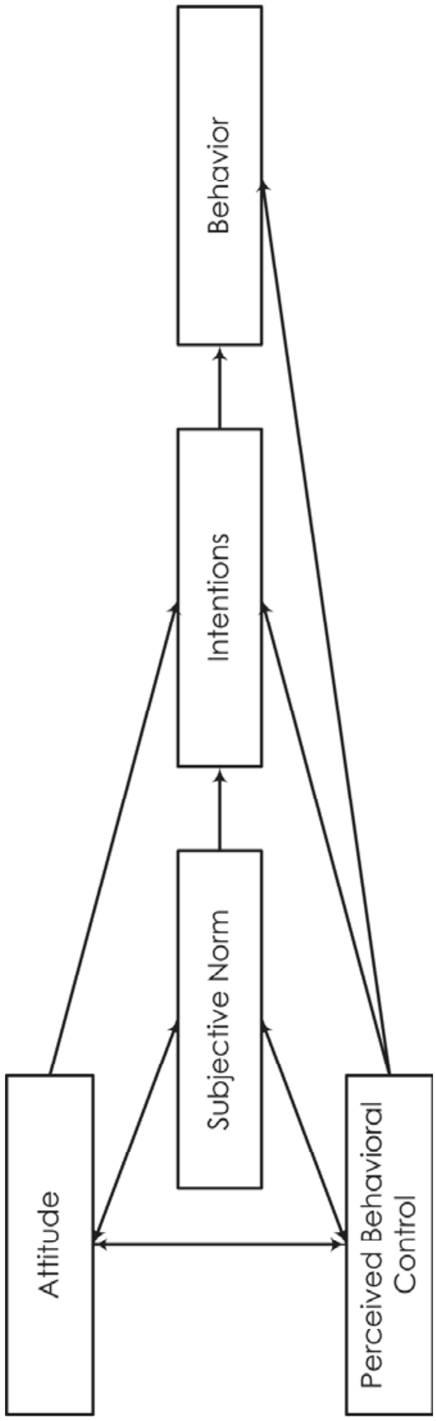

Figure 3.2: Theory of planned behavior (adopted from Ajzen, 1991)

LIMITATIONS OF THE THEORY OF PLANNED BEHAVIOR

The theory of planned behavior could be criticized on its original model and the hypothesized relations between its constructs. Only moderate correlations exist between the global and belief based measures of its constructs (Bensabat & Barki, 2007), which entails that these concepts are not strongly related and other influences might play a role in the formation of people's beliefs about a certain behavior. Moreover, the model suggests correlations between attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991), which results in a lack of knowledge regarding the precise nature of the relations between these concepts.

Meta-analytic reviews on the theory of planned behavior (e.g., Armitage & Conner, 2001; Sheppard, Hartwick, & Warshaw, 1988) indicate that a substantial proportion of the variance of behavior intention remains unexplained by the core variables of attitudinal beliefs, subjective norm and perceived behavior control. This has led other researchers to postulate that other factors play a role in explaining and predicting human behavior (Bentler & Speckart, 1981). The theory of planned behavior has also been challenged for its claim that attitude, subjective norm and perceived behavior control are the sole antecedents of intentions. The critics on this can be divided in four groups: (1) those who challenge the lack of emotional components in the model; (2) those who criticize the sole focus on social pressure in the social components in the model; (2) those who criticize the assumption that all behaviors are consciously performed; and (3) those who argue that much behavior is a result of habitual routines.

First, the theory of planned behavior mainly focusses on cognitive or instrumental components and neglects affective evaluations or emotional aspects of behavior (Bagozzi et al., 2001). However, while both concepts are highly correlated, they can be empirically discriminated and have different functions (Brecker & Wiggens, 1989; Greenwald, 1989). Human behavior is not purely rational. In fact, emotions are considerably tangled in the determination of human behavioral reactions to environmental and internal events of considerable importance for the needs and goals of an individual (Izard, 1977). Many researchers postulate that it is impossible for humans to act or think without involvement of, at least subconsciously, our emotions (Mehrabian & Russell, 1974). Indeed, beside rational evaluations and expectation formation, also non-rational attitudes, feelings and other affective or emotional-related concepts have been acknowledged by other researchers to have an effect on human behavior (Limayem & Hirt, 2003; Manstead & Parker, 1995; Richard, van der Plicht, & de Vries, 1995; Sun & Zhang, 2006). If emotions affect human behavior in general, they might be relevant for HRI research as well. Indeed, several studies indicate that people show emotional reactions when confronted with robots. People are more aroused after watching a robot being tortured as compared to watching a robot being petted (Rosenthal - von der Pütten et al., 2013). Moreover, people's negative affect towards robots decreased significantly after an interaction with a robot, which in return explained a large amount of variance in the overall rating of the robot (Stafford et al., 2010). As negative emotions are naturally unpleasant, people tend to perform corrective behaviors or avoid bad behaviors to mitigate the negative emotions (Izard, 1977). This reasoning clearly states the importance of including emotion as an influencing factor of human behavior.

Second, the theory of planned behavior has a narrow conceptualization and focusses solely on social pressure experienced when making decision about human behavior (Rivis & Sheeran, 2003; Sheeran & Orbell, 1999). Previous studies have mostly used subjective norm to capture the essence of social influence, but their inconsistent findings has led some researchers to question whether it captures the full extent of social influence (Lee, Lee, & Lee, 2006). Therefore, some researchers have expressed the must further articulate the link between social influence and technology acceptance (Karahanna & Limayem, 2000). Only a few empirical studies have investigated the underlying components of normative beliefs (Fisher & Price, 1992), and other researchers suggest the introduction of further dimensions to the theory of planned behavior to tap the complete function of normative beliefs in explaining human behavior (Fishbein et al., 1992; Sheeran & Orbell, 1999). Therefore, an further exploration on additional factors that increase to explanatory power of the normative component is needed.

Third, although making the above extensions and alterations to the theory will enhance the insight in the rational-based and deliberate nature of behavior, its assumption that people consciously perform their behaviors might be a problem on its own. In general, psychological research originates from goal-directed human behavior and rely on expectancy-value models of attitudes and decision making which are rooted in theories of rational choice. The theory of planned behavior may be considered as one of the most influential models in this perspective (Aarts, Verplanken, & van Knippenberg, 1998). Although humans are the only animal species with the ability to meta-cognition or the ability to reflect on your own actions and to think about your own thought (Cartwright-Hatton, & Wells, 1997). For example, when a ball is thrown at you, your reflex will most likely be to catch that ball without thinking about that action. Indeed, our environment is capable of activating goal-directed behavior automatically without a person's awareness (Bargh & Gollwitzer, 1994). Thus, not all human behavior is part of a conscious decision making process, which is an assumption of the theory of planned behavior.

Fourth, in the same line of thought, other researchers postulate that the theory of planned behavior overlooks the fact that human behaviors are executed on a daily, repetitive basis, and therefore may become routinized or a habit (Aarts, Verplanken, & van Knippenberg, 1998). People are likely to use the experiences from similar previous behaviors in the part to make their decision of performing the current behavior. Although Ajzen (1991) incorporates previous behavior into his theory, he presumes that the impact of past behavior produces feedback through subsequent attitudes and perceptions of social norms and behavioral control. However, as the majority of our behavioral repertoire is frequently performed in the same physical and social environment, behavior usually becomes habitual in nature (Ouellette & Wood, 1998; Triandis, 1979). Habits allow us to perform our behaviors in a rather 'mindless' state and therefore may be conceived of as automatic behavior. Automatic processes lack effortful attention (i.e., are cognitively efficient), intentionality, awareness, and/or controllability (Bargh & Chartrand, 1999). Most habitual behavior arises and proceeds efficiently, effortlessly, and unconsciously (Aarts, Verplanken, & van Knippenberg, 1998), and technology use is often associated with habitual use

(Ortiz de Guinea & Markus, 2009). Thus, by omitting non-rational, routinized and automatic behaviors, the theory of planned behavior might in its original state not suitable to predict human behavior. Moreover, robots for domestic use should be socially accepted within our society as well. This is a process that contains, besides rational decisions to adopt a robot system, also emotional evaluations of the technology (Scopelliti, Giuliani, & Fornara, 2005; Weiss, Igelsböck, Wurhofer, & Tscheligi, 2011). Additionally, robots for domestic use have to be accepted by households. Thus, although social robot acceptance might be an individual decision, these decisions are influenced by the social structure of the household which argues for the inclusion of a more social perspective.

TECHNOLOGY ACCEPTANCE MODEL

The technology acceptance model, developed by Davis (1989) is considered to be the most influential and commonly applied theory for describing an individual's acceptance of information systems (Lee, Kozar, & Larson, 2003). The widespread popularity of the technology acceptance model is broadly attributable to three factors. First, it is a parsimonious and IT-specific model designed to provide an adequate explanation and prediction of the acceptance of a wide range of systems and technologies among a diverse population of users within a varying organizational and cultural contexts and expertise levels. Second, the model has a strong theoretical base and a well-researched and validated inventory of psychometric measurement scales, which makes its use operationally appealing. And third, the model has accumulated strong empirical support for its overall explanatory power and has emerged as a pre-eminent model of users' acceptance of technology (Yousafzai, Foxall, & Pallister, 2007). The technology acceptance model views user acceptance as being dependent upon the perceived usefulness of the technology and its perceived ease of use. The model was first developed by Davis (1989) to provide validated measurement scales for predicting the user acceptance of computers, as such subjective measure were not validated at that time and their relationships to systems use were unknown. The model adopts a causal chain of beliefs, attitudes, intention, and behavior which social psychologists (Ajzen, 1991; Fishbein & Ajzen, 1975) have introduced before. Based on certain beliefs, people form attitudes about a certain object, on the basis of which they form an intention to behave with respect to that object. The model is presented in figure 3.3.

Here, also the effects of the independent variables end at intention to use or even attitude towards use. In this model, the only predictor of actual system use is behavioral intention. However, the literature suggests that other factors might play a role in explaining use behavior, such as expected outcomes and habit (LaRose & Eastin, 2004), motives to use a technology (Katz, Blumer, & Gurevitch, 1973), or environmental factors (Bandura, 1986). Together with the fact that the technology acceptance models is based on the principle of the theory of planned behavior, the same recommendation applies for its application in the acceptance stage of use intention.

LIMITATIONS OF THE TECHNOLOGY ACCEPTANCE MODEL

Although the technology acceptance model has been found to be a useful predictor of acceptance behavior in numerous contexts, the technology acceptance model does not provide a mechanism for the inclusion of other salient beliefs (Benbasat & Barki, 2007) as has been done in the unified theory of acceptance and use of technology (Venkatesh et al., 2003). As a result, many recent studies worked on the elaboration of the model including Davis and his colleagues themselves. A review on TAM related research shows that many determinants of perceived usefulness and perceived ease of use have been discovered (Lee, Kozar & Larsen, 2003). Therefore, the creators of TAM have advanced their original model which resulted in the introduction of the second edition of the technology acceptance model (Venkatesh & Davis, 2000) and later even a third edition (Venkatesh & Bala, 2008). But even this third edition of the model is still somewhat limited.

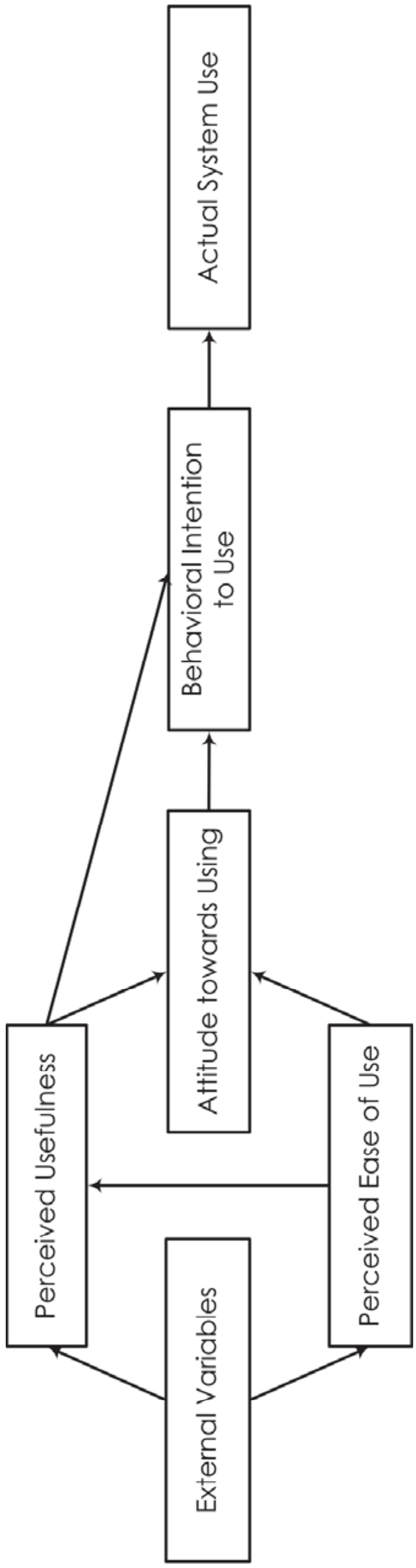

Figure 3.3: Technology acceptance model (adopted from Davis, 1989)

The relation among perceived usefulness, perceived ease of use, and use behavior may be more complex than previously assumed by the technology acceptance model. Social influence, as depicted in the theory of planned behavior (Ajzen, 1991), facilitating conditions (Venkatesh et al., 2003) as well as habitual use (Oullette & Wood, 1998; Triandis, 1979) have also been found to explain actual use directly, and not only, as the original technology acceptance model assumes, mediated through usefulness and ease of use. The construct of social influence may be important in explaining the relation or lack of relation between the beliefs of usefulness and ease of use on the one hand and technology use on the other hand (Karahanna & Limayem, 2000). This would argue for a direct effect from social influence on use behavior. Additionally, the technology acceptance model assumes that technology use is directly accepted or not accepted without any barriers preventing individuals from using a technology. However, many situations, such as lack of time, money or experience, can withhold individuals from using a technology (Mathieson, Peacock, & Chin, 2001). Moreover, an extended literature review on the continued use of information technology concludes that future research on technology use behavior should switch its focus from intentions or decisions to behavior and action (Ortiz de Guinea & Markus, 2009). This implies that the technology acceptance model including its modifications are valuable for understanding initial adoption decisions and technology replacement decisions, but less useful for the foundations for long-term technology acceptance.

Other criticizers argue that the overly simple conceptualization and operationalization of the constructs of usefulness and ease of use have disabled researchers to understand the internal workings of these central constructs within the technology acceptance model (Bensabat & Barki, 2007). Moreover, the focus of the adoption literature on the technology acceptance model, and thus the utilization of the same method, has heightened the risk of common methods variance. Common method variance is the variance attributable to the measurement method rather than to the constructs the measurements represent (Podsakoff et al., 2003). In this case, the problem lies with asking participants whether or not they think a technology is useful together with asking them whether they intend to use that technology in the future. A result of the process of cognitive dissonance (Festinger, 1957) is that people who are using a certain technology would instantly reason that the technology must be useful, otherwise why would they be using that technology? Thus, respondents are not giving the researchers evidence that is independent of the method that is used to collect it (Straub & Burton-Jones, 2007). Common method variance is a potential problem in all behavioral research (Podsakoff et al., 2003) and the only way to avoid it is to collect actual usage behavior (e.g., log data). But this approach goes against the cumulative tradition of technology acceptance research which is largely based on self-reported measures.

Additionally, the literature supporting the theoretical framework of the technology acceptance model largely depends on student samples (Lee, Kozar, & Larson, 2003). This raises the questions of how representative this group is for the working environment over which the studies claim to provide insights in the technology adoption process.

Moreover, a small group of researchers is responsible for most articles published on the technology acceptance model in major information system research journals (Lee, Kozar, & Larson, 2003). This implies that a large body of research on the technology acceptance model has been published from identical perspectives, within similar context, and the researchers may even have used of the same datasets.

The technology acceptance model is a very economical model that does not specifically include other external factors besides usefulness and ease of use. Moreover, the model presumes that all those external factors are moderated by the evaluation of usefulness and ease of use. However, many studies adopting the principles of the technology acceptance model have demonstrated that several other factors directly influence behavioral intentions and actual behavior directly (see Lee, Kozar & Larsen, 2003 for a summary). In the case of social robot acceptance, besides usefulness and ease of use, also social influence, enjoyment and trustworthiness seem to have a direct effect on use intention (Heerink et al., 2010). And when people actually use a robot for a longer period of time, factors such as the physical space, the willingness to learn how to use the robot, the compatibility with habits and routines, emotional attachment and its cost play an important role (Fink et al., 2013). These examples indicate that the acceptance of domestic (social) robots is more complex that the economic model of the technology acceptance model. As a consequence, this raises objections against the applicability of this model for the investigation of social robot acceptance in domestic environments.

UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY

Some of the same researchers that worked on the modifications of the technology acceptance model, developed the unified theory of acceptance and use of technology (Venkatesh et al., 2003). For its development, the researchers conducted a review and consolidation of the constructs of eight theoretical models employed in earlier research to explain information systems use behavior (e.g., theory of reasoned action, technology acceptance model, motivational model, theory of planned behavior, a combined theory of planned behavior/technology acceptance model, model of personal computer use, diffusion of innovations theory, and social cognitive theory). In building this model, the researcher chose an empirical instead of theoretical approach. From all the constructs in all those theories, the researchers only picked those constructs for their model that were found be most significant in an empirical study studying the user acceptance of an information system. The unified theory of acceptance and use of technology holds that performance expectancy, effort expectancy, social influence, and facilitating conditions are direct determinants of use intention and actual use. Gender, age, experience, and voluntariness of use are posited to moderate the impact of these four key constructs on use intention and actual use. The inclusion of moderators to the model is a rather social psychological approach. The model is displayed in figure 3.4.

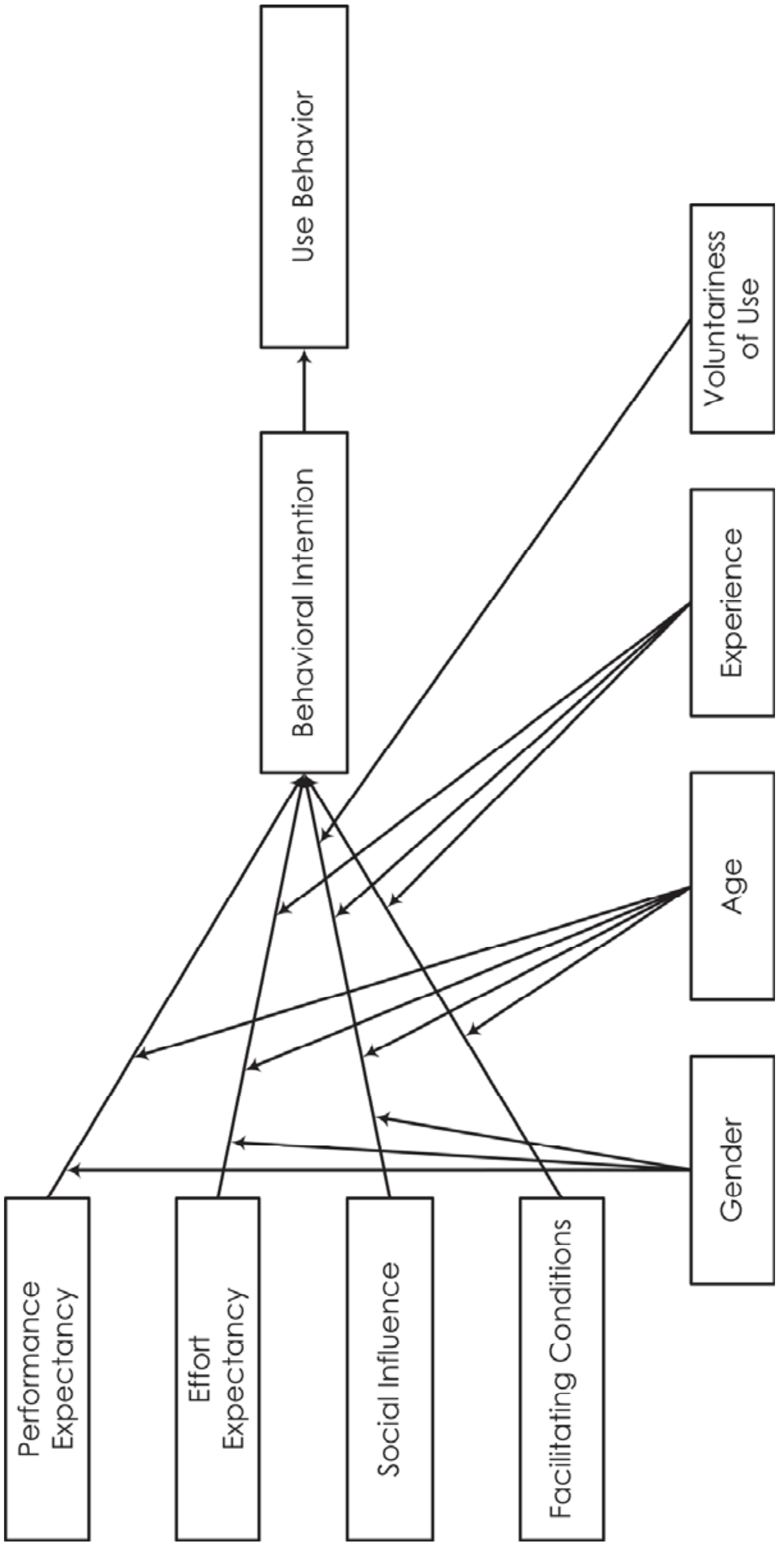

Figure 3.4: Unified theory of acceptance and use of technology (adopted from Venkatesh et al., 2003)

The unified theory of acceptance and use of technology is an eclectic model among others based on the technology acceptance model and the theory of planned behavior. Once more, the effects of the independent variables end at intention to use and the only predictor of actual system use is behavioral intention. Similar to what has been said above in a reflection on the technology acceptance model, the literature suggests that other factors might play a role in explaining use behavior, such as expected outcomes and habit (LaRose & Eastin, 2004), motives to use a technology (Katz, Blumer, & Gurevitch, 1973), or environmental factors (Bandura, 1986). Thus, once again, it is recommended to apply this model for the exploration of technology acceptance in the acceptance stage of use intention.

LIMITATIONS OF THE UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY

Obviously, the unified theory of acceptance and use of technology has both advantages and limitations for its utilization in acceptance research. An advantage is the holistic approach in explaining many psychological and social factors that might impact technology acceptance, together with the consistent validity and reliability of data collection through the instrument (Yoo et al., 2012). However, the unified theory of acceptance and use of technology is also seen as not parsimonious enough as it requires many variables to achieve a substantial level of explained variance (Straub & Burton-Jones, 2007). This, even despite the fact that it is an eclectic model which combines highly correlated variables to create an unnatural high explained variance (Yoo et al., 2012). Parsimony, e.g. the goal to identify factors that account for the most variance, is to be greatly valued (Burgoon & Buller, 1996), however, not at the expense of explanatory power. The unified model of acceptance and use of technology cannot explain the different underlying mechanisms. This would make the unified model more suitable for explaining the user's general opinions about expected use rather than for explaining the user's motivations related to the continued and increased adoption of a particular technology (Peters, 2011).

Even though the founders of the model are trying to extend the original model in a second edition (Venkatesh, Thong, & Xu, 2012), another disadvantage on the model is that both measurements of social influence and facilitating conditions are not robustly constructed. Both concepts are quite complex, but they are both measured with only two items. Additionally, adding social influence and facilitating conditions to the original technology acceptance model essentially brings us back to a model that is not very different from the model of the theory of planned behavior. The two constructs of social influence and facilitating conditions from the unified theory of acceptance and use of technology overlap considerably with the constructs of subjective norm and perceived behavioral control from theory of planned behavior constructs.

Moreover, the original technology acceptance model and the unified theory of acceptance and use of technology constructs were merely developed for utilitarian systems and validated in a working environment. The lack of applicability of these models on hedonic systems or more pleasure oriented systems is limited (van der Heijden, 2004). The use of social robots in domestic environments might cause an experience that goes beyond its utility. Moreover, these robotic systems are acknowledged to evoke social reaction from its users (Kahn et al., 2006; Lee, Park, & Song, 2005; Reeves & Nass, 1996). And the context wherein these models have been validated (e.g., in the working environment) is not in line with the objective of this dissertation, which is social robot acceptance in domestic environments. This suggests that other models might be more appropriate in this case.

MODEL OF ADOPTION OF TECHNOLOGY IN HOUSEHOLDS

The previous two models were primarily made to explain an employee's adoption and use of technologies in organizations. According to Brown and Venkatesh (2005), domestic environments differ from the workplace on numerous dimensions, such as the complexity of interactions and negotiations among the members of a household, differences in types of tasks, and the intricacies connected to the various stages of household life. The model of adoption of technology in households is a variation of the unified theory of adoption and use of technologies, the technology acceptance model and the theory of planned behavior. The model aims to explain individual adoption of technologies in home settings to the extent that it enhances the effectiveness of household activities. Again, the main construct is behavioral intention and is determined by attitudinal belief structure, normative belief structure and control belief structure. Attitudinal belief consists of utilitarian outcomes, hedonic outcomes and social outcomes. Utilitarian outcomes are defined as the extent to which using a technology enhances the effectiveness of household activities (Venkatesh & Brown, 2001). Hedonic outcomes are described as the pleasure derived from the use of a technology itself (Hirschman & Holbrook, 1982). Social outcomes can be thought of as the public recognition that would be achieved as a result of adopting an innovation (Fisher & Price, 1992). Individuals with higher perceived hedonic and utilitarian outcomes will have greater intentions to adopt a technology (Davis, Bagozzi & Warshaw, 1992). A higher positive effect of social outcomes on intention to use are expected from early adopters rather than from later adopters (Venkatesh & Brown, 2001). The normative belief structure, described as social influence, is the extent to which members of a social network influence one another's behavior (Rice et al., 1990), also explained as the perceived pressure to perform a given behavior (Venkatesh & Brown, 2001). According to its creators (Brown & Venkatesh, 2005), the model of adoption of technology in households can be applied to household technology adoption in general. The model is visualized in figure 3.5.

The concepts in this model originate from the technology acceptance model (Davis, 1987) and the unified theory of acceptance and use of technology (Venkatesh et al., 2003). Moreover, the dependent variable in this model is behavioral intention. Therefore, the model of adoption of technology in households is most applicable for research investigating technology acceptance in the acceptance stage of use intention. Yet, some predictors in this model, especially the emotional evaluations of technology use with fear of technology, points to the inclusion of initial causes of technology use. In in this manner, the model could also be applied to the initial causes stage of acceptance.

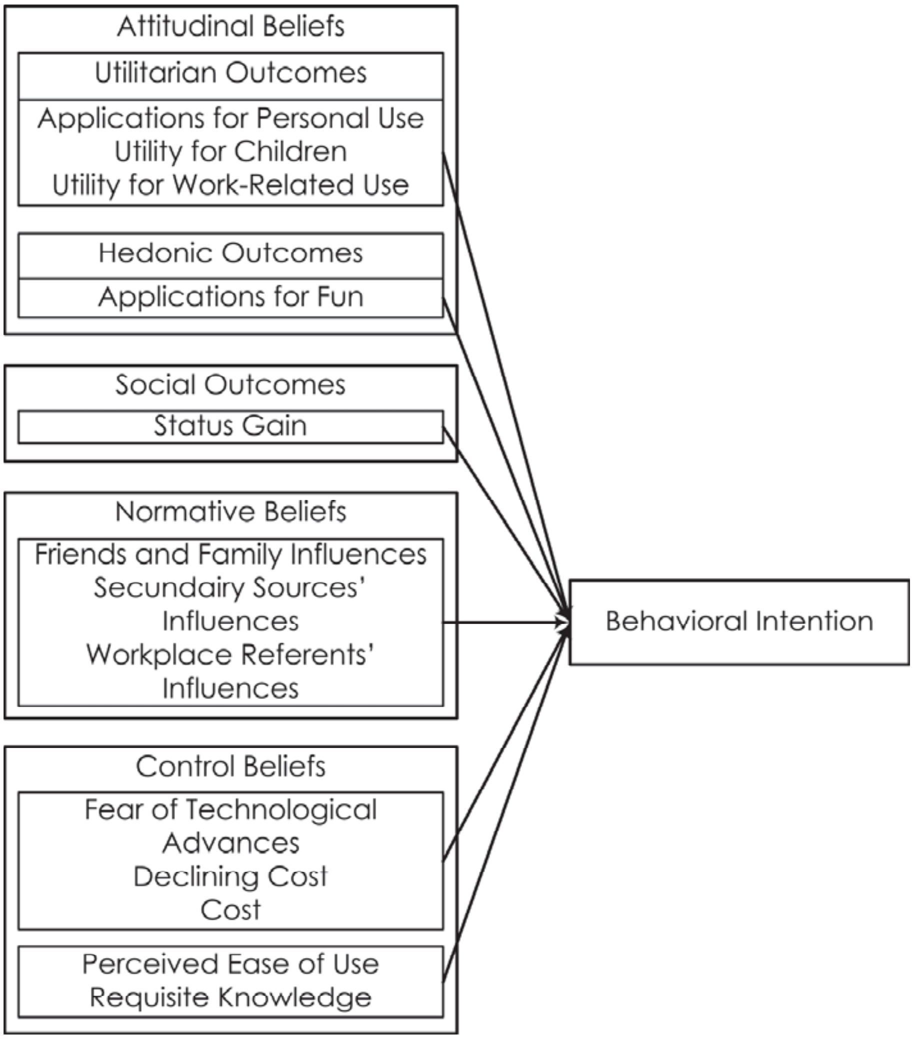

Figure 3.5: Model of acceptance of technologies in households (adopted from Brown & Venkatesh, 2003)

LIMITATIONS OF THE MODEL OF ACCEPTANCE OG TECHNOLOGIES IN HOUSEHOLDS

As with the technology acceptance model and the theory of planned behavior, the model of adoption of technology in households has also been criticized as being one-dimensional and limiting as it is based on rational causal models (Hynes & Richardson, 2009). Additionally, the are no relations hypothesized in this model between the independent variables. However, several studies indicate that such relations exist. For example, the theory of planned behavior hypothesizes correlations between attitudinal beliefs, normative beliefs and control beliefs (Ajzen, 1991). Moreover, the opinions of others persons within one's social network, in this model called normative beliefs, has an effect on self-efficacy, a concept that theoretically links most factors within the spectrum of control believes (Bandura, 1997). When above suggested relations are incorporated into the model, the strength of the direct effects of each of these independent variables will probably change. Moreover, the dependent end variable in the model is behavioral intention and not the actual behavior, which would suggest the actual acceptance of a technology (e.g., a person actually using the technology, not only intending to do so). Nevertheless, this model would be more qualified for studying the user acceptance of social robot in domestic environments, compared to the technology acceptance model and unified theory of acceptance and use of technology, as it includes a more meaningful set of predictors to explain people's use intention.

TRIANDIS MODEL

Most research on behavioral intention mainly focus on initial adoption and lacks the significance of post-adoption behavior of technology acceptance. Moreover, theories have been conducted under the implicit assumption that actual use is determined only by use intention. While this is plausible for initial adoption, this assumption might be inapplicable to post-adoption use behavior as it overlooks the tendency of frequently performed behaviors to transform into habits (Ouellette & Wood, 1998). The Triandis model indicates that probability of performing a given behavior is a function of the habit of performing the behavior, the intention, and the facilitating conditions (Triandis, 1979). Habit is a behavior that is or has become automatic in a given situation. When habit strength increases, behavior will be less guided by intentions to perform the particular behavior (Triandis, 1979). This means that habit strength moderates the relationship between the reason-based concepts of attitudinal beliefs and intentions and the subsequent goal-directed behavior (Ronis, Yates, & Kirscht, 1989). Triandis' (1979) line of thought suggests that although someone is goal oriented in performing the habitual behavior, achieving the goal is no longer guided by consciously created intentions concerning the particular behavior by which the goal is achieved. The assumption made here is that the decisions and actions executed with a specific purpose in a certain context in the past are stored and ready to be retrieved from memory when initiated. This idea is similar to the current conceptualization of goal-directed automaticity of habitual behaviors (Bargh & Gollwitzer, 1994) and supported by a meta-analysis on the effect of habit which indicated that future behavior is mostly influenced by behaviors that are executed frequently and consistently in a stable context (Ouellette & Wood, 1998).

Facilitating conditions are the objective environmental factors that several observers can agree upon make the behavior easy or difficult to perform. Triandis (1979) pointed out that if someone experiences an objective obstacle, then no behavior will occur even when the intention is strong and a habit is well established. Behavioral intention is driven by social factors, affect and perceived consequences of performing the behavior. Social factors are an individual's internalization of the subjective culture inherent in the reference group together with specific interpersonal agreements the individual made with others in specific social situations. This view of social influence is similar to the concept of subjective norm proposed in the theory of planned behavior. However, whereas the theory of planned behavior puts a person on an affective and cognitive bipolar evaluative dimension (Valois et al., 1988), the Triandis model separates the affective component from the cognitive component. Affect is the direct emotional response to the thought of a particular behavior. Perceived consequences are the consequences with value to the performer which are perceived as certain results of a particular behavior. This concept is similar to the concept of perceived usefulness in the technology acceptance model. The Triandis model is depicted in figure 3.6 (see next page).

The Triandis model is appropriate for the exploration of long(er)-term use. As habit is incorporated in the model, suggestions are that the behavior under investigation could have developed automatic use routines that can only occur when behaviors are performed over a longer period of time. Therefore, its main application should focus on technology acceptance in the sustained use stage.

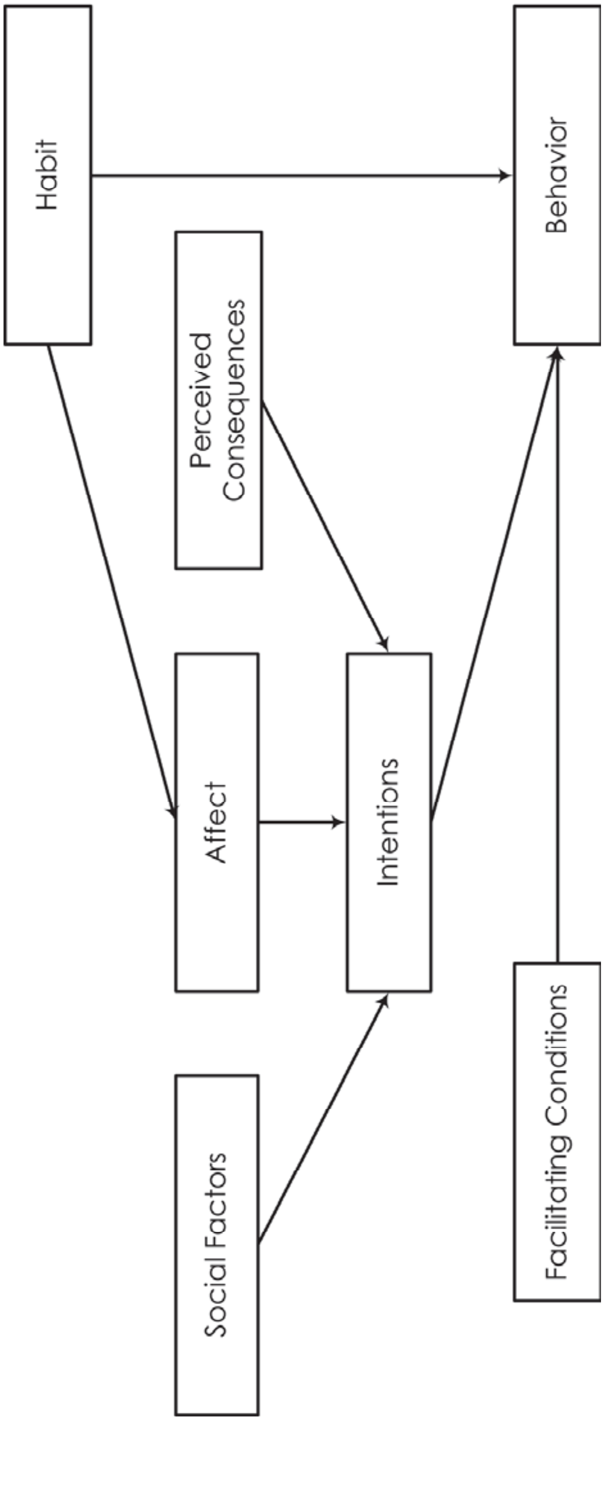

Figure 3.6: Triandis model (adopted from Triandis, 1979)

LIMITATIONS OF THE TRIANDIS MODEL

There are some problems with respect to the Triandis model. First, even though the model is more comprehensive than many other models, it still suffers from weaker and less standardized measurements for most of its constructs (Sheth, 1982). Similar to other models that include habit, some remarks can be found in the inconsistency of the habit measurement (Limayem et al., 2007). Often, the construct of habit is omitted or has been measured as actual use pattern, which does not contribute to the conceptualization of the construct and its role in explaining and predicting human behavior. Another point of criticism is found in the formation of the establishment of habits. The theory states that habitual behavior is triggered by environmental stimuli, but in the literature there is surprisingly little attention for what those stimuli might be (Ortiz de Guinea & Markus, 2009). Whatever the reason for this shortcoming might be, it is good to know that the environment has an influence on the (continuance) of technology use behaviors. Additionally, the operationalization of social factors is not as rigorous, as Triandis and colleagues have found high correlations between social factors and intentions (Sheth, 1982). This might be due to wording problems of the items which only show subtle differences from “I will” do this to “I must” do this to “I should” do this.

Besides the comments on the measurements of the constructs, this model seems both parsimonious and complete. The model includes habitual use, affective evaluations of technology use, social influences on use behavior as well as contextual conditions that might facilitate or impede the use of a technology. Both the concepts of habit and affect are welcome additions to the earlier discussed theories and their models, and could be important factors for the long-term use of social robots in domestic environments. As stated earlier, social robots have the potential to evoke emotional response (Kahn et al., 2006; Lee, Park, & Song, 2005; Rosenthal-von der Pütten al et., 2013), which validates the inclusion of the affective evaluation of a technology. Moreover, as social robot in the future become a commonly used technology in our homes and their users might create automatic or habitual use patterns. Thus, especially for investigating long-term use, the concept of habit could be an important predictor of social robot acceptance.

EXPECTANCY-CONFIRMATION MODEL

In contrast to the technology acceptance model (Davis, Bagozzo, & Warshaw, 1989) and the theory of planned behavior (Ajzen, 1991), the expectancy-confirmation model also looks at the long-term viability and continued use of technology rather than just its initial acceptance and the first time use experiences (Bhattacherjee, 2001). The expectancy-confirmation model does not assume a correlation between initial adoption and continued use as traditional models and theories do, such as the technology acceptance model (Davis et al., 1989) and the diffusion of innovations theory (Rogers, 2003). Bhattacherjee (2001) proposes a model based on the expectation-confirmation theory from Oliver (1980). The expectancy-confirmation theory has been widely researched in the context of consumer behavior to study consumer satisfaction, post-purchase behavior and service marketing in general (Dabholkar et al., 2000; Oliver, 1980). Bhattacherjee (2001) has extended its application to information systems acceptance research. Consumers decide to continue to use a product based on the level of satisfaction and confirmation of their prior expectations (Oliver, 1980). People's prior expectations thus form the baseline or reference level on which they evaluate a product (Bhattacherjee, 2001).

The expectancy-confirmation theory builds on five main hypotheses (Bhattacherjee, 2001). First, users' satisfaction with a technology is positively related to their continued use intention. Studies in consumer behavior have revealed that satisfaction is the major reason why people decide to repurchase products (Oliver, 1980). Based on the similarity between repurchasing products and the continued use of a technology, the expectancy-confirmation model theorizes that a similar relationship will hold in the context of technology's continued use.

Second, user's satisfaction with a technology is determined by users' confirmation of prior expectations. The confirmation of prior expectations suggests that people have obtained expected benefits from using a technology, hence resulting in a positive satisfaction with that technology.

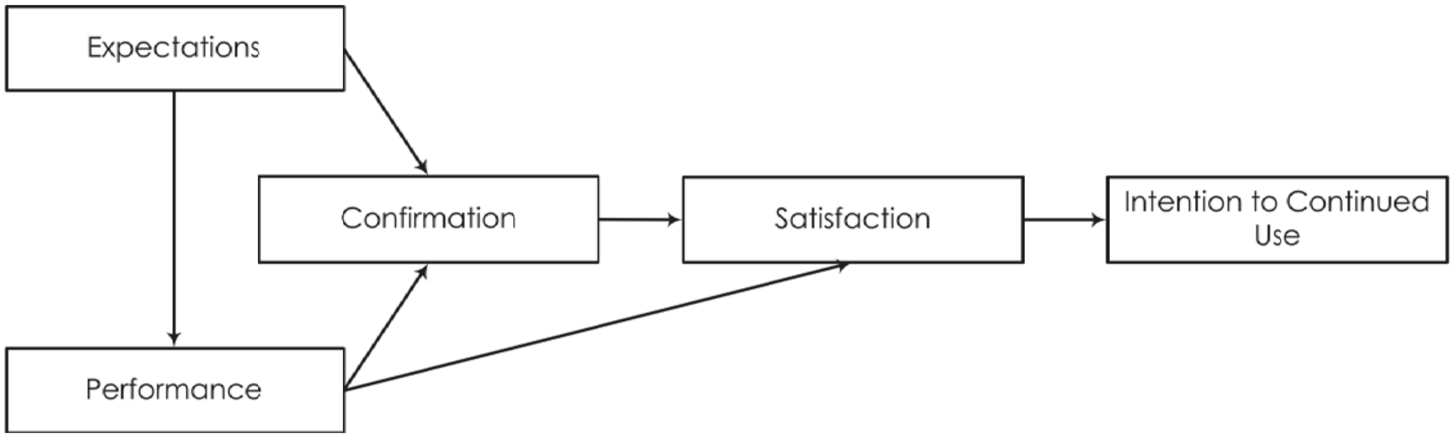

Figure 3.7: Expectancy-confirmation model (adapted from Bhattacherjee, 2001)

Third, users' perceived usefulness of a technology also influences their satisfaction with it. Based on the expectation-confirmation paradigm suggesting that satisfaction results from the confirmation of prior expectations, usefulness is suggested as baseline for reference against these confirmation judgments.

Fourth, a long history of technology adoption literature advocates that the most profound determinant of intention to use a technology is usefulness (Davis, 1989; Taylor & Todd, 1995; Venkatesh & Davis, 2000). The expectation-confirmation model thus postulates a direct influence of usefulness on the intention to continuing the use of a technology.

Fifth, the expectation-confirmation model assumes a positive influence of confirmation of prior expectations on perceived usefulness of a technology. When prior perceived usefulness is not concrete due to the uncertainty of what to expect from the use of a technology, the confirmation of expectations could have an effect on the initial expectations people have of a technology. Figure 3.7 displays the expectancy-confirmation model.

This model is suitable for the exploration of acceptance in the stages of initial or sustained use. The model explains future use of a technology based on (initial) use experiences and people's satisfaction with this use. This clearly endorses ongoing reflections on the technology, which is part of the decision-making process of acceptance in the phase of initial and sustained use.

LIMITATIONS OF EXPECTANCY-CONFIRMATION MODEL

The expectancy-confirmation theory can be criticized on several aspects. First, it overlooks potential shifts in consumer expectations during their use experiences and their impact on the evaluation of other factors of continued use. Pre-adoption expectations are most likely based on others' opinions or media exposures, while post-adoption expectations are influenced by first-hand experiences (Fazio & Zanna, 1981). Thus, the inclusion of social influence and robot related experiences, either through real face-to-face interactions with a robot or by watching or reading science fiction stories, cannot be omitted in a model of social robot acceptance.

Second, early research on expectation-confirmation reports varying and conflicting conceptualizations and operationalization of the constructs of satisfaction (Yi, 1990) as well as expectation (Bhattacherjee, 2001). This deficits the generalizations from the different studies done using this theoretical model.

A third remark can be made on the methodology of the theory and lies primarily in the measurement of disconfirmation. One solution is to directly measure this concept within a single construct, but this causes cognitive difficulties and lacks valuable information about the true nature of the relationship (DeVellis, 1991; Edwards, 2001). Another solution is to indirectly measure the concept of disconfirmation by computing it as performance minus expectation. However, this solutions suffers from measurement issues including ambiguity of expectation, unstable dimensionality, low reliability, discriminant validity and lack of predictive power (Cronbach, 1958; Johns, 1981; Wall & Payn, 1973). So either way, some issues remain with the measurement of disconfirmation. Another way to solve this problem is to avoid difference scores by creating subgroups based on the congruence between two component measures (Church & Waclawski, 1996). With this approach, respondents with self-scores above or below some threshold are classified accordingly. However, these created classifications entail difference score in disguise (Edwards, 2001), as this procedure is nothing more than subtracting another score from self-determined scores and subdividing the resulting difference scores. Therefore, this alternative approach is not a proper solution for this methodological problem.

The principles of expectations versus satisfaction could be very useful for the investigation of social robot acceptance. Some human-robot interaction studies (e.g., Fink et al., 2013; Lohse, 2011) have indicated a gap between people's prior expectations about a robot systems and the system performance in reality. And prior expectations have been found to affect the evaluation of that robot systems once people have been introduced to it (Komatsu, Kurosawa, & Yamada, 2012; Paepcke & Takayama, 2010). The evaluation of social robot acceptance that includes the evaluation of prior expectations and its influence on acceptance might provide additional insights into what kind of people will and will not accept such a robot in the future.

3.3 INSIGHTS FROM A SOCIOLOGICAL PERSPECTIVE

DIFFUSION OF INNOVATIONS THEORY

Diffusion research focuses on the conditions which increase or decrease the likelihood that a new technology will be adopted by prospective users. Studying how innovation occurs, Rogers (2003) has developed the diffusion of innovations theory. His theoretical framework has been widely used in the area of technology diffusion and adoption and has been applied in a variety of disciplines such as political science, public health, economics and education (Dooley, 1999; Stuart, 2000). According to Rogers (2003) diffusion is “the process in which an innovation is communicated through certain channels over time among the members of a social system” (p. 5).

This process of decision making goes through five stages: knowledge, persuasion, decision, implementation and confirmation. The adoption or rejection of an innovation result in changes in an individual or social system, and these consequences may create uncertainty. To reduce this uncertainty of adoption the innovation, people seek information about its advantages and disadvantages to make them aware of all its consequences. Based on this knowledge, in the persuasion stage the individual shapes a positive or negative attitude towards the innovation. Whereas the knowledge stage is more cognitive centered, the persuasion stage involves the affective side of the adoption process. The level of uncertainty and the reinforcement from other individuals in the persons social network affect his or her beliefs and opinions about the innovation. In the decision stage the individual chooses to adopt or reject the innovation. Adoption refers to “the full use of the innovation at the best course of action available” and rejection refers to “not to adopt an innovation” (Rogers, 2003, p. 177). In the implementation stage, the individual actually begins to use the innovation. The uncertainty about its consequences still play a role in this stage, thus an individual may still need assistance from others to reduce the degree of uncertainty. Reinvention usually happens in the implementation stage which mean that an individual changes or modifies the innovation in the process of adoption and implementation (Rogers, 2003). Although the adoption decision has already been made, at the confirmation stage the individual looks for information that supports his or her decision. The adoption decision may be reversed when an individual is confronted with conflicting information about the innovation (Rogers, 2003).

In addition to the adoption stages, the diffusion of innovations distinguishes five categorizes of users: 'innovators', 'early adopters', 'early majority', 'late majority' and 'laggards'. These categories follow a standard deviation-curve, very little innovators adopt the innovation in the beginning (2,5%), early adopters making up for 13,5% a short time later, the early majority 34%, the late majority 34% and after some time finally the laggards make up for 16%.

Moreover, Rogers' (2003) definition of diffusion highlights four key concepts in the theory: innovation, communication channels, time and social system. Rogers (2003) describes an innovation as an idea, practice or project that is perceived as new by an individual or another unit of adoption even if that innovation has been invented a long time ago. The second key concept of the theory is communication channels. Mutual understanding is reached through communication, which is a process or creating and sharing information between individuals. This communication occurs through channels between sources. According to Rogers (2003) diffusion is a special form of decision that includes the elements of the innovation, two individuals or other units of adoption and a communication channel. The social system is a set of interrelated engaging in joint problem solving activities to accomplish a common goal. As the innovation diffusion occurs within a social system, the adoption is influenced by the social structure of that system. Moreover, the nature of the social system affects the individual's innovativeness, which is the main criteria that distinguishes different types of adopters (Rogers, 2003). Rogers (2003) criticizes that the time element is ignored in most behavioral research and that including it is what illustrates one of the strengths of the diffusion of innovations theory. The time element includes the innovation-diffusion process, the adopter categorization and rate of adoptions.

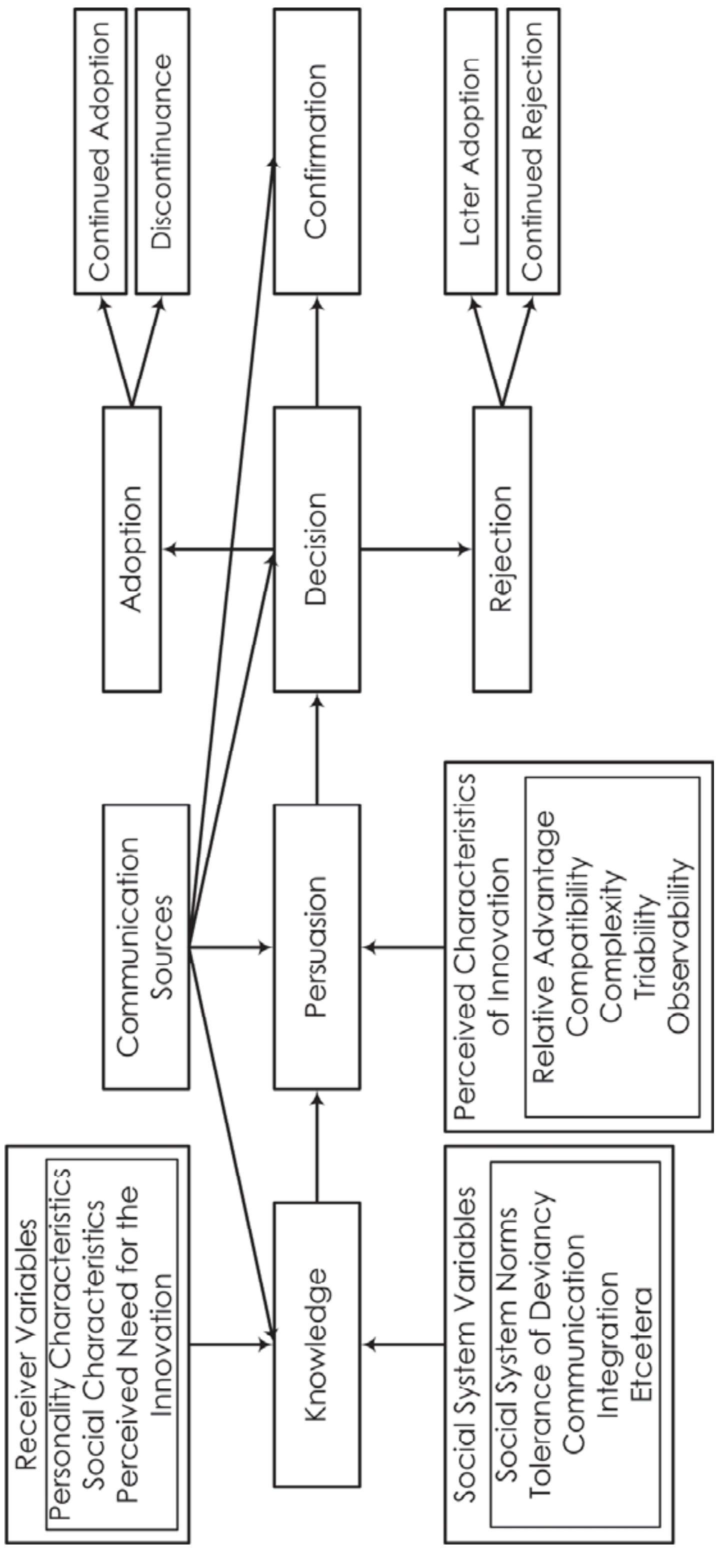

Figure 3.8: Diffusion of innovations model (adopted from Rogers, 2003)

Innovation diffusion research has attempted to explain the factors that influence how and why users adopt a new information medium, such as the Internet. Diffusion research has focused on five elements: (1) the characteristics of an innovation which may influence its adoption; (2) the decision-making process that occurs when individuals consider adopting a new idea, product or practice; (3) the characteristics of individuals that make them likely to adopt an innovation; (4) the consequences for individuals and society of adopting an innovation; and (5) communication channels used in the adoption process. The adoption model of the diffusion of innovations theory is shown in figure 3.8.

This model pays a lot of attention to the predictors that lead to the initial decision to adopt or reject a technology. Although the founder of this theory postulate that his model also includes continued use, the model has its main focus on the adoption decision as there are no predictors linked to the dependent variables of continued adoption or discontinuance nor to later adoption or continued rejection. Therefore, is argued that the main application of this theory belongs within the adoption stage of acceptance.

LIMITATIONS OF THE DIFFUSION OF INNOVATIONS MODEL

One remark on this model is that users appear to be privileged while non-users or informed rejecters are spoken about in terms of ‘missing out on something’ and lagging behind those who have followed the trend and ‘accepted’ the technology (Hynes & Richardson, 2009). Although the diffusion of innovations theory does acknowledge post-adoption phases, the theory regards these phases as an extension of acceptance behaviors hereby implicitly assuming that post-adoption behavior correlates with the initial adoption decision. This reasoning makes the theory incapable of explaining the discontinuance of technologies (Bhattacherjee, 2001). Another point of criticism on the diffusion of innovations theory is that it focusses on the decision to buy or not to buy a technology, and not on the process of using the technology itself (Renaud & Biljon, 2008). The theory can therefore not be used to explain how people use and incorporate technologies in their everyday lives.

DOMESTICATION THEORY

Based on a growing body of research (e.g., Sørensen, 1994; Silverstone & Haddon, 1996) a framework emerged that considered a process of shaping the adoption of use of information and communication systems. Hereby asking what technologies mean to people, how people experience these technologies, and what roles these technologies can play in people's lives (Haddon, 2011). The domestication theory originated partially from anthropology (e.g., Douglas & Isherwood, 1980) and partially from consumption studies (e.g., McCracken, 1990). Both these disciplines focus on how goods and possessions enter into our lives and the symbolic meaning they might have, which both relate to how people use these possessions (Haddon, 2011). The domestication theory aims to provide a framework for understanding how technologies shape, and are shaped by, their social contexts. Domestication emphasized its focus on the consumption rather than the purchase itself, and acknowledges the social structures of the home ecology in which the technology is places and its uses are negotiated both individually and with the other members of the group (Haddon, 2001). The domestication theory does not assume a rational, linear, mono-causal and technologically determined process, but considers a whole series of negotiations in the complexity of everyday life and technology's place within its dynamics, rituals, rules, routines and patterns (Ling, 2004). The domestication concept enables researchers initially to understand media use in the complex structures of everyday life settings, with attention to interpersonal relationships, social background, changes and continuities, but also to the increasingly complex interconnection between different media, and the convergence of different media technologies and media texts (Hynes & Richardson, 2009).

Social constructivist theories, such as the domestication theory, imply that meanings of technologies are shaped through the interactions between designers, social groups and policy makers (Bijker, Hughes, & Pinch, 1987; Fulk, 1993). Norwegian researchers (Lie & Sørensen, 1996; Sørensen, 1994) have linked the domestication theory to the social shaping of technology literature, a body of work concerned with why and how technologies emerge in the form they do. Central to the domestication process is the often subconscious attempt to make technologies fit into their surroundings in a way that makes the technologies invisible or taken for granted. This requires mutual adjustment on behalf of both the users and the technology, and this is where social shaping begins to play a role.

The domestication theory describes five stages in the acceptance process (Silverstone, 1994; Silverstone & Haddon, 1996; Silverstone et al., 1992): imagination, appropriation, objectification, incorporation and conversion. Before a technology has been purchased, that technology enters our consciousness when the imagination takes places (Ling, 2004). This is where the user imagines the usage of the technology. Appropriation happens when a technology leaves the commercial world (Ling, 2004) and people start to use the technology in their personal and social spaces (Silverstone & Hirsch, 1992). Appropriation captures the types of negotiations and consideration that led to the acquisition of technologies. This stage includes the sense that we know of the technology and how it could fit or could not in our lives (Ling, 2004). Objectification refers to how technologies are located spatially and temporarily within the home ecology and how this reflects on our identity (Ling, 2004). Incorporation draws attention to how technologies are scheduled into the routines of the users' everyday life and they fit in the existing array of artifacts (Ling, 2004). It is possible that the way the technology is used by its users is slightly different from the way it was intended by the designers (Silverstone & Hirsch, 1992). It can also occur that the technology saves time or makes users more aware of time, enabling them to spend time on other activities (Silverstone & Haddon, 1996). Conversion connects to how users mobilizes technologies as part of their identity and how they present themselves to others. During this stage the technology may become a tool for making status claims or for expressing a specific lifestyle to family, friends and neighbours (Silverstone & Haddon, 1996). This is where the user hopes to realize the social goal of the technology use.

Essentially, applying the domestication theory provides contextual information about (individuals in) households to better understand why they use technologies in the way they do. However, while the premier research interest lies in technologies, this approach also relates technology use to the nontechnological aspects of people's lives. Therefore, in-depth methods, including interviews and observations, are often favoured to elicit this information. The domestication theory mainly focuses on the acceptance phases after adoption and thus has a its main application within the acceptance stages of initial and sustained use.

LIMITATIONS OF THE DOMESTICATION THEORY

The main criticism on the domestication theory is its reliance on detailed case studies and its rather descriptive approach. It is focused on the everyday life of the individual user in a particular context (Ling, 2004). This makes it difficult to turn the results into prescriptive lessons for business and policy makers (Ayotunde, 2012). Moreover, such a descriptive approach can be time-consuming, which may have been the reason for the limited number of domestication studies (Haddon, 2011). On the other hand, these thick descriptions are the strength of the theory as it enables processes and the complex interplay of artefacts and cultural values to be explored in much more depth than individualistic, quantitative methods. Another issue is more about what this theory makes the researcher focus on, that is the changes in technology use. And although habits change, they often change slowly (Haddon, 2011). So it comes as no surprise that some researchers stressed the fact that observed changes are not as revolutionary as some scholars suggest of hope for (Silverstone, 1994). Thus, researchers employing this theoretical perspective should be aware that technology use might have only a limited impact on the household ecology and that changes in daily routines could be small. Another caveat is that domestication should not be assumed as a sequential process, as Haddon (2001) overtly recognizes. Although the elements of domestication –i.e., the introduction of the technology, its purchase, and it finally being an embedded part of the user's everyday life– the stages itself are not necessarily entered sequentially (Ling, 2004). Another criticism on the theory is that domestication is everything and its five stages are not addressed in many of the contribution in the literature (Gane, 2011; Hartmann, 2006). Although the domestication theory has been applied to technology adoption in a variety of contexts, these studies did not occur within a coherent theoretical framework in such a way that it builds to a further understanding about the processes taking place (Gane, 2011; Hartmann, 2006). Thus, similar to the objections to the uses and gratifications approach, these inconsistencies in applications of the theory makes it difficult to cumulate the results from different studies resulting in the development of a more sound theory. As a consequence, the theory might be better perceived as a descriptive or research approach rather than an explanatory theoretical approach.

The domestication of technology theory originated in the social sciences to investigate social consequences of technology use. The domestication theory, along with its five stages, provides a useful theoretical lens to address user experiences to investigate social robot acceptance. The theory broadens the concept of user experience to the whole ranging from technology adoption and functional use to detailed user interface design aspects, such as usability problems, and the learning process. It assumes that we alter technologies to fit in our lives and, in return, these technologies have consequences for the arrangement of our everyday lives (Ling, 2004). This is where Verbeek talks about a mediation of technology, "when technologies are used, they help to shape the context on which they fulfill their function, they help to shape human actions and perceptions, and create new practices and ways of living" (Verbeek, 2008, p. 92). Thus, the meaning of a technology is not limited to the mechanisms, physical and technical properties, or actual capabilities of the technology. In addition, the domestication theory acknowledges the influence of social factors when investigating the use of a technology. Domestication focuses on the interactions between the individual and the technology in the perspective of the social context in which these interactions take place (Ling, 2004). Moreover, the domestication theory provides insights into the intricate processes whereby the user assigns meaning and significance to the artefact, and how this is experienced by domestic users during the acquisition and consumption of the technology (Hynes & Richardson, 2009). While the diffusion of innovations theory is useful in the ways it explains how technologies are appropriated, the domestication theory is more valuable in the ways it interprets how technologies become part of the user's everyday life. A combination of both angles could provide a more thorough perspective on long-term use of social robots in home environments.

3.4 INSIGHTS FROM A COMMUNICATION SCIENCE PERSPECTIVE

USES AND GRATIFICATIONS APPROACH

One of the first research traditions focusing on media use behavior from a user's perspective is the uses and gratification approach (Bryant & Miron, 2004). This approach emphases why people use the media and what they do with it. Because people have options and free will, they will make specific decisions about which media to use and when to use them (Katz, Blumer, & Gurevitch, 1973). Personal needs and values that one wishes to fulfill will guide the choices and decisions people make. These needs and values generate expectations of the media which lead to different patterns of media use. Subsequently, these media uses result in need gratifications and other, perhaps mostly unintended, consequences.

The uses and gratifications approach is based upon three theoretical assumptions. First, it suggests that media use is active and goal driven based on individual needs. Katz, Blumer, & Gurevitch (1973) believed that people actively use various media to fulfill certain needs or goals. Prior research widely considers motivations as an important initiator of perceptions and behaviors (Stafford, Stafford, & Schkade, 2004). Indeed, based on motivation-oriented perspectives, information systems research has revealed that motivations, both intrinsic and extrinsic, are essential determinants of individual use intentions (Davis, Bagozzi, & Warschaw, 1992). Second, people must identify their needs and make a media choice. As stated by Katz, Blumer, & Gurevitch (1973), people choose a medium and allow themselves to be influenced and affected by that medium. Third and last, media outlets compete with other available means of satisfying personal needs. The media are only one of many ways to fulfill needs and goals (Katz, Blumer, & Gurevitch, 1973). Thus, people may choose to satisfy their needs by engaging in individual activities, other times by dealing and communicating with other people, and sometimes by using the media.

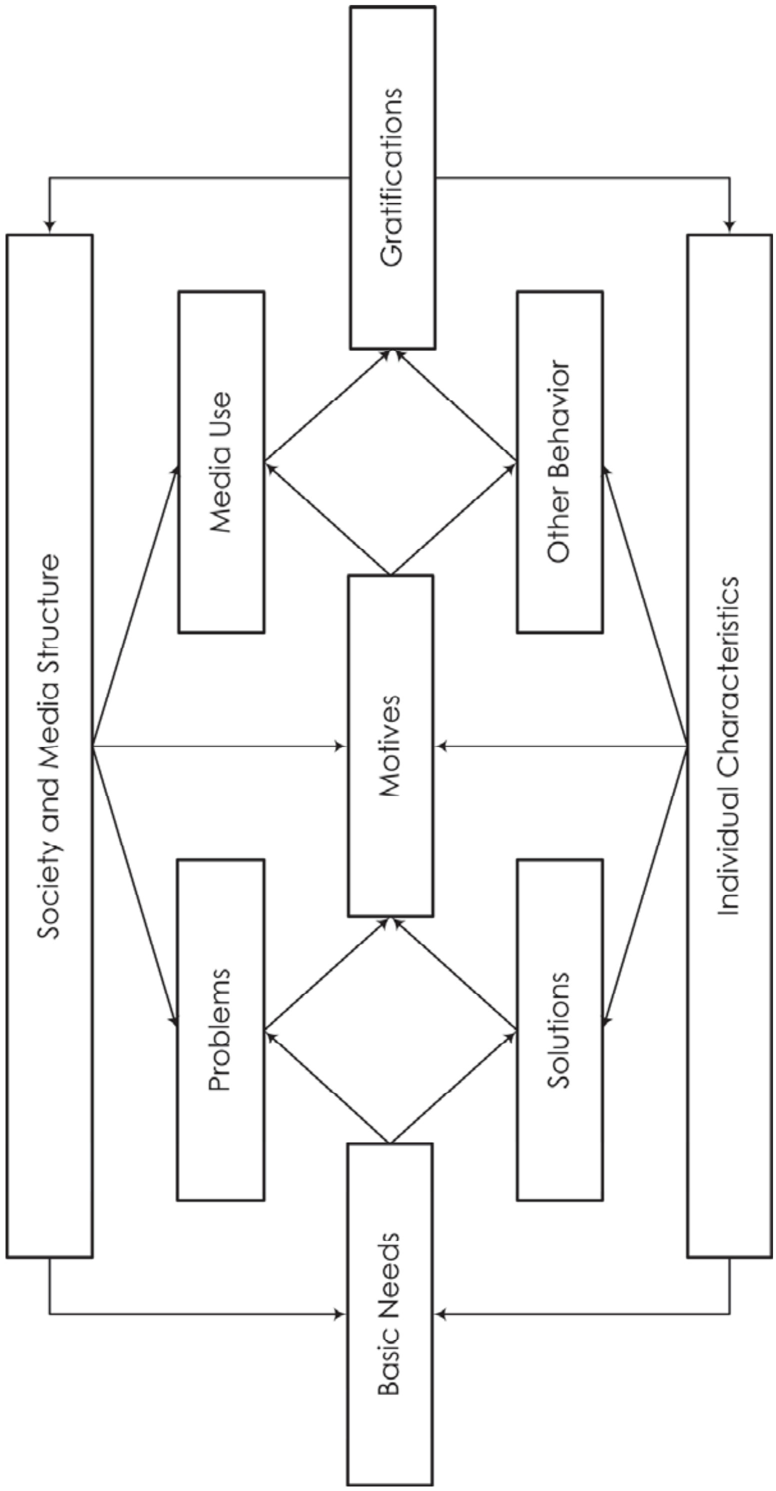

Figure 3.9: Uses and gratifications model (adopted from Rosengren, 1974)

According to uses and gratifications theory, people use media technologies to fulfill different types of needs (Katz, Gurevitch, & Haas, 1973). Cognitive needs are fulfilled by obtaining information or knowledge and satisfying their curiosity. Affective needs are fulfilled by having emotional and pleasurable experiences. Personal integrity needs are fulfilled by finding reinforcement for personal values and status. Social needs are fulfilled by interacting with other people and society. And tension-release needs are fulfilled by escaping from routines and burdens of problems found in everyday life. The model of the uses and gratifications approach is displayed in figure 3.9 on the previous page.

The uses and gratifications approach can be applied when people already use the technology. Some gratifications will be gained directly after media use behavior whilst other gratifications take more time to be processed. Therefore, this model could be used for research focusing on both the acceptance stages of initial and sustained use.

LIMITATIONS OF THE USES AND GRATIFICATION APPROACH

According to Ruggiero (2000) most scholars agree that, particularly early research into uses and gratification, had little theoretical coherence and was primarily behaviorist and individualist in its methodological tendencies (McQuail, 1994). Commonly used objections to the approach have been made on the fact that it: (1) depended strongly on self-reports through open-ended questions; (2) was unsophisticated about the social origin of the needs that audiences bring to the media; (3) was too uncritical of the possible dysfunction of certain kind of needs, both for self and society, that audiences bring to the media; and (4) was too focused on the inventive diversity of audiences used to pay attention to the constraints of the text (Katz, 1987).

One of the weakest points of uses and gratifications approach is the lack of an unambiguous, theoretically sound classification of the needs and gratifications (de Boer & Brennecke, 2003; Ruggiero, 2000). Although the approach provides a classification list, some researchers create their own lists while others adapt the list to the specific media or purpose of their own study. Consequently, despite the fact that there are many studies conducted on this topic (Galloway

& Meek, 1981; Rubin & Bantz, 1981; Rubin, 1983; Peters & Ben Allouch, 2005; Stafford, Stafford, & Schkade, 2004), these variations in need classifications make it difficult to cumulate the results from different studies impeding the development of a more sound theory.

Another point of concern is the basic assumption of the approach that people are proactive and make motivated choices of media to obtain gratifications sought by specific needs. Sometimes people use media ritualistically or habitually without any conscious intention of gratification seeking. In other occasions, people use media just as background noise with a low level of attention involved (Severin & Tankard, 2001), which the uses and gratifications approach cannot explain. Some scholars argue that media uses appear to dependent more on habit than on internalized need states (Elliott & Rosenberg, 1987; Stone & Stone, 1990). Additionally, the addictive use of computers or video games shows habitual use of media rather than goal-directed use to obtain specific gratifications (LaRose, Lin, & Eastin, 2003). Therefore, studying the acceptance and use of social robots only from the perspective of goal-oriented users who seek to fulfill specific needs, can produce results different from what actually happens.

Over the decades, uses and gratifications scholars challenged their own approach and debated for greater theoretical soundness, for example by adding an expectancy-value perspective to the theoretical approach as used within social psychology (e.g., Galloway & Meek, 1981; Rayburn & Palmgreen, 1984). However, despite these attempts to be more rigorous and comprehensive, several weaknesses remain to attack the uses and gratifications approach. Scholars probably continue the debate whether or not the uses and gratifications approach should be acknowledged as a validated communication theory. Nevertheless, for its believers, the uses and gratifications approach still remains one of the most influential theories in the field of communication research (Lin, 1998). Additionally, the criticized concept of needs is as nearly as impossible to unravel in more established disciplines such as psychology. For psychologist, needs are the foundation of some of the most important theoretical works within their field, including cognitive dissonance theory, social exchange theory and attribution theory (Lull, 1995). Thus, as Ruggiero (2000) concludes, many researchers have acknowledged the flaws of the uses and gratifications approach.

Though, regardless of perceived theoretical and methodological imperfections, there are several reasons for today's scholars to continue to use the uses and gratifications approach in their studies. One reason might be the argument of interactivity. Interactivity significantly strengthens the basic assumption on which the uses and gratifications approach is build, namely that the use of media is active and goal driven (Williams, Rice, & Rogers, 1988). As social robots are socially interactive technologies, this reason might validate the applicability of the uses and gratifications approach in the context of social robot acceptance. Also, with the growth of (new) media and technology, people will have more options to choose from to fulfill their needs. This reasoning causes new media scholars to breathe new life into the approach. As a more fundamental purpose, the uses and gratification approach could be useful to provide a deeper understanding of what needs are exactly, where they originate, and how they are gratified (Lull, 1995). Continuing the application of the uses and gratification approach might be the key to disentangle the secrets of our needs, which in return will be a contribution to the research fields of both media use and psychology.

Additionally, the uses and gratifications approach provides scholars the opportunity to examine challenges and barriers to using a particular medium that people are experiencing today. As social robots are not yet widespread in society, more insight into the challenges and barriers of the social acceptance of these technologies might be gladly welcomed by robotics developers. On the whole, the uses and gratifications approach has always offered a cutting-edge theoretical approach in the initial stages of each new media, including newspapers, radio, television, and later the internet (Ruggiero, 2000). In this line of thought, the uses and gratifications approach might still be a suitable means to study how and why people use a social robot, as this is a new technology, in their own homes. However, an contradictory perspective is provided by Peters (2011) who states that people must start with establishing the first and foremost expectancy-value judgment clusters that match the use of the technology. This depicts the uses and gratifications approach more suitable for studying already socially accepted technologies. From this viewpoint, the uses and gratifications approach is inadequate for the study of social robot use behaviors, as social robots have yet not been gradually accepted into society.

Taking it all together, the uses and gratification approach might become more useful for studying social robot acceptance when the technology has been more widely accepted within society. Only then can researchers start to establish an unambiguous, theoretically sound classification of the needs and gratifications specified to the unique features of this type of socially interactive technology. The lack of such sound classifications have been the criticism of the uses and gratification tradition (de Boer & Brennecke, 2003; Ruggiero, 2000). Because people often find it difficult to express their needs for a new technology and the entire usefulness or need for a technology become clear only after people start using it. A similar process has happened with the introduction of the mobile phone. Nobody thought they would actually need it, but now most people will not leave their home without it (Ling, 2004). Moreover, as social robots are socially interactive technologies and presumably used with a specific purpose, the basic assumption on which the uses and gratifications approach is build, namely that the use of media is active and goal driven (Williams, Rice, & Rogers, 1988), can be met.

SOCIAL COGNITIVE THEORY

Bandura's (1977) social cognitive theory of mass communication has been widely used to study the media's influence on human behavior. The social cognitive theory is an extension of the social learning theory which fails to incorporate the creation of novel responses or the processes of delayed and non-reinforced imitations. Bandura and Walters (1963) broadened this view on social learning by adding the principles of observational learning and vicarious reinforcement. Bandura (1977) finalized this theory by adding the importance element of self-beliefs to the theory and advanced this view on the social cognitive theory in his later publication (1986). The social cognitive theory is based on several assumptions. First, in contrast to broad applicability of the social learning theory, the social cognitive theory specifically focuses on mass media influence on cultural ideology. Bandura (2001) was particularly concerned with the mass media's ubiquity and social construction of reality and are tremendously influential in shaping our view on what is 'normal'. A second assumption is that people are capable of self-reflection and thus able to self-examine their behaviors (Bandura, 2001). Self-reflections can be both rightful as well as faulty and its quality depends partly on the deductive reasoning process, information used in the assessment, and one's own biases (Dainton & Zelley, 2014). Third, the most central claim is that people learn behaviors by observation through modeling (Bandura, 1977). Thus, simply by taking note of what others do, people can learn about relationships, social norms, and acceptable behavior in particular situations.

The social cognitive theory posits reciprocal causation among personal, behavioral and environmental influences which create interactions that result in a triadic reciprocity (see figure 3.10). Behavior is an observable act and the performance of that behavior is largely determined by the expected outcomes of that behavior, expectations formed by our own direct experiences or mediated by vicarious reinforcements observed through others. The theory views people as self-organizing, proactive, self-reflecting and self-regulating rather than as reactive organisms shaped and shepherded by environmental forces or driven by concealed inner pulses. The emphasis in this theory is on 'cognition', as it plays a critical role in people's capability to construct reality, self-regulate, encode information and perform behaviors.

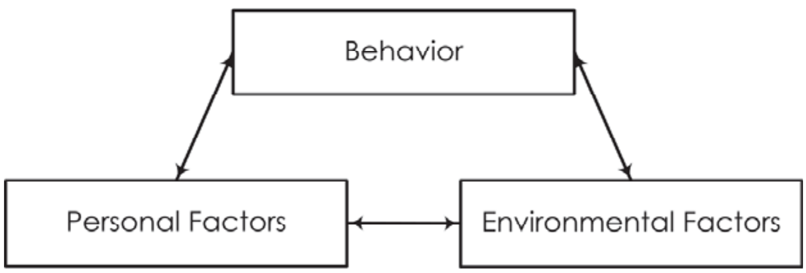

Figure 3.10: Model of the social cognitive theory (adopted from Bandura, 1986)

In this theory, behavior is explained by both personal and environmental factors, but these personal and environmental factors, in turn, also influence behavior. This suggests that the particular behavior is already happening. Especially when researchers focus on explanation of technology use on other factors, people should be using the technology for a longer period of time, as only then the use effects of the technology will arise. This implies that this theory has its main application in the acceptance stage of sustained use.

LIMITATIONS OF THE SOCIAL COGNITIVE THEORY

Bandura's social cognitive theory provides a clear contrast to theories of human functioning that overemphasize the role that environmental factors play in the development of human behavior and learning, such as the domestication theory described in section 3.4. From a sociological perspective, inner processes are viewed as transmitting rather than causing behavior and with that dismissed as a redundant factor in the cause and effect process of behavior. However, for psychologists such as Bandura, it is by examining their own conscious mind that people make sense of their own psychological processes. And the influence of environmental stimuli can only be understood by examining how people cognitively process and interpret these environmental stimuli. According to the social cognitive theory people engage proactively in their own development and can make things happen by their actions. Personal factors, and especially self-beliefs, enable people to exercise a measure of control over their thoughts, feelings and actions, that "what people think, believe and feel affects how they behave" (Bandura, 1986, p. 25). In in this manner, people are viewed as both products and producers of their own environments and of their social systems. People work together on shared beliefs about their capabilities and common aspirations to better their lives. This view makes the theory also applicable to human adaptation and change in collectivistic societies as well as individualistic ones.

Of all the thoughts that affect human functioning, and standing at the very core of social cognitive theory, are self-efficacy beliefs which are defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p.

391). Self-efficacy beliefs provide the foundation for human motivation, well-being and personal accomplishment. This is because unless people believe that their actions can produce the desired outcomes, they have little incentive to act or to persevere in the face of difficulties. Much empirical evidence supports Bandura's contention that self-efficacy beliefs touch virtually every aspect of people's lives (Stajkovic & Luthans, 1988), whether they think productively, self-debilitating, pessimistically or optimistically. The central thought on human functioning is that "people's level of motivation, affective states and actions are based more on what they believe than on what is objectively true" (Bandura, 1997, p. 2). For this reason, how people behave can often be better predicted by the beliefs they hold about their capabilities than by what they are actually capable of accomplishing. In additions, this helps to explain why people's behaviors are sometimes disjoint from their actual capabilities and why their behavior may differ widely even when they have similar knowledge and skills. In general, researchers have established that self-efficacy beliefs and behavior changes and outcomes are highly correlated and that self-efficacy is an excellent predictor of behavior. Self-efficacy, particularly in psychology and education, has proven to be a more consistent predictor of behavioral outcomes than any other motivational construct (Graham & Weiner, 1996). Clearly, it is not simply a matter of how capable one is, but of how capable one believes oneself to be.

The social cognitive theory is rather comprehensive and complex, which makes it somewhat difficult to operationalize. This causes some researchers who apply the social cognitive theory to focus on one or two constructs while ignoring the other constructs (Peters, 2011). In in this manner, the complete structure of influencing factors of human behavior is neglected, which could result in deviated results in its explanation. Moreover, similar to the remark on the theory of planned behavior, this model also suggests correlations between all of its constructs, which results in a lack of knowledge regarding the precise nature of the relations between these concepts.

MODEL OF MEDIA ATTENDENCE

LaRose & Eastin (2004) developed the model of media attendance by integrating the uses and gratifications approach within the social cognitive theory. The view on media attendance derived from Bandura's (1986, 1989) social cognitive theory offers a theoretical explanation for the often observed (e.g., Papacharissi & Rubin, 2000) empirical correlation between media gratifications and media usage. LaRose and Eastin (2004) propose that the uses and gratifications can be understood in socio-cognitive terms. The gratifications and needs from the uses and gratifications approach are introduced in the model of media attendance as expected outcomes and behavioral incentives respectively. According to the model of media attendance, media usage is directly determined by expected outcomes, self-efficacy, habit strength and deficient self-regulation (see figure 3.11).

The expected outcomes are divided into six basic types of incentives for human behavior which were derived from Bandura's social cognitive theory (1986): novel sensory, social, status, monetary, enjoyable activity and self-reactive incentives. However, LaRose and Eastin (2004) propose that these incentives are theoretically constructed rather than statistically derived from exploratory factor analysis, which is the common approach within the uses and gratifications tradition. Expected outcomes of media behavior influences the media behavior directly but can also result in habitual media behaviors (LaRose & Eastin, 2004). To further extend the uses and gratifications approach, LaRose and Eastin (2004) incorporate the two additional mechanisms of self-efficacy and self-regulation from the social cognitive theory into their development of the model of media attendance. Self-efficacy is the belief in one's capability to organize and execute a particular behavior (Bandura, 1986). Self-efficacy is particularly relevant for novice users who have not yet acquired the requisite skills to perform the particular behavior. The social cognitive construct of self-regulation (Bandura, 1991) describes how individuals monitor their own behavior (self-monitoring), judge it in relation to personal and social standards (judgmental process), and apply self-reactive incentives to moderate their behavior (self-reaction). Deficient self-regulation is defined as the state in which conscious self-control is diminished and adds to habit strength (LaRose &

Eastin, 2004). When self-regulation occurs, the media behavior tends to become an end in itself and is no longer subject to active consideration of its expected outcomes. Thus, according to the model of media attendance, self-regulation influences habits. Habit is the reoccurrence of a behavioral pattern and is a well-established predictor of behavior (LaRose & Eastin, 2004; Oulette & Wood, 1998; Triandis, 1979). Habit is a form of automaticity, a behavioral pattern, that follows a fixed cognitive schema, triggered by an environmental stimulus or by recalling a goal, and performed without further self-instruction (Aarts, Verplanken, & van Knippenberg, 1998; Bargh & Gollwitzer, 1994). Habit strength represents patterns of behavior established by past thinking about outcome expectations or gratifications that is no longer repeated in the present (LaRose & Eastin, 2004).

As the dependent variables is actual behavior, this model is suitable for research after adoption. And the inclusion of habitual use implies that this theory is especially qualified for investigating technology acceptance during the stage of sustained use, as habits are created use routines that are established over time.

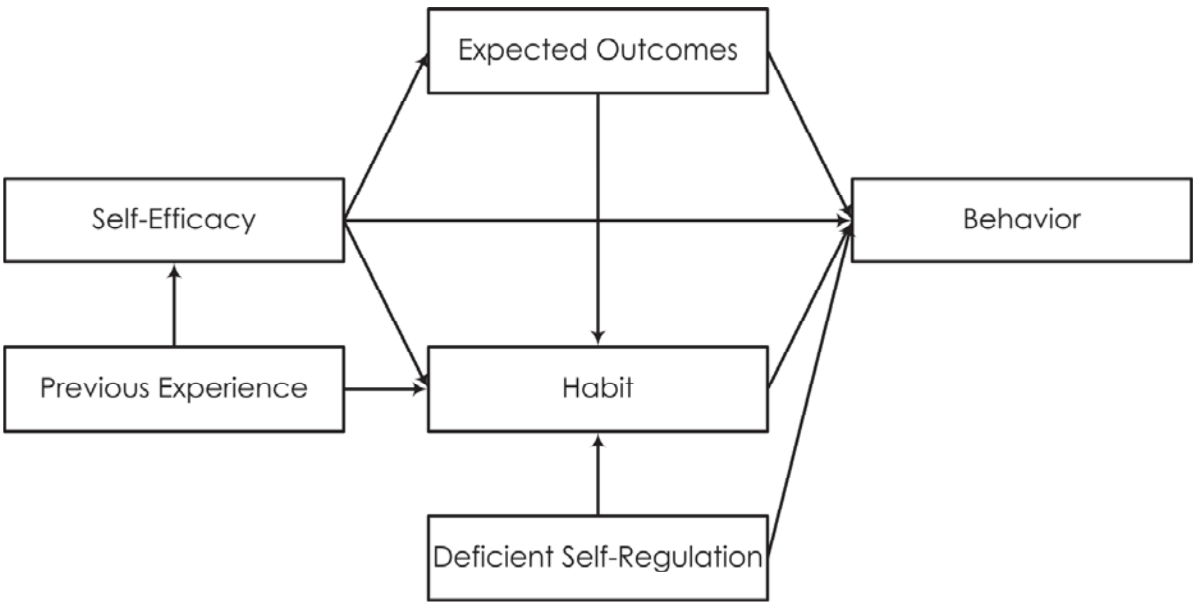

Figure 3.11: Model of media attendance (adopted from LaRose & Eastin, 2004)

LIMITATIONS OF THE MODEL OF MEDIA ATTENDANCE

The model of media attendance provides a new perspective on the uses and gratifications approach by redefining gratifications as expected outcomes which may have merit on both conceptual and operational levels (LaRose & Eastin, 2004). Still, some limitations need to be addressed. First, the model of media attendance postulates that behaviors repeatedly performed and reinforced within a certain situational become habitual and directly influence current behavior. However, some theorists (Ronis et al., 1989) have argued that the correlation between prior and current behavior is caused by other unmeasured determinants, such as self-identity and personal norms. This argument weakens the explanatory power of habit strength obtained from the observed explained variance between past and future behavior. Although habit has been indicated as a predictor of future behaviors (Ouellette & Wood, 1998), theories that incorporate an interaction between measures of habit and intentions may reveal the role of habit more clearly (Aarts, Verplanken, & van Knippenberg, 1998), because intentions are less predictive of behavior as the role of habit increases (Triandis, 1979). Despite the fact that many behaviors are repeatedly and routinely executed in everyday life, the role of habit is relatively underexplored in social psychological research on the determinants of goal-directed behavior (Aarts, Verplanken, & van Knippenberg, 1998; LaRose, 2010; Verplanken & Aarts, 1999). Thus, more research in this direction is needed.

Second, outcome expectancies play an important role in the model of media attendance (Heuvelman, Fennis, & Peters, 2005). For example, it is expected that watching television brings relaxation or that a subscription to an information source keeps you up to date. Within Bandura's social cognitive theory (1986), habit strength is a failure of the self-monitoring sub-function of self-regulation. LaRose and Eastin (2004) argue that through repetition one becomes inattentive to the reasoning behind one's media behavior. This means that the human mind no longer devotes attention resources to evaluating it, freeing itself for more important decisions. In their model of media attendance, LaRose and Eastin (2004) incorporated this shortcoming in the construct of deficient self-regulation, a state in which conscious self-control is diminished. Habit strength and deficient self-regulation are related because persons with deficient self-control are also expected to be engaged in habitual behavior (LaRose & Eastin, 2004). This diminishes the effect of outcome expectancies on behavior.

3.5 INTEGRATING KNOWLEDGE ON TECHNOLOGY ACCEPTANCE

This chapter has taken a first step in formulating neutral stages of technology acceptance with the goal to provide a framework to connect existing general theories of technology acceptance to their main application within a specific acceptance stage. In this chapter, several theories of technology acceptance have been presented and for each theory main acceptance stage has been indicated. Figure 3.12 again displays the different stages of the decision-making process of technology acceptance, but now visualizes the main application of all the theories presented in this chapter within the acceptance stages.

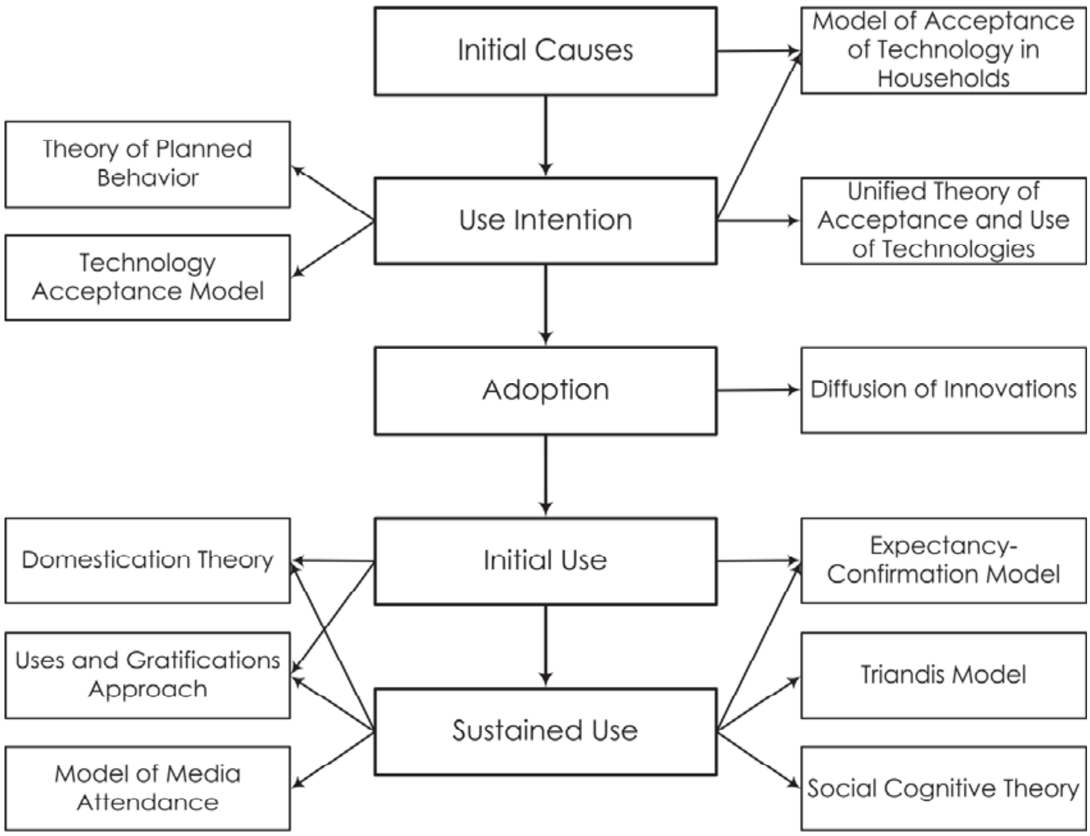

Figure 3.12: Technology acceptance theories linked to the stages of technology acceptance

TOWARDS A MODEL OF SOCIAL ROBOT ACCEPTANCE

Although existing theories and models to explain technology acceptance behavior have received considerable empirical validation and confirmation, they could all be criticized on several points. Their limited explanatory power and inconsistent relationships call for taking additional factors into account. As the research question of this dissertation focusses mainly on psychological aspects of the individual users, it is chosen to build upon an existing theory from a psychological perspective. To propose a new model for social robot acceptance, the framework of the theory of planned behavior (Ajzen, 1991) will be used as a starting point to develop a model for social robot acceptance. The theory of planned behavior is chosen as a guiding framework, because: (1) it is especially suitable for explaining and predicting volitional behaviors including technology adoption (Mathiesson, 1991; Taylor & Todd, 1995; Venkatesh & Brown, 2001); (2) it has been successfully applied to explain a wide range of behaviors (Ajzen, 1991); and (3) its origin invites researchers to extend the model to adapt to a specific behavior (Ajzen, 1991). Moreover, when considering use intention as the main outcome variable to explain future use of a new technology, in this case social robots, the explanatory power of the theory of planned behavior is greater than that of the technology acceptance model and its successors, especially when it is decomposed to a specific technology (Taylor & Todd, 1995). This decomposition would allow the inclusion of factors from other theories (Bensabat & Barki, 2007). As the theory of planned behavior only includes a rational perspective on human behavior, components for affective evaluations, the social context of behavior and habits are included in the newly proposed model for social robot acceptance.

Following others (Taylor & Todd, 1995; Venkatesh & Brown, 2001), the three constructs of attitudinal beliefs, social normative beliefs and control beliefs from the theory of planned behavior will be decomposed to reflect the specific underlying factors based on a detailed literature on social robot acceptance. Here, a variety of salient beliefs may be generated depending on the context of use of a specific technology, in this case social robots. This course of action would open up the left hand side of the model (e.g., the influencing factors), which provides an adequate theoretical grounding to incorporate various factors from other theories (Bensabat & Barki, 2007). In this case those factors relevant for social robot acceptance into the model. Especially missing factors covering the affective and interactive use of social robot (e.g., hedonic attitudes), as well as the social and societal influences (e.g., normative beliefs such as privacy and trust) on robot technology use will be included. Additionally, when investigating long-term use, also the inclusion of actual use behavior and habitual use behavior will be argued for in the next chapter (chapter 4) to complete the conceptual model of social robot acceptance.

Because intentions are found to be good predictors of specific behavior, they have become a critical part of many contemporary theories of human behavior (Ajzen & Fishbein, 2005). And although these theories differ in detail, they all show convergence on a small number of factors that account for much of the variance in behavioral intentions. These factors can be viewed as three major kinds of considerations that influence the decision to engage in a given behavior. First, attitudinal beliefs are the (expected) positive or negative consequences of the behavior which, in the case of social robot acceptance, can be viewed as the user's evaluation of the beliefs when using a robot (in the future). Second, normative beliefs are the (expected) approval or disapproval of the behavior by prevailing norms in the social environment of the individual which, in the scope of this dissertation, can be perceived as the user's evaluation of the prevailing norms involved with using a robot. And third, the control beliefs are the factors that may facilitate or impede the performance of the behavior which can be observed here as the contextual factors that play a role while using a robot. The next chapter will focus on these influencing factors and propose a new model of social robot acceptance.

4

A CONCEPTUAL MODEL OF SOCIAL ROBOT ACCEPTANCE

"It is the framework which changes with each new technology and not just the picture within the frame."
– Marshall McLuhan –

As argued at the end of chapter 3, it has been decided to use the theory of planned behavior as a starting point in an attempt to explain the (long-term) acceptance of social robots in domestic environments. Some research takes the approach to revise existing theoretical models by adding an independent variable as parallel predictor of the dependent variables along with established predictors, such as the transition from TRA (Fishben & Ajzen, 1975) into TPB (Ajzen, 1991). The goal of this approach is to account for more variance by specifying processes formally contained in error terms in test of the theory. Such an approach could be characterized as theory broadening. A second approach to the revision of any theory is by introducing a variable that explains how existing predictors function to influence intentions, such as the many studies have done to expand the theory of planned behavior (Liao et al., 2007; Pavlou & Fygenson, 2006; Perugini & Bargozzi, 2001; Wand, 2011). Here, the idea is to better understand theoretical mechanisms and their effects by introducing a new variable that mediates or moderates the effects of existing variables. Such an approach could be characterized by theory deepening.

The goal of this chapter is to present a conceptual model of social robot acceptance. This conceptual model both expands and deepens the theory of planned behavior by providing a comprehensive overview of predictors for technology acceptance and behavioral intention from psychology, information systems, communication science, human-computer interaction and human-robot interaction which have been shown to play a role in the acceptance and use of technology in general and robots or virtual agents specifically.

This chapter will start with a short review on existing models of social robot acceptance that have been tested with structural equation modeling. Consecutively, the three sections that follow will discuss the three categories of attitudinal beliefs, normative beliefs and control beliefs. First, attitudinal beliefs are the (expected) positive or negative consequences of the behavior which, in the case of social robot acceptance, can be viewed as the user's evaluation of the beliefs when using a robot (in the future). Second, normative beliefs are the (expected) approval or disapproval of the behavior by prevailing norms in the social environment of the individual which, in the scope of this dissertation, can be perceived as the user's evaluation of the prevailing norms involved with using a robot. And third, the control beliefs are the factors that may facilitate or impede the performance of the behavior which can be observed here as the contextual factors that play a role while using a robot. A fourth section discusses user characteristics as potential moderating variables and the last section presents the dependent variables of social robot acceptance.

This chapter concludes with the presentation of a conceptual model of social robot acceptance. It should be noted that research on social robot acceptance is still in its exploratory phase, thus for now all possible explanatory factors will be included. However, some factors may have a larger impact when people are anticipating to accept a social robot, but the same factors might have minor effects when the same people have used that same robot for a longer period of time. A large body of future social robotics research is necessary to identify those factors that possess the most explanatory power in certain acceptance phases and how their influences changes throughout the long-term process of social robot acceptance phases. Parts of this chapter have been published before as:

> Graaf, M.M.A. de, & Ben Allouch, S. (2013). Exploring influencing variables for the acceptance of social robots. *Robots & Autonomous Systems, 16*, 1476-1486.

4.1 EXISTING ACCEPTANCE MODELS FOR SOCIAL ROBOTS

To my knowledge, only two user acceptance models for robots have been proposed so far using structural equation modeling. The most cited model for social robot acceptance today is probably the Almere model of Heerink et al. (2010). Another initiative to create an acceptance model for socially interactive robots was proposed by Shin and Choo (2011). However, there are some weaknesses in these models that must be addressed.

First, both the Almere model and the acceptance model for socially interactive robots developed by Shin and Choo (2011) have their roots in the unified theory of acceptance and use of technologies, which has been criticized to be a not parsimonious (Straub & Burton-Jones, 2007), eclectic model which combines highly correlated variables to create an unnatural high explained variance (Yoo et al., 2012). This dissertation argues that the theory of planned behavior offers a more suitable theoretical bases for a model of social robot acceptance.

Second, the Almere model (Heerink et al., 2010) has been developed for the acceptance of socially interactive agents in the context of eldercare facilities, and the acceptance model for socially interactive robots (Shin & Choo, 2011) has been tested on a student sample. This dissertation focusses on the general population, for which both models have not been validated yet.

Third, both models are based on grouped findings from earlier research in human-robot and human-computer interaction. They both lack a theoretical foundation and strong arguments for the inclusion of the chosen variables in the model and the exclusion of other variables.

Fourth, the structural equation modeling performed to test the Almere model was done of a dataset which actually consisted of a combination of four separate datasets. Similarly, the acceptance model for socially assistive robots (Shin & Choo, 2011) is based on different groups of participants who used different types of robots with varying functionalities. Neither of the two statistically confirmed similarities between the datasets to justify the applicability of one sample for testing their models.

A final fifth weakness of the Almere model can be found in the application of the model modification indices, which were considered without any theoretical support. Based on these weaknesses of both models, it was chosen to deviate from these existing models by proposing a new model for social robot acceptance.

4.2 ATTITUDINAL BELIEF

The attitudinal belief structure involves the user's favorable or unfavorable evaluation of a particular (future) behavior (Ajzen & Fishbein, 2005), or in this case the evaluation of behavioral beliefs resulting from the (anticipated) use of a social robot. An important contribution to the information systems literature is Hassenzahl et al.'s (2000) distinction between pragmatic quality and hedonic quality. The first relates to the usability of the product, which addresses the underlying human need for security and control. The latter refers to quality dimensions with no obvious relation to task-related goals such as originality and innovativeness. The experiences people have with interactive systems are thus two-fold. User experience deals with human needs, emotional aspects and the nature of the interaction (Hassenzal & Tractinsky, 2006). According to some researchers in the field of human-computer interaction (Hassenzahl, 2004; Van der Heijden, 2003), there are both utilitarian and hedonic product aspects. Utilitarian aspects are attributes connected to the practicality and usability of a product. In contrast, hedonic aspects are attributes related to the user experience while using a product. It is believed here that both type of product aspects influence the user's attitudinal belief of social robot acceptance.

The dichotomy of both utilitarian and hedonic attitudes as determinants of technology acceptance also arises from motivation theory suggesting a main classification between extrinsic and intrinsic motivators of human behavior which are based on the different reasons or goals that encourage a person's actions (Ryan & Deci, 2000; Vallerand, 1997). Extrinsic motivation refers to doing something because it leads to a separate valued outcome (e.g., utilitarian attitudes). Intrinsic motivation connects to the performance of an activity for no apparent reinforcement other than the process of performing that behavior itself (e.g., hedonic attitudes). Intrinsic motivations are expected to be a powerful incentive of human behavior when a person can autonomously decide what to do (Deci & Ryan, 1985). Therefore, as social robot acceptance in this dissertation is studied in the context of voluntary use, intrinsic motivations or hedonic attitudes should be included as part of the influential factors.

A body of research has confirmed the influence of both extrinsic and intrinsic motivators of technology acceptance (Yoo et al., 2012). A meta-analysis of 128 studies investigating intrinsic and extrinsic motivators of human behavior in diverse contexts suggests that both extrinsic and intrinsic motivators are equally important and interrelated (Deci, Koestner, & Ryan, 1999). The inclusion of both types of motivators is thus important to evaluate the acceptance of any socially interactive system, including social robots.

UTILITARIAN ATTITUDES

Utilitarian attitudes are tied to usability and emphasize the extrinsic motivations to accept or use a technology. Several utilitarian attitudes can be derived from the research literature that are generic for most types of technologies, namely usefulness, ease of use, and adaptability. For social robot acceptance, some additional utilitarian attitudes are highlighted, namely embodiment, intelligence, cognitive development, and personality of the robot.

USEFULNESS AND EASE OF USE

Usefulness and ease of use are two prominent predictors of technology acceptance that stem from the technology acceptance model (Davis, 1989), and are categorized as extrinsic motivations for technology use (Davis, Bagozzi, & Warshaw, 1992). The concept of usefulness is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p. 320). This is similar to the concept of relative advantage from Rogers’ (2003) diffusion of innovation theory which provides the following definition “the degree to which an innovation is perceived as being better than the idea of its supersedes” (p. 229). The concept of ease of use is defined as “the degree to which a person believes that using a particular system would be free from effort” (Davis, 1989, p. 320). Rogers’ (2003) diffusion of innovations theory presents the similar, though opposing, concept of complexity which is defined as “the degree to which an innovation is perceived as being difficult to understand and use” (p. 257).

According to the technology acceptance model, usefulness and ease of use directly both influence an user's intention to use the technology whilst ease of use also has a mediated influence on use intention via usefulness (Davis, 1989). The explanatory power of these influences have been supported in the context of human-robot interaction research (Heerink et al., 2010; Shin & Choo, 2011), and should thus be included when studying social robot acceptance.

ADAPTABILITY

Another concept that has been studied as an extension to the technology acceptance model is adaptability (Lee, Kozar & Larsen, 2003). The concept of adaptability is defined as the ability of a system to adapt its behavior to its user's preferences and needs (Broadbent, Stafford, & MacDonald, 2009; Heerink et al., 2010). This is similar to Rogers' (2003) concept of compatibility which is defined as "the degree to which an innovation is perceived as being consistent with existing values, needs, and past experiences of potential adaptors" (p. 240).

Adaptability has been studied in the context of human-robot interaction as well. People expect a robot to look and act appropriately, given the task in a specific context (Goetz, Kiesler, & Powers, 2003). If a robot is designed for social interaction with humans, which the case for social robots, such a robot must project some amount of humanness so that the user feels comfortable to socially engage with the robot (Fong, Nourbakhsh, & Dautenhahn, 2003). A robot's appearance must thus match its intended function. A robot's adaptability influences usefulness (Heerink et al., 2008c; Shin & Choo, 2011), enjoyment (Shin & Choo, 2011), use intention (Heerink et al., 2008c; Shin & Choo, 2011), and people's use behavior (Broadbent, Stafford, & MacDonald, 2009).

The three utilitarian attitudes of usefulness, ease of use and adaptability have been studied intensively in the context of information systems adoption (Lee, Kozar, & Larsen, 2003) as well as in several studies exploring the acceptance of social robots (e.g., Heerink et al., 2010; Shin & Choo, 2011), which justifies there inclusion when studying social robot acceptance.

EMBODIMENT

In additional to these three general utilitarian attitudes, one of the factors that makes robots a new technological genre is that they are embodied and physically present in our personal spaces. Their embodiment is fundamental for social robots, as it influences how people perceive them (Breazeal, 2005; Hegel et al., 2009; Goetz & Kiesler, 2002), interact with them (Austermann et al., 2010; Bartneck & Forlizzi, 2004; Goetz, Kiesler, & Powers, 2003; Kanda et al., 2008; Libin & Libin, 2004; Looije et al., 2008; Severinson-Eklund, Green, & Hüttenrauch, 2003), and build relationships with them (Lee et al., 2006a).

According to Ishguro (2007), the ideal robot form for working in everyday surroundings is a humanoid. First, because our daily surroundings are designed for human, which makes it easier for a humanoid to work without any modifications to the environment. Second, because the human brain has various functions for recognizing human beings and anthropomorphize other beings when interacting with them. Research has found that a human-like appearance can encourage humans to share responsibility with a robot (Broadbent, Stafford, & MacDonald, 2009) and will facilitate human-robot collaborations (Hinds, Roberts, & Jones, 2004). Thus, a humanoid shape might be appropriate for social robots for domestic purposes as their users must trust these robots to adequately perform several tasks around the home.

However, a humanoid appearance of a robot raises specific expectations from its users (Lee et al., 2005; Rızvanoğlu, Öztürk, & Adıyaman, 2014), which might have a negative effect when the robot's behavior does not meet these expectations (Lohse, 2011). Other researchers believe that people may find interactions with zoomorphic robots more satisfying than interactions with humanoid robots, because they do not expect full responsiveness from animals (Kahn et al., 2006). Thus, especially until the robotic technology is able to engage in human social behavior more realistically, a zoomorphic appearance might be more appropriate for robots that must work alongside or with humans.

Embodiment not only constitutes appearance but also entails its size and gender representation. The size of the robot is often important for practical and role reasons (Giulini et al., 2005). People are more likely to follow the recommendations from a smaller robot (Shiomi et al., 2013), and are more willingly to accept smaller robots for assistive tasks (Wu, Fassert, & Rigaud, 2012). Moreover, a robot's apparent gender deduces traditional role stereotypes (Broadbent, Stafford, & MacDonald, 2009; Kuchenbrandt et al., 2012), influence how they are evaluated (Eyssel et al., 2012), and affect human-robot collaboration (Koulouri et al., 2012). As the embodiment of robots influences many aspects of the user's interaction experiences with these robots, researchers should incorporate their influence when evaluating human-robot interaction and social robot acceptance.

INTELLIGENCE AND COGNITIVE DEVELOPMENT

Besides the varying effects of their embodiment on the user's interaction experience, robots face the significant challenge of attempting to appear intelligent to provoke their users to perceive them as genuine. The intelligence of a robot is defined as the user's evaluation of the robot's level of intelligence (Bartneck et al., 2009).

A robot that is evaluated as more intelligent is liked more and perceived as more realistic (Cuijpers et al., 2011). As the authenticity of a robot depends on its intelligence, it is important to include this factor when studying social robot acceptance. Today, some robots, such as the iCub, are programmed with the ability to learn from its interactions with other humans and its environment. Therefore, another factor to consider, related to intelligence, is the cognitive development of a robot. Developmental changes are especially important when the robot is designed for long-term interaction, because people will feel a stronger social presence and are more willing to bond with the robot (Lee et al., 2005). Therefore, intelligence and cognitive development are especially important when studying the acceptance of social robots.

PERSONALITY OF THE ROBOT

As robot have realistically and appear to have cognitive abilities, people might perceive a robot to have a personality. In psychological terms, personality is the set of distinctive qualities that distinguish individuals (Engler, 2009; Michel, Shoda, & Smith, 2004). Since the late 1980s, the most widely accepted taxonomy of personality traits has been the ‘Big Five Inventory’ (John, 1990), describing personality in terms of five traits: extroversion (sociable, outgoing, confidence); agreeableness (friendliness, nice, pleasant); conscientiousness (helpful, hard-working); neuroticism (emotional stability, adjusted); openness (intelligent, imaginative, flexibility).

Just like a human’s personality, a robot’s personality will affect how people react to the robot (Heerink, Krose, Evers, & Wielinga, 2006a), their ability to predict its future behaviors (Persson et al, 2002), and their willingness to bond with it (Breazeal, 2002). However, these effects also depend on the personality of the user, as matching the user’s personality with the personality of an interactive technology leads to a more positive evaluation (Nass et al., 1995; Nass & Lee, 2000). Other evidence suggests that the personality of a robot needs to be matched to its intended role (Broadbent, Stafford, & MacDonald, 2009). Although the exact nature of its role in human-robot interaction, the fact that a robot’s personality influences the interaction has been shown in research results which validates its inclusion for studying social robot acceptance.

HEDONIC ATTITUDES

Besides utilitarian attitudes, interacting with a social robot also induces hedonic attitudes. Both consumer behavior research and information systems research have indicated various constructs related to the users’ experience while performing the task. These constructs emphasize the intrinsic motivations in technology acceptance. (Brown & Venkatesh, 2005; van der Heijden, 2004). Well-known hedonic attitudes in technology acceptance research are enjoyment and attractiveness (Davis, Bagozzi, & Warshaw, 1992). However, the autonomous behavior of robots and their intentions for social interaction call the must include additional hedonic attitudes for social robot acceptance, namely animacy, social presence, sociability and companionship.

ENJOYMENT

In technology acceptance models enjoyment is defined as “the extent to which the activity of using the system is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated” (Davis, Bagozzi, & Warshaw, 1992, p. 1113). Perceived enjoyment seems to be a crucial factor in hedonic or pleasure oriented systems (Van der Heijden, 2004), and its importance becomes stronger when users gain more direct experience with that system (Venkatesh, 2000). Enjoyment is thus an important factor in the evaluation of social robot acceptance.

ATTRACTIVENESS

Attractiveness plays an important role in all types of first impressions in both human-human (Patterson, 1976) and human-robot interaction (Mumm & Mutlu, 2011). The concept of attractiveness is defined here as the user’s evaluation of the attractiveness of the robot’s physical appearance (Lee, Kozar, & Larsen, 2003). The influence of attractiveness is explained by the ‘what is beautiful is good’ paradigm (Dion, Berscheid, & Walster, 1972), which causes people to receive positive reinforcements from an attractive stimuli (Byrne & Nelson, 1965). This can be explained by the positive role of aesthetics on emotions, which in turn positively affects cognition (Norman, 2004). In evaluating hedonic systems, perceived attractiveness has been indicated as an important factor (Schenkman et al., 2003), and shown to be the mediator for other qualities of such systems (Epley et al., 1991; van der Heijden, 2004). Attractiveness will, therefore, be included when evaluating social robot acceptance.

ANIMACY

Together with these general factors of technology acceptance, social robots provide other hedonic attitudes that influence the user experience because of their embodiment. Being physically embodied and operating autonomously, social robots could be viewed as genuine or real. The concept of animacy in the context of human-robot interaction has been proposed by Bartneck et al. (2009) and resembles the degree to which users believe a robot behaves and responds realistically. Several studies have indicated that the increase of animacy may indeed improve the interaction between humans and robots

(Bartneck et al., 2009; Groom et al., 2009), make the robot to be perceived as more intelligent (Bartneck et al., 2009) and as a friendly companion (Libin & Libin, 2004; Rubin & Perse, 1987). These results indicate that animacy could play a role in the acceptance of social robots and should thus be included in an initial exploration of social robot acceptance.

SOCIAL PRESENCE

When robots elicit explicit cues of identity of social agency, it is possible that people will treat these entities as social actors (Kahn et al., 2006; Lee, Park, & Song, 2005; Reeves & Nass, 1996). This phenomenon is called anthropomorphism, which is the tendency to regard and describe objects in human terms, attributing human characteristics to them with the intention to rationalize their actions (Duffy, 2003) and is triggered when people sense a social presence. In computer-mediated communication, social presence is defined as “the degree of salience of the other person in the (mediated) interaction and the consequent salience of the interpersonal relationships” (Short, Williams, & Christie, 1976, p. 65). In human-robot interaction, this presence is created by the agent that induces a mental simulation of other intelligence (Biocca, 1997). The concept of social presence for human-robot or human-agent interaction is defined “a psychological state in which virtual social actors are experienced as actual social actors in either sensory or non-sensory ways” (Lee, 2004, p. 37).

The tendency to sense a social presence depends on the situation, and a person’s personality, age and culture (Epley, Akalis, & Cacioppo, 2008). Lonely people, explained by the must connect with others (Baumesiter & Leary, 1995), and anxious or uncertain people, as people feel the must control their environment (Epley, Akalis, & Cacioppo, 2008), are more likely to experience social presence when interacting with a social robot. Perceiving the social presence of an interactive systems has found to be an important factor both directly and indirectly affecting the acceptance of these systems (Heerink et al., 2010; Epley, Akalis, & Cacioppo, 2008; Lee e al., 2006). These results show that social presence plays an important role in human-robot interactions and should therefore be included when studying user acceptance of social robots.

SOCIABILITY

Additionally, as social robots are designed for social interaction, they should possess a considerable amount of social skills. In observing human-human interactions, there are several characteristics that make certain people more likeable than others in social interactions. These characteristics are conceptually combined as social competence (Rubin & Martin, 1994), here called sociability. The concept of sociability is the user's belief that be robot possesses the social, emotional and cognitive skills required for successful social adaptation.

A more sociable robot is more effective is its communication, and therefore expected to be more useful, and easier and more pleasant to interact with (Breazeal, 2003; Heerink et al., 2010; de Ruyter et al., 2005; Shin & Choo, 2011). Moreover, people will more readily perceived the robot as a social entity (Heerink et al., 2010). Thus, sociability is an important factor to include in a model of social robot acceptance.

COMPANIONSHIP

Combining the knowledge about animacy, social presence and sociability, one might assume the possibility for people to regard social robots as potential companions. The concept of companionship is defined here as the user's willingness to perceive or treat the robot as a companion. In the study of Dautenhahn (2005) on futuristic social roles for robots, 70% of the participants have indicated that they would eventually prefer to have companionship with robots.

Bonding with a social robot influences the user's intention to continue the use of that robot (de Graaf & Ben Allouch, 2012; Kanda et al., 2007; Klamer, Ben Allouch, & Heylen, 2010). Although, the effects of companionship on other factors in the evaluation of social robot acceptance has not been studied yet, its direct effect on acceptance makes it essential to include in a model of social robot acceptance.

ATTITUDINAL BELIEFS AND THEIR INITIAL THEORETICAL INTERRELATIONS

The attitudinal beliefs of social robot acceptance comprises of both utilitarian and hedonic attitudes of human-robot interaction. Including both types of attitudinal beliefs allows to broaden the view on robots as social actors in an interaction scenario and enables the evaluation of interactive and pleasure orientated aspects besides usability aspects. In this manner, the unique factors are acknowledged that distinguishes social robots as a new technological genre, and demonstrates the must include these unique factors in addition to the traditional antecedents in human-computer interaction. Several sources in the information systems literature (e.g., Agarwal & Karahanna, 2000; Lee, Kozar, & Larsen, 2003) and the human-robot interaction literature (e.g., Heerink et al., 2010; Lee et al., 2006; Shin & Choo, 2011) indicate that hedonic attitudes directly influence the utilitarian attitudes of system use or social robot use. Additionally, most theories (e.g., theory of planned behavior, diffusion of innovations, the Triandis model) indicate that attitudinal beliefs influence people's intentions to perform a particular behavior. These interrelationships result in the following hypotheses which are visualized in figure 4.1.

H_1: *The users' utilitarian attitudes of a robot directly influence their intention to use that robot.*

H_2: *The users' hedonic attitudes of a robot directly influence their intention to use that robot.*

H_3: *The users' hedonic attitudes of a robot directly influence their utilitarian attitudes of that robot.*

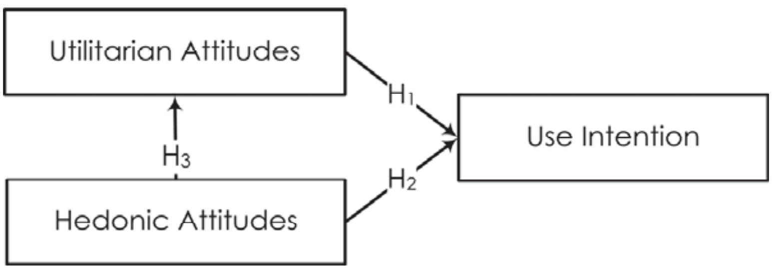

Figure 4.1: Attitudinal beliefs and their initial theoretical interrelations

4.3 NORMATIVE BELIEFS

The social context plays an important role in technology acceptance, especially with early adoption behavior (Rogers, 2003). Yet, only a few empirical studies have investigated the underlying components of normative beliefs (Fisher & Price, 1992). Miniard (1981) argues that the normative beliefs structure comprises both a social normative and a personal normative component. The social component encompasses an individual's beliefs about the likelihood and importance of the social consequences of performing a particular behavior. The personal component contains an individual's beliefs that engaging in a particular behavior leads to salient personal beliefs. These personal beliefs are connected to what is perceived as the norm within one's social environment. In the sections below, several concepts of both the social and personal component of normative beliefs are described in the context of social robot acceptance.

SOCIAL NORMS

Social norms comprises of the user's evaluation of the likelihood and importance of the social consequences of performing a particular behavior. Underneath the social norms of social influence, media influence and status are discussed.

SOCIAL INFLUENCE

The technology adoption literature has mostly focused on the normative concepts of social influence and status, and their effects on technology acceptance have been widely acknowledged in this domain (Lee, Kozar & Larsen, 2003). The concept of social influence is defined here as the user's perception of how other people think about using a social robot. In the context of social robot acceptance, social influence has a positive effect on attitudinal beliefs and use intention (Heerink et al., 2010; Shin & Choo, 2011).

Theoretical insights show that the effect of social influence decreases once direct experience with a system increases (Triandis, 1980). However, its precise effects on other factors in the technology adoption process remain unclear (Lee, Kozar & Larsen, 2003). Some studies have omitted the construct completely (Adams et al., 1992; Szajna, 1994, 1996), whilst others found the construct to be non-significant (Davis et al., 1989, Mathieson, 1991). Therefore, some researchers have expressed the must further articulate the link between social influence and technology acceptance (Karahanna & Limayem, 2000). Still, a review shows that there are other studies have found the construct to be significant (Taylor and Todd, 1995).

Technology acceptance research primarily focuses on organizational settings (Taylor & Todd, 1996) where the use is often mandatory. Some researchers assume that social influence plays a bigger role in a consumer context where technology acceptance is voluntary (Brown et al., 2002). When future social robots will be used in and around the home, user will probably consider the opinions of other household members. Future adopters might thus be affected by positive of negative worth-of-mouth from family, friends, and other adopters (Venkatesh & Brown, 2001). As the focus in this dissertation is on domestic use of social robot, the social influence of family members should thus be included in a model of social robot acceptance.

MEDIA INFLUENCE

Additionally, as most people do not have direct experiences with real robots and are more likely to first think of robots as movie creatures, it might very well be that people are influenced by the media when considering the acceptance of a social robot into their homes. The concept of media influence is defined here as the user's perception of how robots are appear in the media including both science-fiction and fact-orientated news sources.

Media influence is particularly strong for early adopters (Rogers, 2003). When there are fewer informed friends and family members to exert pressure, the media is often the source that provides first impressions (Young et al., 2007). As only a few people have encountered robots in real life, their experiences with robots are most likely mediated which argues for the incorporation of media influence in a model of social robot acceptance. Together, the concepts of social influence, status and media influence, as they affect the process of technology acceptance, are relevant for studying social robot acceptance.

STATUS

Moreover, if significant others support the use of an innovation, it is believed that using that innovation will elevate one's status within that group (Venkatesh & Davis, 2000). This concept of status is defined as "the users' belief that the use of an innovation is perceived to enhance one's image or status in one's social system" (Moore & Bensabat, 2001, p. 195). In addition to social influence, one might thus seek public recognition achieved from adopting an innovation (Fisher & Price, 1992). Experiencing status enhancement from one's social environment could have consequences for the user's acceptance of that innovation (Rogers, 2003). Social robots, being a relatively new technology on the consumer market, might be subject to this process of status as well.

PERSONAL NORMS

Personal norms contain an individual's beliefs that engaging in a particular behavior leads to salient personal beliefs, and for social robot acceptance includes the factors of privacy, trust and attitude towards robots.

PRIVACY

Besides one's evaluation of effects of what others think or will do related technology acceptance, people also hold personal beliefs about what should or should not be in the context of social robot acceptance. In today's digital age, personal information can easily be copied, transmitted and integrated, which enables companies to construct detailed descriptions of individuals. Hence, the exposure of digital personal information could pose a serious threat to one's privacy if this data is not handled with care. Robots should thus carefully handle the information it collects from its users. On the other hand, this personal information could also be used to provide personalized services which enables robots to adapt to its users personal needs. In other words, there are two sides on collecting personal information that it is both expedient and bothersome.

Information privacy refers to "the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extend information about them is communicated to others" (Westin, 1967, p. 7). Theoretically, this definition may sound straightforward, however, practically people's privacy boundaries varies with several factors such as culture and law (Milberg et al., 1995). These factors, combined with personal characteristics and previous experiences (Donaldson & Dunfee, 1994), also cause variations in people's perceptions of their own information privacy concerns. Privacy concerns are related to the inputs, use and control of data (Campbell, 1997) and increased privacy concerns have a negative effect on trusting beliefs (Malhotra, Kim & Agarwal, 2004).

TRUST

Autonomous systems take over control of some of the technological processes by actively selecting data, transforming information and making their own decisions (Li, Rau, & Li, 2009). User must then trust such systems to do all this in an acceptable manner. Trust in human-robot interaction is very much related to trust in automation in general (Cramer et al., 2008), and can determine the overall acceptance and use of an autonomous system (Parasuraman, & Riley, 1997). Trust is thus an important factor influencing the acceptance and use of social robots (Hancock et al., 2011). The concept of trust is defined as "the belief that the trustee will act cooperatively to fulfill the trustor's expectations without exploiting its vulnerabilities" (Pavlou & Fygenson, 2006, p. 123).

Trust has long been recognized as a key aspect of social interactions where uncertainty, delegation of authority, and fears of opportunism are present (Luhmann, 1979). As social robots are autonomous systems designed to socially interact with people, the concept of trust could also play a role in their acceptance in society. Indeed, trust is has been found a crucial factor in maintaining effective human-robot interactions and human-robot relationships (Hancock, Bilings, & Schaefer, 2011). Trust positively influences the use attitude and intention to use in the technology adoption process (Ben Allouch, Van Dijk, & Peters, 2009; Yu et al., 2005), as well as a user's perceived behavioral control (Heerink et al., 2009; Pavlou, & Fygenson, 2006).

ATTITUDE TOWARDS ROBOTS

When evaluating social robot acceptance, one must also consider the user's general attitudes towards future human-robot interaction scenarios. People's general perceptions towards a technology influence how they evaluate its impact on society, the quality of life and their understanding of the technology (Brosnan, 1998). Nomura et al. (2006, 2008) have investigated the people's evaluations of future human-robot interaction scenarios, and found that these opinions influence both human behavior and human emotions in interactions with robots. Moreover, these evaluations have been found to influence the acceptance of assistive robots in people's own homes (Nomura et al., 2009). Thus, people's attitudes towards robots may influence people's decisions of acceptance of robots in own homes.

NORMATIVE BELIEFS AND THEIR INITIAL THEORETICAL INTERRELATIONS

Based on the above discussion, the assumption is that normative beliefs are divided into social and personal norms about using a social robot. This distinction between social and personal norms, as far as I know, do not yet exist in theories of technology adoption or human behavior. Therefore, for now, the theoretically grounded relations between normative beliefs and other factors I the model will be assumed for both social and personal norms as personal norms arise from beliefs that are considered to be the norm in one's social environment. The goal of this dissertation is to investigate these interrelationships in the context of social robot acceptance.

The diffusions of innovations theory depicts in its model that factors of the social system influence the knowledge a person processes upon which he or she forms his or her opinion about using a technology (Rogers, 2003). Thus, the characteristics of one's social environment, in this dissertation categorized under the normative beliefs, directly affects that person's attitudinal beliefs. This theoretical interrelation between normative beliefs and attitudinal beliefs have been acknowledged in both the information systems literature (e.g., Ben Allouch, Van Dijk, & Peters, 2009; Lee, Kozar, & Larsen, 2003; Yu et al., 2005) and the human-robot interaction literature (e.g., Heerink et al., 2010; Shin & Choo, 2011). Additionally, most theories (e.g., theory of planned behavior, the unified theory of use and adoption of technology, and the model of adoption of technology in households) indicate that normative beliefs influence people's intentions to perform a particular behavior. These interrelationships result in the following hypotheses which are visualized in figure 4.2.

H_4: *The users' personal norms involving the use of a robot directly influence their intention to use that robot.*

H_5: *The users' social norms involving the use of a robot directly influence their intention to use that robot.*

H_6: *The users' personal norms involving the use of a robot directly influence their utilitarian attitudes of that robot.*

H_7: *The users' personal norms involving the use of a robot directly influence their hedonic attitudes of that robot.*

H_8: *The users' social norms involving the use of a robot directly influence their utilitarian attitudes of that robot.*

H_9: *The users' social norms involving the use of a robot directly influence their hedonic attitudes of that robot.*

H_{10}: *The users' social norms involving the use of a robot directly influence their personal norms involving the use of that robot.*

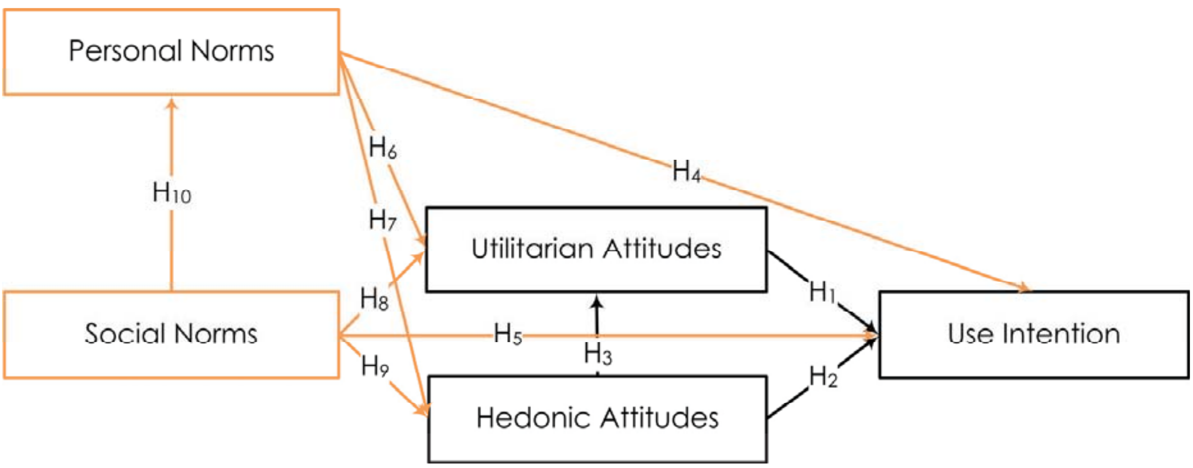

Figure 4.2: Normative beliefs and their initial theoretical interrelations

4.4 CONTROL BELIEFS

Psychology research, and research on the theory of planned behavior in particular, have established the inhibiting effects of constrains for both the intention to perform a behavior as well as the behavior itself (Ajzen, 1991). Specifically, information systems research has identified several factors as barriers to technology acceptance (Mathiessen et al., 2001; Taylor & Todd, 1995). Control beliefs consists of the user's beliefs about salient control factors, that is their beliefs about the presence or absence of resources, opportunities and obstacles which may facilitate or impede the performance of the behavior. For social robot acceptance the control beliefs of self-efficacy, previous experiences, prior expectations, personal innovativeness, safety anxiety towards robots and cost are included.

SELF-EFFICACY

The core part of the control beliefs is self-efficacy, which is defined as "a person's judgments of his or her capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). Self-efficacy is theoretically related to the concept of perceived behavioral control in Ajzen's theory of planned behavior (1991). Self-efficacy is mainly relevant for novice users who have not yet acquired the requisite skills to successfully perform the behavior (LaRose & Eastin, 2004). As social robots are not widespread in society, most people are unfamiliar with these systems.

PREVIOUS EXPERIENCES

Yet, people have varying levels of exposure to robots through either media or personal experiences. Previous experiences with the behavior in question is the most influential source for self-efficacy believes (Bandura, 1997). Being familiar with robots has profound effects on the manner in which people perceive the robot's accessibility, desirability and expressiveness (Fong, Nourbakhsh, & Dautenhahn, 2003). On the other hand, a lack of familiarity can be a reason to feel uncertain when confronted with robots (Broadbent, Stafford, & MacDonald, 2009). People's robot related experiences could influence the user experience and are thus important for the user acceptance of social robots.

PRIOR EXPECTATIONS

Based on these previous experiences, people will form prior expectations about the technology. In human-human interaction research, expectations have played an important role (Blanck, 1993). Because people react similarly to robots as they do to other people (Kerepesi et al., 2006), it could be that people hold high expectations of the robot's ability to behave as a social agent (Young et al., 2011). When expectations are not met in actual experiences with a robot, an expectation gap could arise (Lohse, 2011). And such expectation gaps have negative effects on the user's evaluation of a robot (Paepcke & Takayama, 2010). Prior expectations are thus important to incorporate when studying the user acceptance of social robots.

PERSONAL INNOVATIVENESS

Some people are more willing to experiment with or try out innovative technologies. This trait is conceptualized as personal innovativeness by Serenko (2008), and can be used to indicate early adopters (Rogers, 2003). Personal innovativeness serves as a key mediator for antecedents as well as the consequences of perceptions on innovations (Aragwal & Prasad, 1998). Innovative people evaluate technologies as easier to use (Serenko, 2008) and have higher intentions to use new technologies (Lee, Kozar, & Larsen, 2003). Contrary to global innovativeness, domain-specific innovativeness has an explanatory power on innovation adoption behaviors when applied to a specific innovation context (Goldsmith & Hofacker, 1991).

SAFETY

As robots become more capable of autonomous behavior and become part of our society, safety issues will become of particular interest. The concept of personal safety is defined as the user feeling comfortable or safe when sharing the shame physical space with a robot (Bartneck et al., 2009). Robots provide a level of potential danger seldom experienced with other domestic technologies in the past because of their autonomous physical presence (Young et al., 2007). This potential danger might result in anxious feelings when confronted with a robot.

ANXIETY TOWARDS ROBOTS

Emotional states are important in the formation of control beliefs (Bandura, 1977). Strong emotional reactions to a certain behavior generates beliefs about the anticipated success or failure of the performance of that behavior. At the beginning of the rise of personal computers, many computer users felt anxious when interacting with personal computer, especially during initially interactions (Ganzel, 1998). As most people are unfamiliar with robotic systems, anxiety might play a role in social robot acceptance as well. Moreover, as the 'robots will take over the world' scenario is predominant in Western societies (Kaplan, 2004; MacDorman et al., 2009), it seems reasonable to pay attention to the role of negative emotions towards robots in human-robot interaction.

The concept of anxiety towards robots is defined as "human anxiety towards robots evoked in real and imaginary human-robot interaction situations" (Nomura et al., 2008a, p. 444). When people experience negative thoughts and fears about their capabilities, those affective reactions can themselves lower self-efficacy beliefs and trigger additional stress and agitation that help ensure inadequate performance they fear. Thus, when people feel anxious and unsafe in the presence of a robot, their self-efficacy beliefs about their capabilities of interacting with a robotic system decrease. However, by the time computer users had familiarize themselves with the system interface and functionality, they generally had overcome their initial anxious feelings and had develop favorable perceptions towards personal computers (Liu, Reed, & Phillips, 1992). Similar results will be expected when social robots become more ubiquitous in society.

COST

In contrast to the work-related context, in the consumer context people are responsible for the expenses associate with technology use. The concept of cost is an individual's perception on the expensiveness of a robot. The perceived cost is found to be a barrier in the adoption of home technologies (Brown & Venkatesh, 2005). Particularly, cost influences people's technology use, yet, perceived higher hedonic benefits may decrease this influence (Venkatesh, Thong, & Xu, 2012). Thus, perceiving a robot as something expensive might be another factor to consider when evaluating social robot acceptance.

CONTROL BELIEFS AND THEIR INITIAL THEORETICAL INTERRELATIONS

The model of media attendance visualizes that people's self-efficacy influences both expected beliefs and habit (LaRose & Eastin, 2004). The expected beliefs are similar to what the theory of planned behavior indicates as the attitudinal beliefs, and self-efficacy is indicated by Bandura (1986) as the core of a person's control beliefs as defined in the theory of planned behavior (Ajzen, 1991). This theoretical interrelation between control beliefs and attitudinal beliefs has been found in several studies in both information systems literature (Hackbarth et al., 2003; Karahanna & Limayem, 2000) and human-robot interaction literature (Bartneck et al., 2007b). Consequently, the model of social robot acceptance defines a direct influence of control beliefs on both attitudinal beliefs structures. Moreover, both the theory of planned behavior (Ajzen, 1991) and the social cognitive theory (Bandura, 1977) indicate that control beliefs are affected by opinions form one's social network. Thus, my model of social robot acceptance will incorporate the effect of social norms on control beliefs. Additionally, most theories (e.g., theory of planned behavior, the unified theory of adoption and use of technology, and the model of adoption of technology in households) indicate that control beliefs influence a user's intention to use a technology. These interrelationships result in the following hypotheses which are visualized in figure 4.3 on the next page.

H_{11}: *The users' control believes involving the use of a robot directly influence their intention to use that robot.*

H_{12}: *The users' control believes involving the use of a robot directly influence their utilitarian attitudes of that robot.*

H_{13}: *The users' control believes involving the use of a robot directly influence their hedonic attitudes of that robot.*

H_{14}: *The users' social norms involving the use of a robot directly influence their control believes involving the use of that robot.*

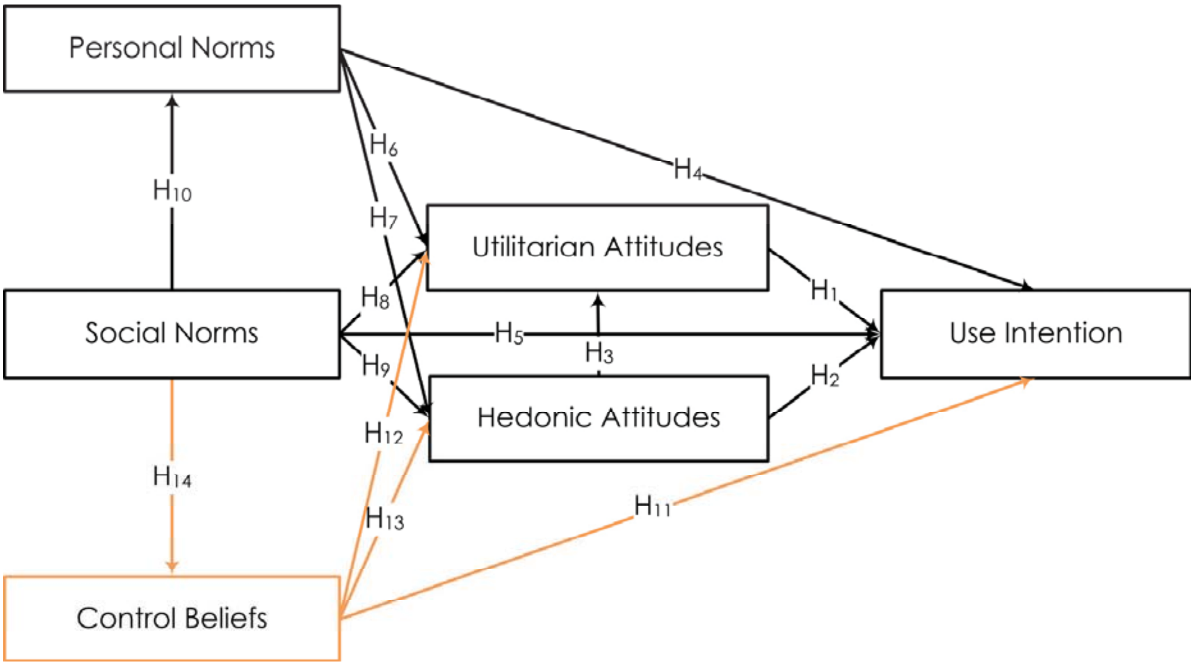

Figure 4.3: Control beliefs and their initial theoretical interrelations

4.5 DEPENDENT VARIABLES OF ACCEPTANCE

Technology acceptance is a process that begins with an individual becoming aware of a technology and, ideally, ends with that individual incorporating the use of that technology in their everyday life. This is where the technology exceeds its functional purpose and becomes a personal object because the individual gets attached to it.

USE BEHAVIOR

The ultimate goal of my conceptual model of social robot acceptance is to explain and predict people’s use behavior or full acceptance of a social robot in their own homes. Acceptance in technology adoption literature is often defined as “the demonstrable willingness within a user group to employ technology for the tasks it is designed to support” (Dillon & Morris, 1996). However, this definition does not distinguish between short term and long-term use. Therefore, Heerink et al.’s (2010) definition might be more appropriate who define acceptance as “the actual use of the system over a longer period in time” (p. 364). This indicates that full acceptance entails the user’s continued use behavior when employing a social robot in their own homes.

USE INTENTION

Most theories agree that people's intentions to perform a behavior is the sole predictor of that actually performing that particular behavior (e.g., theory of planned behavior, technology acceptance model, the unified theory of adoption and use of technologies). The concept of use intention in the context of social robot acceptance is defined as "the intention to use the system over a longer period in time" (Heerink et al., 2010, p. 364).

HABITUAL USE

When people perform the same behavior on a routine basis, these behaviors might become habitual in nature. The concept of habit is defined as the extent to which people tend to perform a learned sequence of behaviors as an automatic response to specific cues, and are functional in obtaining certain goals or needs (Limayem, Hirt, & Cheung, 2007; Verplanken & Orbell, 2003). When we repeat and practice a skill in a given setting, the cognitive processes initiating and controlling our responses become automatic and can be performed quickly in parallel with other activities and with allocation of minimal focal attention (Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). As Ajzen & Fishbein (2005) noted, feedback from previous experiences will influence various beliefs and, consequently, future behavior performances. Habit is thus conceptualized as the perceptual construct that reflects results of previous experiences in the various beliefs structures of performing a (future) behavior. However, habits are not included in most contemporary social psychological models of human behavior because of the supposed limited explanatory power of behavioral repetitions which has discouraged the development of theoretical explanations for past behavior effects (Ouellette & Wood, 1988). Nevertheless, some theories are challenging the role of use intention as the key predictor of technology adoption and use by indicating habitual use as the main predictor of use behavior (Lymayem, Hirt, & Cheung, 2007). Indeed, as Triandis (1980) pointed out, the best predictor of future behavior is past behavior. Habit could be helpful to dismiss the error variance between use intention and use behavior. Thus, when evaluating social robot acceptance, the factors of use intention, use behavior and habitual use must be taken into account.

DEPENDENT VARIABLES AND THEIR INITIAL THEORETICAL INTERRELATIONS

Based on the section above, it is assumed that actual use can be a result of either the process of automatic repetition of past actions resulting in habits or the process of controlled, conscious reliance on behavioral intention. When people's conscious intentions correspond with their habitual behaviors, actual behavior will most likely be a result from recurring features of the situation and be relatively automatic. However, when intentions counteract habitual behavior, actual use will most likely arise from intentions insofar that intentions are powerful enough to override the existing habits.

The Triandis model depicts that habit directly influences people's use behaviors as well as people's affective evaluations of using a technology (Triandis, 1980). These affective evaluations are similar to the hedonic intrinsic motivations to use a technology described in this dissertation. Thus, my conceptual model of social robot acceptance includes an influence of habit on hedonic attitudes. The model of media attendance tells us that people's self-efficacy influences habit (LaRose & Eastin, 2004). The concept of self-efficacy is indicated by Bandura (1986) as the core of a person's control beliefs as defined in the theory of planned behavior (Ajzen, 1991). Thus the model of social robot acceptance defines a direct influence of control beliefs on habit. Additionally, according to some theories on human behavior (e.g., theory of planned behavior and the Triandis model) control beliefs directly influence use behavior. These interrelationships result in the following hypotheses visualized in figure 4.4.

H_{15}: *The users' intention to use a robot directly influence their actual use of that robot.*

H_{16}: *The users' habitual use of a robot directly influence their actual use of that robot.*

H_{17}: *The users' habitual use of a robot directly influence their hedonic attitudes of that robot.*

H_{18}: *The users' control beliefs involving the use of a robot directly influence their intention to use that robot.*

H_{19}: *The users' control beliefs involving the use of a robot directly influence their habitual use of that robot.*

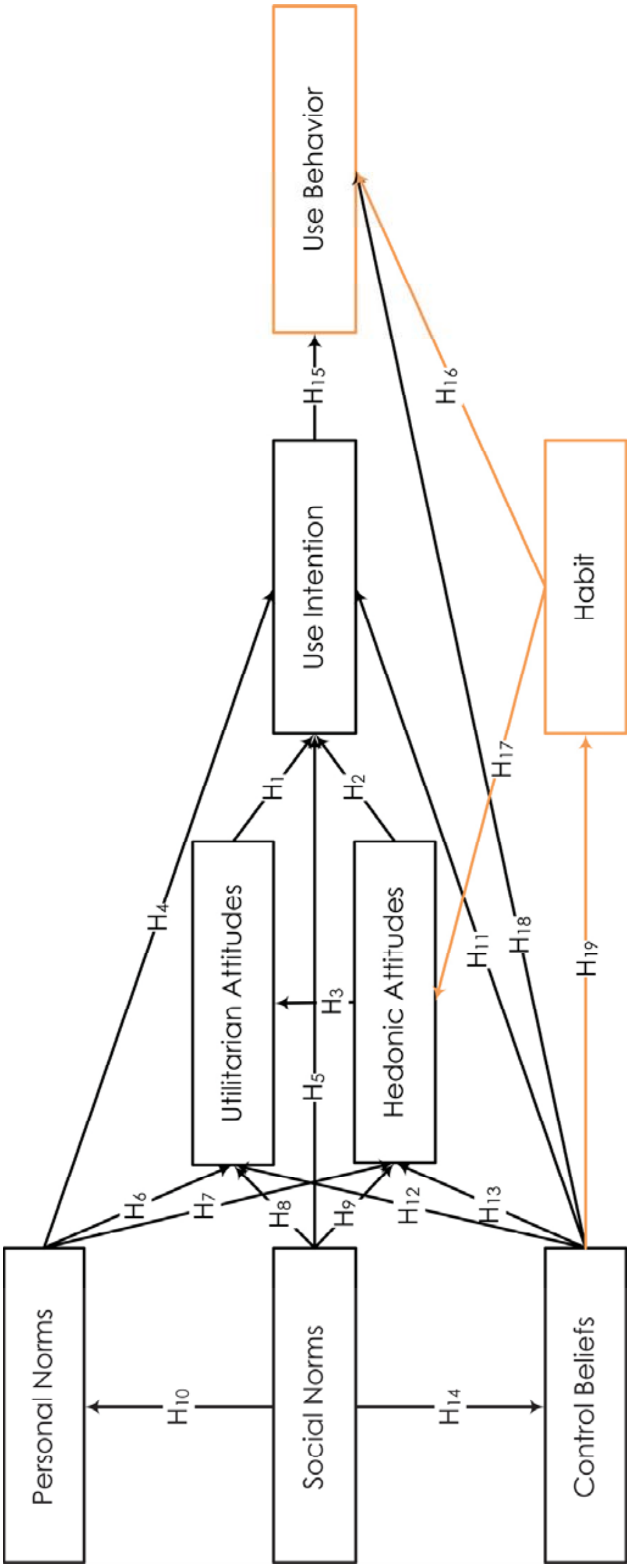

Figure 4.4: Dependent variables and their initial theoretical interrelations

4.6 MODERATING FACTORS: THE USER CHARACERISTICS

In addition to the factors defined in the model of social robot acceptance, there are also factors involving the user's characteristics that could moderate the interrelations between concepts in the model. Indeed, some technology acceptance models incorporate so called moderating factors, such as age, gender, educational level and voluntariness (Sun & Zhang, 2006; Venkatesh et al., 2003; Venkatesh, Thong, & Xu, 2012), and their effects have been found in human-robot interaction research as well (Heerink, 2011; Scopelliti, Giuliani, & Fornara, 2005). Underneath the user characteristics of age, gender, nationality or cultural background, and educational level are discussed.

AGE

Stereotypes suggest that older adults are unwillingly, unable, or afraid to use technological devices (Flandorfer, 2012; Kuo et al., 2009), but their intentions to use technological devices increases when older people discover that these devices are convenient and useful (Van Dijk, 2005). In human-robot interaction research, age has been related to the evaluation of attitudinal beliefs (Lessister et al., 2001; Libin & Libin, 2004) and control beliefs (Heerink, 2011), as well as to the intention to use a robot (Broadbent, Stafford, & MacDonald, 2009; Heerink, 2011). Nonetheless, most older adults indicate that they are willing to accept robots to assist them when they are no longer capable of performing their daily tasks (Arras & Cerqui, 2005).

GENDER

Psychology research indicates gender differences in the schematic processes of decision making (Bem & Allen, 1974). Indeed, gender differences play a role in the acceptance and use of technological devices, because of the differences between males' and females' social behavior and their social roles in society (Norman, 1994). The differences in perception of technology causes gender differences for attitudinal beliefs (Sun & Zhang, 2006; Venkatesh & Morris, 2000), normative beliefs (Eagly, 1978; Miller, 1986; Minton & Schneider, 1980) and control beliefs (Venkatesh & Morris, 2000). Gender has been shown to be an significant factor in human-robot interaction as well (Arras & Cerqui, 2005;

Forlizzi, 2007; Heerink, 2011; Kuo et al., 2009; Scopelliti et al., 2005). Therefore, investigating gender differences and their mediating effects on social robot acceptance seems to be a relevant approach.

NATIONALITY AND CULTURAL BACKGROUND

Besides age and gender, each culture possesses its own level of exposure to robots through either media or personal experiences (Broadbent, Stafford, & MacDonald, 2009). The typical ‘robots take over the world’ scenarios that are often portrayed in Western cultures is less dominant in Japan and other Asian countries (Kaplan, 2004). Someone’s cultural background has a significant effect on attitudinal beliefs towards using a robot (Bartneck et al., 2006; Li, Rau, & Li, 2010; Libin & Libin, 2004; Nomura et al., 2008b) and human behaviors in interactions with robots (Libin & Libin, 2004). However, these results must be adapted with care, because of the differences in the deviation of gender and age among the participant groups within these studies.

EDUCATIONAL LEVEL

As various studies report on the influence of educational level on technology acceptance, it is important to consider these factors for the acceptance of social robots as well. Higher education was found to be associated with greater acceptance of technological solutions for everyday problems (Giuliani et al., 2005). There are only a few studies on the effect of educational level on attitudes towards robots (Broadbent, Stafford, & MacDonald, 2009). Less educated people hold more negative feelings towards robots compared to higher educated people (Scopelliti et al., 2005). Higher educated people were less open to perceive the sociability of a social robot (Heerink et al., 2011). Together, these moderating factors should be taken into account when investigating social robot acceptance.

INVESTIGATING MODERATING FACTORS

This section described several socio-demographic factors as influencing factors of technology acceptance. However, the influence of these factors is much more complex, because they are believed to be interlinked. Older people might be less educated or less experienced with technological matters, and they may thus accept and use technological devices in a different way younger higher educated people do (Czaja, Charness, & Fisk, 2006; Ellis & Allaire, 1999). The mediating effect of experience with technology may hold true for gender as well, because men are more familiar with technology than women (Sun & Zhang, 2006; Venkatesh & Morris, 2000), and might thus be more willing to accept social robots. Also, how people perceive social robots is subject to psychological factors, which are again related to socio-demographic factors as well (Flandorfer, 2012). These interrelations between the user characteristics makes it more difficult to draw conclusions when only some of these are incorporated into the research design or the research model. Therefore, the conceptual model of social robot acceptance presented in this dissertation will not incorporate any user characteristics. However, when investigating the effects on social robot acceptance, additional analyses will be performed to investigate whether these user characteristics moderate the effects found for the complete sample.

4.7 A CONCEPTUAL MODEL OF SOCIAL ROBOT ACCEPTANCE

The review of relevant theories and existing research presented in chapter 3 has identified the importance of considering different factors of the robot and the user, as well as the context of use. The proposed conceptual model of social robot acceptance, as visualized in figure 4.5, advances existing technology acceptance and robotics research by grounding new factors into the theory of planned behavior, and adapts it for the new context of social robot acceptance.

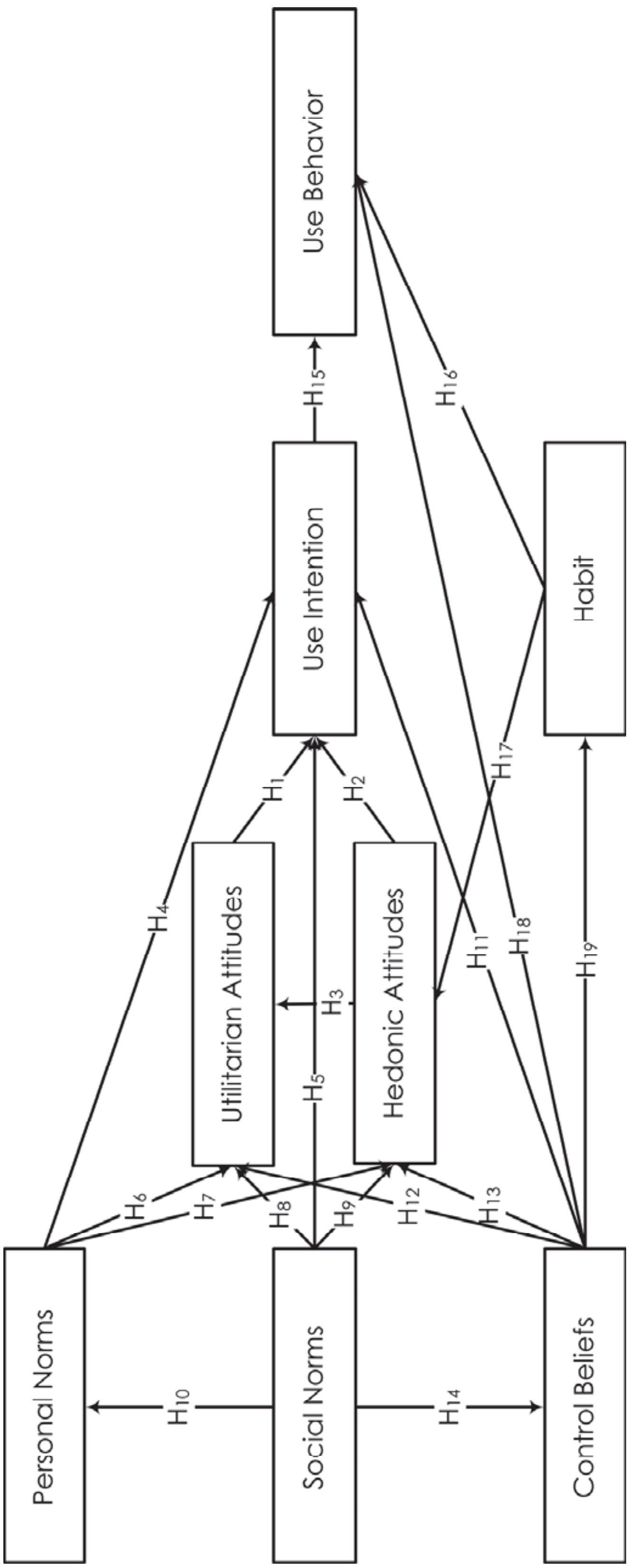

Figure 4.5: Full conceptual model of social robot acceptance

The theoretical factors in the model are based on an extensive literature review taking the current state-of-the-art of (social) robotics research into account, as well as related work from other relevant fields such as information systems, human-computer interaction, (social)psychology, behavioral science and communication science. Based on this literature review, three key acceptance categories were identified that are important when evaluating social robot acceptance in domestic environments. First, the attitudinal beliefs, existing of both utilitarian and hedonic attitudes, that reflect the user's evaluation of the beliefs when using a robot. Second, the normative beliefs, existing of both personal and social norms, that entail the user's evaluation of the prevailing norms involved with using a robot. And third, the control beliefs that comprises of the contextual factors that play a role while using a robot. By adding components for affective evaluations (i.e., hedonic attitudes), the normative context of behavior (i.e., social and personal norms) and habits to the newly proposed model for social robot acceptance, it endeavors to overcome the flaws of the theory of planned behavior which approaches human behavior from a rational and purely psychological perspective. Hence, this dissertation contributes to the literature on the human-robot interaction by modeling the behavioral processes that attempts to explain the intention to use social robots.

5

TESTING THE CONCEPTUAL MODEL OF SOCIAL ROBOT ACCEPTANCE

“Remember that all models are wrong; the practical question is how wrong do they have to be not to be useful.”
– George Box –

Chapter 4 has discussed several factors of social robot acceptance and presented a conceptual model of social robot acceptance. This chapter will test the conceptual model by means of an online acceptance survey administering the anticipated acceptance of social robots in domestic environments. As the diffusion of social robots in society at the time of this dissertation only exists in its very early stages, it is chosen to focus on anticipated acceptance. As a consequence, the concepts of actual use and habit cannot be accounted for in this study, which means that only a part of the conceptual model of social robot acceptance can be tested in this study.

As a first step to test the conceptual model of social robot acceptance among the general Dutch population, a pilot study was conducted and presented in the first section to pretest existing acceptance variables in the context of social robot acceptance. Afterwards, the research method of the Acceptance Survey will be outlined including the representativeness of the sample and the design of the questionnaire. In a separate section the establishment of the measurement model will be discussed. Consecutively, some initial descriptive analysis will be described, followed by testing the model along with its hypotheses. This chapter concludes with the implications of these results. Parts of this chapter have been published before as:

Graaf, M.M.A. de, & Ben Allouch, S. (2013). Exploring influencing variables for the acceptance of social robots. *Robots & Autonomous Systems, 16*, 1476-1486.

Graaf, M.M.A. de, & Ben Allouch, S. (2015). The evaluation of different roles for domestic social robots. *Paper presented at the International Symposium of Robot and Human Communication (RO-MAN 2015), Kobe, Japan*.

5.1 PRE-TESTING ACCEPTANCE VARIABLES FOR SOCIAL ROBOT ACCEPTANCE

Before conducting the Acceptance Survey on social robot acceptance, it was decided to first explore several existing acceptance variables in a pilot study. Although some scales have been adapted to the field of social robot acceptance, others have never been used in this context. Therefore, the purpose of this pilot study is to test the reliability and validity of existing scales for the acceptance variables, as described in chapter 4, in the context of human-robot interaction. Furthermore, as the conceptual model of social robot acceptance will include several acceptance variables, a second goal of this pilot study is to create a compact measurement instrument to test the conceptual model of social robot acceptance.

INTERACTION WITH A HUMANOID ROBOT

For the pilot study, a laboratory based user interaction study was conducted in December 2011 with the academic robot platform of the NAO Academic Edition. The NAO robot is an autonomous, programmable, medium-sized humanoid robot developed by Aldebaran Robotics. We employed the NAO for two reasons. First, NAO is the most widely used robot for academic purposes. Second, NAO is a humanoid robot, and earlier robotics research shows that people are interacting more naturally with humanoids because of familiarity (Fong et al., 2003; Oztop et al., 2005). NAO's body has 25 degrees of freedom and has a series of sensors: two cameras, four microphones, a sonar distance sensor, two IR emitters and receivers, one inertial board, nine tactile sensors, and eight pressure sensors. For expression it has a voice synthesizer, LED lights, and two speakers. NAO was programmed to interact with the participants according to the procedure as described below. To appear to be life-like, NAO waved as the participants entered the room and its eyes lit up when it was listening to the answers of the participants. Robots using gestures were more positively evaluated and were perceived as having higher anthropomorphism even when using only incongruent gestures (Salem et al., 2011). These results demonstrate that using any type of gesture is better than no gestures at all.

The procedure utilized in this study is adopted from Nomura et al. (2008). Participants were requested to have a informal conversation in which the robot would take the lead. As social robots are designed to interact with people in a natural way, an information discourse was deemed an appropriate way in which to evaluate their acceptance. The robot was pre-programmed to interact with the participants in a room, and each participant communicated alone with it for a few minutes. The procedure for each session was as follows:

1. Just prior to entering the room, participants were instructed to take a seat at the table where the robot was situated and allow the robot take the lead in the acquaintance conversation.
2. Participants entered the room alone. NAO greeted the participant with a hand wave and by saying, “Hello” and, after a brief interval, stated, “Take a seat, please.”
3. After the participant has taken a seat at the table, the robot asked, “I am NAO. What is your name?”
4. After conversing with the robot or after a continuous amount of time (30s) passed, the robot asked, “Can you tell me something about yourself?”
5. After conversing with the robot again or after continuous amount of time (30s) passed, the robot then asked, “Tell me one thing that recently happened to you”, in order to encourage participants to respond.
6. After they replied to the robot or a continuous amount of time (30s) passed, the robot uttered a sentence to encourage physical contact, “Will you touch my head?”
7. After touching the robot or a continuous amount of time (30s) passed, the robot finished the session by saying, “Nice meeting you. You may go back to the researcher now.”
8. After the session, the participants completed the questionnaire including age and gender. Afterwards, the researcher conducted a short debriefing before the participants departed.

The interactions with NAO lasted on average between 5 and 10 minutes, and completing the questionnaire averaged between 20 to 30 minutes. Although the interaction was programmed, none of the participants mentioned being suspicious about the robot’s interactivity during the debriefing.
Students from the faculty of behavioral sciences of a Dutch university were recruited to participate in this study in exchange for credits. A total of 60 students, between 18 and 28 years old (M= 20.60, SD= 2.35) participated in this study. An equal distribution of gender was almost accomplished with 28 male (46.7%) and 32 female (53.3%) participants.

QUESTIONNAIRE

All the administered constructs from the questionnaire deployed after the interaction with the NAO are well established in previous human-computer interaction and human-robot interaction research. Each construct in the questionnaire has been drawn from an extensive literature review (see chapter 4 and de Graaf, & Ben Allouch, 2013a) and only those constructs validated in earlier studies were utilized. Yet, some constructs were adapted to the context of social robot acceptance and all items were translated into Dutch. Two bilingual speakers using the back-translation process to complete the translation. This process ensures that meaning and nuance are not lost, and that the translated versions remain as true to the original construct as possible. Prior to the main study, a pilot test for the questionnaire was conducted to confirm the clarity of the wording of the questions and answers as well as the relevance of the questions to the concept of the variable. The pre-test was undertaken by a sample of both researchers and graduated students (n= 8). Their comments on question variation, meaning, task difficulty, interest and attention were employed to create the final version of the questionnaire. Completing the final version took approximately 20 to 30 minutes.

VALIDITY AND RELIABILITY OF ACCENTANCE SCALES IN A HRI CONTEXT

Calculating Cronbach's alpha tested internal consistency of each scale. Reversed coded items were recoded. Table 5.1 displays the used constructs, their source, the number of items from the original scale together with its initial internal consistency of the constructs, and the final number of items to be used in further analyses and their internal consistency. According to Nunnally (1978), an acceptable level of internal consistency is a Cronbach's alpha value of .70 or higher.

Table 5.1: Internal consistency of the acceptance constructs

Construct	Source	Original # of Items	α	Final # of items	α
Adaptability	Heerink et al. (2010)	3	.62	3	.62
Animacy	Bartneck et al. (2009)	6	.77	3	.89
Anxiety towards robots	Nomura et al. (2008)	11	.85	4	.83
Attitude towards robots	Nomura et al. (2008)	14	.75	5	.61
Attractiveness	McCroskey et al. (1974)	4	.85	4	.85
Companionship	McCroskey et al. (1974)	4	.74	4	.92
Ease of use	Heerink et al. (2010)	5	.70	3	.94
Enjoyment	Heerink et al. (2010)	5	.71	3	.92
Personal innovativeness	Aragwal et al. (2000)	4	.82	4	.82
Self-efficacy	Bandura (1977)	10	.84	3	.91
Sociability	Rubin & Martin (1994)	10	.58	3	.90
Social influence	Karahanna et al. (2000)	3	.71	3	.71
Social presence	Biocca et al. (2001)	6	.76	4	.79
Status	Moore et al. (2000)	3	.67	3	.67
Use intention	Moon et al. (2001)	3	.85	3	.85
Usefulness	Heerink et al. (2010)	3	.62	3	.62

The original scales for adaptability, attractiveness, companionship, personal innovativeness, social influence, status, use intention and usefulness were maintained for the final version of the questionnaire. Not all scales have met the criteria for an acceptable level of internal consistency, i.e. $\alpha > .70$ (Nunally, 1977). However, other sources advocate that an internal consistency higher than 0.60 together with both the inter-item correlations and the corrected item-total correlations ranging between 0.30 and 0.70 indicates an acceptable scale (Ferketich, 1991). All scales have met these criteria. Therefore, it was decided to maintain these scales as the goal is to test the full conceptual model of social robot acceptance.

To obtain a more compact measurement model for the Acceptance Survey, some other scales were reduced to three items. Incorporating fewer items in the questionnaire leads to a more parsimonious model and lowers the burden on the participants. The criteria of complexity and faithfulness for model evaluation (Myung, Pitt, & Kim, 2005) were balanced out in the process of item reduction. Faithfulness aims at the model’s ability to capture the underlying phenomenon of interest from the theoretical principles rather than from choices made by computational instantiation. Complexity aims at not only describing the data well, but also do this in the least complex or simplest way.

This process of item reduction was performed for the scales of animacy, ease of use, enjoyment, self-efficacy and sociability. To measure animacy, those items were chosen that best represented the life-likeness of the robot. For the scale of ease of use, two items were removed based on their conceptual overlap with the concept and items of self-efficacy. Regarding the scale for enjoyment, one item specifically involved talking to the robot and another one was negatively formulated. It was chosen to remove both of these items. The scale of self-efficacy exists of ten items. It was chosen to continue with three of these items that best described the original definition of the concept of self-efficacy. The scale of sociability taps into several dimensions of interpersonal communication competence (Rubin & Martin, 1994). It was chosen to continue with the items of empathy, social relaxation and interaction management. Empathy is an important factor for establishing and maintaining human-robot social interactions (see chapter 2 for further discussion). Social relaxation and interaction management account for the robot's ability to feel comfortable in social interaction and being able to smoothly switch between conversation topics. For all scales, the remaining three items had an acceptable level of internal consistency, i.e. α > .70 (Nunally, 1977).

For some other scales, it was decided to incorporate a subscale of the original scale for the final version of the online questionnaire. To measure people's anxiety towards robots, the subscale of anxiety towards discourse with robots from Nomura et al. (2008) was included in the Acceptance Survey. The interaction mode of social robots is by means of natural language. Future users thus must talk to these robotic systems. The subscale produced an satisfactory level of internal consistency (α= .83) in the pilot study. For attitude towards robots, it was decided to continue with the subscale of social influence of robots from Nomura et al. (2008). This scale contains five items that reflect people's beliefs about the societal impact robots might have in the future. The pilot study provided an internal consistency of α .61 for the subscale, but met all the criteria from Ferketich (1991). To measure social presence, only the subscale of co-presence from Biocca et al. (2001) was included in the Acceptance Survey. The remaining four items provide a satisfactory level of internal consistency (α= .79).

Now that the existing acceptance variables have been tested on reliability and validity in the context of human-robot interaction and the final constricts have been established, the next section will further describe the method on the Acceptance Survey to test the full conceptual model of social robot acceptance.

5.2 RESEARCH METHOD OF THE ACCEPTANCE SURVEY

After the exploration of several existing acceptance variables in a pilot study to validate these variables in the context of social robot acceptance, the next step was to administer a large scale survey on the anticipated acceptance of social robots among the general Dutch population. This section discusses the method deployed for the Acceptance Survey and focuses on aspects such as the sample of participants, the design of the questionnaire and the pre-testing of the questionnaire.

SAMPLING OF PARTICIPANTS

For the execution of structural equation modeling, which is necessary to test the conceptual model of social robot acceptance, it is often advised to employ a larger sample size it is important to have a large sample to enhance the precision of parameter estimation (Iacobucci, 2010). To find such a larger sample for this study, a Dutch panel sample administrated by a profit research and consultancy company was employed. The participants completed the questionnaire in return for credits. In December 2013 a total of 4750 people representative of the Dutch population were invited via email to voluntarily participate in the study. In total, 1649 people actually started with the questionnaire, of which 1248 participants completed the questionnaire. This yielded a response rate of 26,3%. A reasonable explanation for the drop-out during the questionnaire is related to its length, which was with 80 items quite long.

Among these completed questionnaires, 86 were removed from the data because of straight lining in the answers. This turned the final number of completed questionnaires to be included in further data analysis to n= 1162.

The demographic characteristics of the participants included in the final sample are displayed in table 5.2 together with the demographics of the general Dutch population (Central Bureau of Statistics, 2013). It is shown that the sample used in the Acceptance Survey serves as a satisfactory representation of the Dutch population.

Table 5.2: Characteristics of the participants (*n*= 1162) versus the Dutch population

	Sample (in %)	**Population** (in %)
Gender		
- Male	51.1	49.5
- Female	48.9	50.5
Age		
- 18-29	20.9	22.1
- 30-44	26.9	29.6
- 45-60	27.5	26.5
- 60+	24.7	21.8
Education		
- Low	22.8	23.1
- Middle	47.8	48.2
- High	29.4	28.7

DESIGN OF THE QUESTIONNAIRE

An online survey was designed to investigate the anticipated acceptance of a social robot in people's own homes. The questionnaire contained three parts. The first part of the questionnaire collected the demographic data (i.e., gender, age, educational level, income, and household type) from the participants, together with the more static trait-like and general constructs (i.e., personal innovativeness, societal impact of robots and anxiety towards discourse with robots). These constructs were assumed to be stable measures (Aragwal & Karahanna, 2000) and it was the goal to capture these constructs without any interference from the other measures or scenarios as used in the questionnaire. The items were presented on a 7-point Likert scale.

The second part of the questionnaire started with a definition of a social robot. A social robot was defined as a robot that can perceive and react to social situations, and can interact naturally with humans using verbal and nonverbal communication. The technology acceptance literature argues that varying aspects could play a dominant role in the acceptance of different technologies with different applications (van der Heijden, 2004; Chesney, 2006). It is expected that this will be similar for different appearances of robots with various roles for domestic use. For this reasons, three different potential future scenarios of the domestic social robot were implemented for the questionnaire: butler, information source, or companion. The butler robot was described as a servant that can do several chores in and around the home according to one's personal preferences. The information robot was portrayed as a talking Internet connected database that answers all your questions. The companion robot was defined as a sociable intellect that builds on online shared stories and with whom users can talk when feeling down or lonely. The participants were randomly assigned to one of three versions of the questionnaire. Then, the participants were confronted with pictures of the four types of robotic appearances (i.e., humanoid, zoomorphic, caricatured and functional). The pictures used for these types of robots are displayed in figure 5.1 on the next page. The participants were asked to choose the robot appearance that would be most suitable for the role as described in the assigned condition, and asked them to provide their rationale for this choice in an open field question.

The goal of the third part was to empirically test the conceptual model of social robot acceptance as described in chapter 4. The participants were confronted with different statements about aspects of what and how robots ought to be when they would be developed for the purposes as described in the second part (i.e., butler, information source, or companion) and to be put to use in their own homes. All these aspects were included in the model and the used scales were all appropriate measurement instruments for model development (DeVellis, 2003). Both Likert scales and semantic differentials were included in the questionnaire to prevent monotony. All answers contained 7-point scales. The Likert scales ranged from 1 'completely disagree' to 7 'completely agree' and for the semantic differentials 1 and 7 represented the opposite ends of adjective pairs (e.g., untrustworthy versus trustworthy).

Figure 5.1: Pictures of robotic appearances used in the Acceptance Survey

The scales from the pilot study described in section 5.1 were incorporated in third part of the questionnaire. These were the utilitarian attitudinal beliefs of usefulness, ease of use and adaptability, and the hedonic attitudinal beliefs of enjoyment, attractiveness, animacy, social presence, sociability and companionship. For the social normative beliefs these were social influence and status, and for the personal normative beliefs this was societal impact of robots. Finally, for the control beliefs these were anxiety towards robots and self-efficacy.

In addition to the explored variables in the pilot study, in the Acceptance Survey also the concepts of privacy concern and trust were included as personal normative beliefs. And personal safety and cost were added to the Acceptance Survey as control beliefs. To function optimally, a robot for domestic purposes should be able to collect information about the home and the people living in it such as time schedules and referred places to store objects. However, collecting such data could generate some privacy concerns from the robot’s user. Therefore, to evaluate privacy concerns the privacy concern scale from Malhotra, Kim and Agarwal (2004) was adapted to the context of social robot acceptance. As the total scale entails 15 items representing four subscales (i.e., collection, unauthorized secondary use, improper access and errors), it was chosen to select one item from each subscale in the final questionnaire. Additionally, as future users must be able to depend on robots to assist them with several tasks, these users should trust the robot to perform those tasks in a satisfactory way. Consequently, to administer trust the reexamined subscale of trustworthiness from McCroskey and Teven (1999) was used. Moreover, autonomously operating robots could raise safety issues from their users. Hence, to measure personal safety, the scale from Bartneck et al. (2009) was used. And finally, as in the private context users must buy product from their house budget, the cost of a robot should be incorporated. To measure cost the scale from Brown and Venkatesh (2005) was adapted to the context of social robot acceptance. All items used in the Acceptance Survey can be found in appendix A.

PRE-TESTING THE QUESTIONNAIRE

A pre-test was executed with 100 participants from the same panel as the main survey. The pre-test mainly focused on validity and reliability of the items. A qualitative evaluation, such as ambiguity of words, misinterpretation of questions or inability to answer a question, has already been tested during the pilot study described in section 5.1. The pre-test revealed low reliability measures for the construct of privacy concern. Thus, for the final questionnaire, it was decided to continue with items from the subscale on data collection of the privacy concern measures as reported by Malhotra, Kim and Agarwal (2004). Moreover, it was decided to add the option 'no opinion' to each statement in the final questionnaire, because of the occurrence of straight lining in the pre-test. The 'no opinion' option provided the participants an escape so that they are not forced to have an opinion on all the statements. As a results, the occurrence of straight lining is expected to decline. All other measures from the questionnaire were considered to constitute reliable and valid scales after initial statistical exploration of the data.

5.3 THE MEASUREMENT MODEL OF THE ACCEPTANCE SURVEY

The purpose of this chapter is to test the proposed conceptual model of social robot acceptance with the data collected. The conceptual model describes that social robot acceptance is a result of the evaluation of several acceptance variables, and consists of a second order that describe how these variables are grouped into three separate sets of beliefs (e.g., attitudinal beliefs, normative beliefs and control beliefs). Previous research on such second order factor models has mostly relied on exploratory factor analysis, and followed a two-step fashion by analyzing the factor correlations among the first order factors obtained using an obligue rotation (Rindskopf & Rose, 1988). Prior to developing a structural model to empirically test the proposed theoretical model of social robot acceptance, it is important to establish a measurement model that is reliable and fits the data well. In case of a second order factor model, this is done by first establishing a first order factor model before trying to fit the second order factor model (Brown, 2006).

The questionnaire used for the Acceptance Survey consist of several 7-point Likert-scales. Several sources to date (Atkinson, 1988; Babakus et al., 1987; Muthén & Kaplan, 1985) support the notion that when the number of categories is large enough, e.g. more than four, and the data approximate a normal distribution, scale items can be analyzed as continuous variables (Bentler & Chou, 1987). The data were explored for normality by examining the histograms of the items. Based on these histograms, it can be concluded that, in general, the data seem normally distributed. However, a remark needs to be made for the items of cost, for which the data were skewed towards robots being evaluated as expensive goods.

CONFIRMATORY VERSUS EXPLORATORY FACTOR ANALYSIS

When doing structural equation modeling, the latent variable measurement specification uses the Jöreskog (1969) confirmatory factor analysis model. Confirmatory factor analysis measurement model specifies, based on theory and prior analyses, a simple structure in which each item is only influenced by a single factor, which causes a number of factor loadings to be fixed at zero (e.g. that there are no cross-loadings). Confirmatory factor analysis measurement modeling has both advantages and disadvantages (Asparouhov & Muthén, 2009). An advantage is that researchers are encouraged to formalize their measurement hypotheses and develop measurement instruments that have a simple measurement structure. This makes the definition of the latent variables better grounded in subject-matter theory and leads to parsimonious models.

The main disadvantage of this method here is that the causal theory behind my conceptual model has not been tested yet in the field of social robot acceptance. It would be too ambitious and practically not feasible in this project to test a complete and assumed fixed theory in a more or less unexplored field with new challenges where exploration precedes causal theory building. Another disadvantage is that a confirmatory approach requires strong measure conditions that is often not available in practice. Measurement instruments often have many small cross-loadings that are well motivated by either substantive theory or by the formulation of the measurements (i.e., the items in the questionnaire). And fixing the cross-loadings to be zero may therefore force researchers to specify a more parsimonious model than is actually suitable for the data (Asparouhov & Múthen, 2009; Morin, Marsh, & Naggengast, 2013). Together, this contributes to poor applications of structural equation modeling where the believability and replicability of the final model is in doubt. Moreover, fixing factor loadings at zero tends to give distorted factors, as the correlation between items representing different variables is forced to go through their main factors only (Asparouhov & Múthen, 2009). This process usually leads to overestimated factor correlations and subsequent distorted structural relations. It is thus important to extend structural equation modeling to allow less restrictive measurement models to be used together with the traditional confirmatory factor analysis models.

Based on this reasoning, it is chosen to add exploratory factor analysis measurement model parts to the creation of the measurement model. As most concepts used in this study are new in the context of social robot acceptance, starting directly with a confirmatory approach would probably result in extensive model modifications to find a well-fitting measurement model (Browne, 2001). Therefore, the adoption of an exploratory approach is preferred. Moreover, although it is convenient to distinguish between exploratory and confirmatory research, in practice this distinction is not as clear cut and both methods can be thought of as an ordered progression (Anderson & Gerbing, 1988). This progression will become clearer in the next section where the first order factor model will be established using both methods.

ESTABLISHING THE FIRST ORDER FACTOR MODEL

The establishment of the first order factor model will be realized by a first step of data reduction. This was done to realize a compact set of items that are of good quality using exploratory factor analysis. A second step is to test the robustness of the measurement model which enable the decision to either adopt a ‘normal’ structural equation modeling (SEM) approach or that the more recently developed exploratory structural equation model (ESEM) approach is more appropriate to develop a model. Finally, the last section will focus on finalizing the measurement model.

EXPLORATORY FACTOR ANALYSIS

Before developing a structural model of social robot acceptance, it is essential to have a measurement model fitting to the data. The first step is to explore how the items fit into clusters with factor analysis. An exploratory factor analysis was executed to check for construct validity to obtain evidence that the items from the questionnaire load onto separate factors in the expected manner (Brown, Chorpita, & Barlow, 1998). Exploratory factor analysis is an exploratory and descriptive technique to determine the appropriate number of common factors and to uncover which measured items are reasonable indicators of the constructs (Brown, 2006). Exploratory factor analysis was performed in Mplus version 7.11 developed by Muthén and Muthén (1998-2012) to analyze the intended measurement model which included all items. Consecutively, several measurement models were run with a varying number of factors, but included all the items. The model with the best fit was chosen based on the model fit measures of bayesian information criterion (BIC) and akaike information criterion (AIC) indices. BIC provides insight into the model complexity and prefers parsimonious models with fewer parameters and AIC is used to compare various models and indicates the better-fitting model with a lower value (Kline, 2011). All analyses used an oblique (Geomin) rotation as factors were expected to be interrelated (Sass & Schmitt, 2010). Additionally, oblique rotation is preferred when aiming at confirmatory factor analysis that fits the data well (Brown, 2006). For the extraction, the maximum likelihood method was used to estimate the common factors. This was done, because this is most frequently used with continuous indicators when the data is normally distributed (Brown, 2006), and because it has the desirable asymptotic properties of being unbiased, consistent and efficient (Kmenta, 1971).

As the total questionnaire contains 20 different scales, it was expected to find 20 separate factors in the EFA. Therefore, several models were run with factor variations from 17 to 23 factors. In the end, a 19 factor set was considered to be most suitable based on the AIC and BIC indices. Moreover, when a model was run with more than 19 factors, the additional factors contained no factor loadings above the value of .3 and thus did not represent a new concept or construct within the data. The results of the first EFA analysis, including all the items, can be found in appendix C. Each factor comprises a unique set of items belonging to separate constructs. The model fit indices of the first EFA solution are presented in table 5.3. The chi-square values were not reported as they are always non-significant with large sample sizes, and even small differences between the observed model and the perfect-fit model may lead to non-significant results (Jöreskog, 1969). Moreover, there seems to be an over-reliance towards overall goodness of fit indices as in actuality models with good fit indices could still be considered poor based on other measures (Chin, 1998).

Table 5.3: Model fit indices of the exploratory factor analysis

Fit Indices	First Solution	Second Solution	Third Solution	Final Solution
RMSEA	.031	.030	.026	.026
RMSEA CI	.029 - .033	.029 - .032	.024 - .029	.024 - .029
CFI	.978	.981	.986	.986
TLI	.955	.960	.970	.971
SRMR	.012	.011	.010	.010
AIC	224730	212976	206466	203311
BIC	230974	218902	212180	208919

The first exploratory factor analysis, where all items were included, provided a root mean square error of approximation (RSMEA) and standardized root mean square residual (SRMR) that both indicate a good model fit, .031 and 0.12 respectively. The RMSEA is a fit statistic of parsimony which prefers a value of less than or equal to .05, however a value of less than or equal to .08 shows an adequate fit (Morin, Marsh, & Nagengast, 2013). Others argue that a value of less than or equal to .06 is the cutoff for a good model fit (Hu and Bentler, 1999). The SRMR is another indicator of absolute fit and well-fitting models have a value less than .05, however, a value up to .08 is considered as acceptable (Hu & Bentler, 1998). Moreover, also the comparative fit index (CFI) and Tucker-Lewis index (TLI) both indicate a good model fit, .978 and .955 respectively. The TLI prefers simpler models and a disadvantage is that this value is sensitive to small sample sizes. A value of 1 indicates a perfect model fit, but a value of at least .90 is required to accept a model (Hox & Bechger, 1998) and a value of at least .95 can be considered as a good model fit (Hu & Bentler, 1999). The CFI compares the model fit with a null model (Bentler, 1990) which assumes that all latent variables are uncorrelated.

A value of greater than or equal to .90 is needed to ensure that miss-specified models are rejected, however, a good model fit is indicated by a value of greater than or equal to .95 (Hu & Bentler, 1999). Altogether, these fit indices indicate an acceptance measurement model after the first run.

However, despite the acceptance model fit, it is chosen to exclude those items from the analysis that poorly loaded onto its unique factor. In total, 3 items (RAS01, RAS02 and SP02) were removed before a second exploratory factor analysis was run. Results of this second solution are also presented in table 5.3. The fit indices of the CFI and TLI are increased, .981 and .960 respectively, and the AIC and BIC are decreased, 212976 and 218902 respectively. This points to an improved model fit. However, in this second solution, two items with cross-loadings on other factors occurred.

In the third EFA analysis, these two items (PU03 and PR03) were removed from the analysis and the model fit indices are also reported in table 5.3. The fit indices of the CFI and TLI increased, .986 and .970 respectively, and the AIC and BIC decreased again, 206466 and 212180 respectively. However, once more an item that poorly loaded onto its unique factors occurred. Thus, a fourth EFA analysis was ran without this item (PAD01). The fit indices of the CFI and TLI did not change much, .986 and .971 respectively, but the AIC and BIC decreased again, 203311 and 209819 respectively. Although a few cross-loadings still existed, it was chosen to continue with this fourth and final solution as eliminating any more items from the model did not improve the model fit indices. The final factor solution is shown in table 5.4 on the next two pages.

Table 5.4: Final EFA solution

Code	UI F1	PEOU F2	PAD F3	PENJ F4	PA F5	SP F6	AN F7	SB F8	COM F9	PR F10	TR F11	SOCI F12	SI F13	IM F14	SE F15	PIIT F16	RAS F17	SAFE F18	CST F19
UI01	**.933**	.019	.038	-012	.011	.043	.005	-.025	-.014	-.004	-.011	-.011	.011	.013	-.014	.011	.003	.011	.013
UI02	**.929**	.029	.013	-013	.002	.-003	-.009	-.010	.014	-.014	.008	.003	.012	.041	-.007	-.002	-.029	-.024	-.001
UI03	**.677**	.011	-.131	.075	-.005	.063	.009	.040	.046	-.050	.015	-.017	.038	.027	.027	.014	.046	.016	-.024
PU01	**.664**	-.010	.087	.095	.007	.023	.024	.046	.037	.021	.039	-.015	.038	-.051	.023	.020	-.027	.029	-.001
PU02	**.840**	-.002	-.091	.069	-.019	-.017	.012	.023	.009	.017	-.009	.010	-.002	.045	.050	.006	-.004	.024	-.003
PEOU01	.039	**.696**	.091	-.045	.007	.021	-.014	.029	.031	-.007	.067	.008	-.008	-.033	.041	.058	-.043	.036	.055
PEOU02	.263	**.455**	.021	.248	-.019	.017	-.017	.027	.013	-.011	.026	-.017	.059	.045	-.019	-.030	.033	-.009	-.018
PEOU03	-.026	**.831**	-.036	.057	-.005	-.010	.078	-.023	.002	-.012	-.031	-.010	.012	.015	.005	.016	-.020	.049	-.008
PAD02	-.028	.042	**.406**	**.330**	-.021	-.006	.014	.065	-.012	.011	.042	-.004	.054	.025	.075	-.026	.041	.118	.050
PAD03	.087	.021	**.377**	**.415**	-.010	.017	.037	.042	.006	-.029	.032	.009	.084	.026	.022	-.008	-.035	.032	.030
PENJ01	.056	.013	-.055	**.653**	.036	.020	-.004	.004	.262	-.020	-.031	0.31	-.045	.013	.022	.011	-.036	.024	.011
PENJ02	.105	.035	.034	**.706**	-.023	.019	.044	-.055	.133	-.077	.030	-.011	.006	.029	-.004	.001	.004	.036	-.025
PENJ03	.002	-.005	.149	**.660**	.054	.044	-.005	.043	.055	-.004	-.001	-.036	.055	-.006	.021	.094	-.014	-.044	.005
PA01	-.029	-.021	-.040	.153	**.638**	-.050	.132	.060	-.020	.000	.143	.005	.061	.006	.017	-.007	-.014	.011	-.038
PA02	.046	-.001	.041	.011	**.676**	.053	-.002	-.020	-.023	.014	.244	-.036	-.019	.000	-.034	.009	-.008	.059	.023
PA03	-.032	.010	.001	-.039	**.782**	.012	.082	-.005	.084	-.048	.087	.016	.033	.021	.020	.007	.013	-.008	.026
SP01	.020	.032	-.009	.016	-.005	**.899**	-.002	.013	-.022	.006	-.002	.005	.003	.020	.025	.019	-.012	-.030	-.016
SP03	-.014	-.005	-.007	-.006	.000	**.824**	.019	.007	.037	.000	.031	-.021	.010	.069	.016	.012	.004	.025	.001
SP04	.057	-.009	.036	.092	.007	**.587**	.014	.005	.144	-.028	-.014	.013	.062	-.026	.003	-.014	-.007	.029	.014
AN01	.055	.017	.019	.009	**.301**	.003	**.587**	.005	.027	-.025	.024	-.035	-.022	-.005	-.005	.022	.025	.019	.016
AN02	-.023	-.014	.017	.039	.041	.009	**.863**	.021	002	.018	.019	.013	.036	-.014	-.001	.010	.009	-.010	.029
AN03	.036	.050	-.004	-.022	.021	.022	**.780**	.001	-.003	.004	.004	.007	-.036	.022	.024	-.001	-.019	-.022	-.033
SB01	.005	-.028	-.012	.013	-.011	-.018	.006	**.958**	.030	-.034	-.019	-.032	-.013	.018	-.002	.007	.023	-.007	.015
SB02	.039	.075	.139	-.001	-.001	.072	.037	**.484**	-.033	.006	.052	-.003	.019	-.007	.038	.017	-.014	.094	-.002
SB03	-.002	.044	**.340**	.005	.089	.030	-.022	**.275**	**.344**	.053	.018	.102	.030	-.007	-.009	.001	-.124	.004	-.017
COM01	.023	.012	-.027	-.032	.043	.012	.004	.037	**.894**	-.018	-.019	.015	.019	.011	-.012	-.009	-.025	-.009	.001
COM02	.091	-0.21	.087	.200	-.004	.050	.015	.018	**.593**	-.062	-.003	.021	-.010	-.038	.069	.044	-.018	.021	.022
COM03	.070	.003	.018	.083	-.027	.007	.012	-.018	**.720**	-.022	-.027	-.040	.006	.044	.055	.017	.060	.037	-.012
COM04	-.055	.024	-.013	.025	-.036	.004	.015	-.004	**.869**	.031	.036	-.050	.020	.079	-.010	-.002	.029	-.028	-.033
PR01	-.042	-.008	-.014	-.027	-.030	.004	-.009	-.001	.001	**.805**	.036	.045	-.027	.038	.015	-.026	-.023	.028	.044
PR02	.035	-.029	.040	.018	-.014	-.017	.020	-.017	-.005	**.925**	-.028	.170	.034	-.040	-.011	.025	.029	.003	-.018
PR04	-.034	.047	-.072	-.038	.069	.021	-.023	.014	-.006	**.337**	-.002	.027	-.039	.017	.002	-.011	.015	-.069	**.305**

Table 5.4: Final EFA solution (continued)

TR01	.012	.006	-.076	.017	.195	.001	.097	.047	-.002	.010	**.647**	.011	.023	.014	-.005	-.051	-.042	.025	.005
TR02	-.021	.018	.016	.020	.011	.034	-.033	.004	.002	.001	**.954**	-.020	-.017	-.021	.013	.016	.014	-.014	-.016
TR03	.040	.010	.055	-.014	.107	-.044	.035	-.020	-.008	-.012	**.780**	.040	.021	-.011	.012	.028	-.010	-.009	.023
SOCI01	.021	.080	.058	.000	.049	-.083	-.133	.007	-.093	.038	.030	**.316**	-.039	-.030	.011	.040	.114	-.097	.046
SOCI02	-.002	-.019	-.102	-.018	-.131	.138	.036	.027	.054	-.025	.008	**.553**	.049	.001	-.034	.005	.007	-.011	.033
SOCI03	.015	.052	.034	.021	.110	-.086	-.086	-.018	-.030	.072	.004	**.480**	-.020	-.068	.005	.004	.171	-.028	.023
SOCI04	-.011	-.045	.047	.022	-.001	.012	.016	-.036	-.020	-.039	-.063	**.800**	-.012	.018	.029	.006	.004	.028	-.032
SOCI05	.018	-.023	-.026	-.028	-.070	-.020	.020	.006	.014	.066	-.012	**.542**	.022	.017	-.038	-.030	.230	-.007	-.027
SI01	.031	.020	.089	.190	.019	.035	-.057	-.011	-.043	-.088	.058	-.002	**.622**	.046	.009	.030	-.006	-.015	.026
SI02	.000	.026	-.163	.033	.042	.053	-.008	.033	.141	.019	-.025	-.020	**.765**	.004	-.004	-.005	.028	.025	-.022
SI03	.228	-.012	.034	-.048	-.021	.034	.056	-.015	.019	-.028	.012	.025	**.662**	-.014	.088	.000	-.049	.025	.034
ST01	.042	-.003	.003	.062	-.032	-.013	.025	.014	.030	.020	.001	.040	.049	**.759**	.023	.019	-.019	-.033	.016
ST02	-.011	.008	.012	.025	.027	.010	-.013	-.016	.013	.003	-.024	-.020	.004	**.900**	-.009	-.026	.003	.040	-.023
ST03	.054	.003	-.002	-.035	.028	.039	-.003	.022	.000	-.021	-.002	-.013	-.015	**.847**	.022	.029	.017	-.002	.005
SE01	.129	.033	.147	.043	.054	.276	.014	.016	.093	.001	-.030	-.015	-.021	-.014	**.307**	-.025	.066	-.002	-.015
SE02	-.006	-.013	-.041	-.014	-.023	-.001	-.010	-.019	.025	-.012	.037	.000	.014	.007	**.978**	-.006	-.002	.026	.017
SE03	.018	.041	.062	.154	.019	.035	.023	.071	-.041	.028	.058	-.006	.157	.041	**.488**	.0302	-.019	-.041	-.046
PIIT01	.008	-.034	.098	.008	.-017	.109	-.006	.015	-.048	.015	.047	.067	.001	.000	-.009	.427	.002	.102	.014
PIIT02	-.062	.047	-.026	.022	-.107	.006	.075	.010	.018	-.046	.023	.008	.019	.095	-.032	**.745**	.055	.055	-.047
PIIT03	.024	-.022	.062	-.015	.039	-.018	-.046	-.006	.047	.019	-.008	.008	-.023	.004	.051	**.815**	-.053	-.002	.038
PIIT04	.053	.090	-.019	.013	.051	-.009	.016	.010	-.033	.012	-.041	-.161	.030	-.100	-.006	**.469**	-.366	-.117	-.014
RAS03	-.004	.017	-.015	-.043	.035	.024	-.001	.020	.004	.011	-.049	.083	.011	.009	.018	-.035	**.819**	-.058	.000
RAS04	.017	-.039	-.011	.015	-.010	-.009	.012	-.016	-.014	.002	-.008	.004	-.014	-.020	-.018	.024	**.839**	-.005	.002
SAFE01	.021	.047	.102	.108	.089	.063	-.003	-.017	.015	-.015	-.025	-.057	.030	-.004	.015	.060	-.065	**.630**	.000
SAFE02	-.001	.005	-.005	-.031	.030	-.002	.019	.047	-.012	.025	.013	.013	-.026	-.004	.002	-.031	-.036	**.795**	.048
SAFE03	.034	.050	-.017	.012	-.020	-.033	-.027	.011	.018	-.007	.010	.000	.037	-.005	-.002	.040	.053	**.720**	-.068
CST01	.007	-.008	-.017	.004	.001	-.004	-.032	.016	-.002	.022	.038	.027	-.014	.023	-.003	.005	-.001	.009	**.877**
CST02	-.008	-.048	.074	-.031	-.060	-.017	.033	-.015	.005	-.037	.015	-.052	.030	.008	-.014	.023	.020	.021	**.901**
CST03	.006	.052	-.012	.012	-.057	.009	.009	.006	-.025	.046	-.066	.008	.018	-.059	.011	-.039	-.016	-.017	**.772**

Factor loadings > .3 are depicted in bold

Note: UI= Use Intention, PEOU= Ease of Use, PAD= Adaptability, PENJ= Enjoyment, PA= Attractiveness, SP= Social Presence, AN= Animacy, SB= Sociability, COM= Companionship, PR= Privacy, TR= Trust, SOCI= Societal Impact, SI= Social Influence, ST= Status, SE= Self-Efficacy, PIIT= Personal Innovativeness, RAS= Anxiety towards Robots, SAFE= Safety, CST= Cost.

FINAL FACTOR SOLUTION

The items of the final factor solution of the explorative factor analysis were examined for internal consistency using coefficients of Cronbach's α. A reliable construct has a coefficient above .70 (Nunally & Bernstein, 1994). The first factor, labelled as personal innovativeness, had an acceptable internal consistency (α= .74). The second factor was labeled as societal impact with an acceptable level of internal consistency (α= .77). The third factor was labeled as anxiety towards robots. Two items (RAS01 and RAS02) showed high cross loading onto the third factor. Therefore, these two items were removed from further analysis in the second solution. The remaining two items formed an acceptable level of internal consistency (α= .87). The fourth factor contains two theoretical concepts, namely use intention and usefulness. The items used in this study to conceptualize usefulness are more related to the utility evaluation of a technology. The definition of a technology, at least at a basic level, is for it to help people doing things (Orlikowski, 1992). This tightly links the definition of a technology to its evaluation of its meaning, significance and utility which is the crucial underlying motivator for the potential user (Silverstone, 1996). Therefore, it is not surprising that the theoretical concepts of use intention and usefulness cannot be distinguished empirically. Hence, this fourth factor was labeled as use intention since this is covers the overall concept of this factor. One item (PU03) loaded poorly onto this factor and was removed from further analysis in the third solution. The remaining items produced an acceptance internal consistency (α= .97). The fifth factor, labelled as ease of use, resulted in an acceptable level of internal consistency (α= .86). The sixth factor was labelled as adaptability. One item (PAD01) loaded poorly onto this factor and showed a cross loading onto the fifth factor. Hence, it was decided in the fourth and final solution of the explorative factor analysis to remove this item from further analyses. The remaining two items resulted in an acceptable level of internal consistency (α= .82). The seventh factor, labeled as enjoyment, had an acceptable internal consistency level of α= .92. The eighth factor was labelled as social presence. One item (SP02) loaded poorly onto this factor and was therefore removed from further analyses in the second solution. The remaining three items formed a construct with an internal consistency level of α= .92. The ninth factor was labelled as self-efficacy with an acceptable level of internal consistency (α= .83). The tenth factor, labelled as social influence, had an acceptable level of internal consistency (α= .88). The eleventh factor was labelled as status with an internal consistency level of α= .91. The twelfth factor was labelled as privacy concern. One item (PR03) was removed from further analysis in the third solution as it showed cross-loadings onto the eleventh factor and the remaining items showed an acceptable level of internal consistency (α= .80). The thirteenth factor, labelled as cost, had an acceptable level of internal consistency (α= .90). The fourteenth factor was labelled as safety with an internal consistency level of α= .81. The fifteenth factor, labelled as sociability, had an acceptable level of internal consistency (α= .75). The sixteenth factor was labelled as companionship with an internal consistency level of α= .94. And the seventeenth factor, labelled as attractiveness, had an acceptable level of internal consistency (α= .92). The eighteenth factor was labelled as animacy with an acceptable level of internal consistency (α= .88). And the twentieth and final factor was labeled as trust with an internal consistency level of α= .93.

In addition to the internal consistency, the final factor solution was also checked for discriminant validity. Discriminant validity concerns the degree to which items measure distinct or differentiate between constructs. According to Fornell and Larcker (1981) discriminant validity is proven when items load more strongly onto their corresponding constructs than onto other constructs included in the analysis. Table 5.5 shows the correlation matrix of the items included in the final measurement model. Observed is that the items strongly correlate with the other items from their corresponding construct. However, the items of the construct of use intention also correlate strongly with items from the constructs of ease of use, sociability and self-efficacy. Additionally, strong correlations were found between the items from negative attitude towards robots and anxiety towards robots, between self-efficacy and enjoyment, and between sociability and adaptability. These observed correlations can very well be explained from a theoretical perspective and interrelations between these constructs are hypothesized in the conceptual model in chapter 4. As the model fit indices in the EFA together with the internal consistency coefficients are considered to be sufficient, it is decided to continue with robustness testing.

Table 5.5: Correlation matrix of the factor scores

	UIPU	PEOU	PAD	PENJ	PA	SP	AN	SB	COM	PR	TR	NRS	SI	IM	SE	PIIT	RAS	SFE	CST
UIPU	-																		
PEOU	.667	-																	
PAD	.727	.686	-																
PENJ	.866	.680	.769	-															
PA	.291	.392	.406	.347	-														
SP	.666	.494	.573	.734	.235	-													
AN	.370	.371	.377	.452	.706	.406	-												
SB	.561	.630	.693	.608	.446	.597	.481	-											
COM	.692	.489	.528	.808	.202	.745	.413	.564	-										
PR	-.307	*-.191*	*-.188*	-.350	*-.089*	-.266	-.218	*-.151*	-.384	-									
TR	.263	.405	.403	.280	.875	.163	.571	.416	.102	*-.032*	-								
NRS	-.289	-.303	-.249	-.297	-.233	*-.198*	-.206	-.217	-.217	.406	-.259	-							
SI	.763	.648	.760	.771	.395	.606	.373	.621	.586	-.206	.362	-.229	-						
IM	.518	.284	.328	.524	.055	.556	.221	.322	.609	-.169	-.024	-.036	.450	-					
PBC	.732	.608	.718	.730	.308	.676	.360	.656	.629	-.152	.279	*-.174*	.753	.473	-				
PIIT	.405	.551	.372	.447	.202	.300	.226	.360	.315	-.221	.229	-.260	.363	*.176*	.293	-			
RAS	-.208	-.356	-.287	-.224	-.248	*-.115*	-.123	-.233	-.062	.226	-.287	.725	-.246	*.118*	*-.134*	-.350	-		
SFE	.531	.681	.569	.573	.359	.435	.305	.548	.422	-.217	.365	-.382	.543	*.176*	.448	.458	-.431	-	
CST	*.004*	*.126*	.185	*-.036*	.211	*-.078*	*.016*	*.162*	-.212	.392	.252	*.157*	.124	*-.162*	*.037*	*-.058*	*-.013*	*.041*	-

Non-significant correlations at $p > .05$ are in italic. The hypothesized second order factor correlations are displayed in boxes.

ROBUSTNESS TESTING OF THE FIRST ORDER MEASUREMENT MODEL

Once the final exploratory factor model had been established, the robustness of the data was tested to ensure the continuance with confirmatory factor analysis. The large number of parameters and latent variables within the dataset causes the measurement model to be very complex. Continuing with confirmatory factor analysis is preferred, because it allows data analysis with a more simple model (Browne, 2001). Some researchers (Morin, Marsh, & Naggengast, 2013) argue that it is a commonly used approach "to use exploratory EFA to 'discover' an appropriate factor structure and then incorporate this post hoc model into a CFA framework" (p. 400). Although some purist may be offended by this approach as it blurs the distinction between exploratory and confirmatory factor analysis, Morin, Marsh, & Naggengast (2013) do not instantly discard this approach as long as researchers are careful with their interpretations and apply them with appropriate caution.

To decide whether it is appropriate to continue with CFA and thus conventional SEM, the robustness of the data was tested. Testing for robustness means that a small part of the measurement model, in this case the weakest part according to the final exploratory factor solution, is run in both an exploratory and confirmatory factor analysis setting. In the exploratory factor analysis all items are related to the defined number of factors, and in the confirmatory factor analysis the relation between the items and its latent variable are pre-defined. Additionally, an intermediate model is tested which only includes the observed significant relations in the exploratory factor analysis.

All this is done for a small part of the model, in this case the items of adaptability, enjoyment, companionship, sociability, cost and privacy concern. Reasons for the inclusion of these items in the robustness test is the cross-loading of the items of adaptability (PAD02 and PAD03) on the factor of enjoyment, the cross-loading of an item of sociability (SB03) on both the factors of companionship and adaptability, and the cross-loading of an item of privacy concern (PR04) on the factor of cost. The three models (e.g., EFA model, Intermediate model, and CFA model) are depicted in figure 5.2.

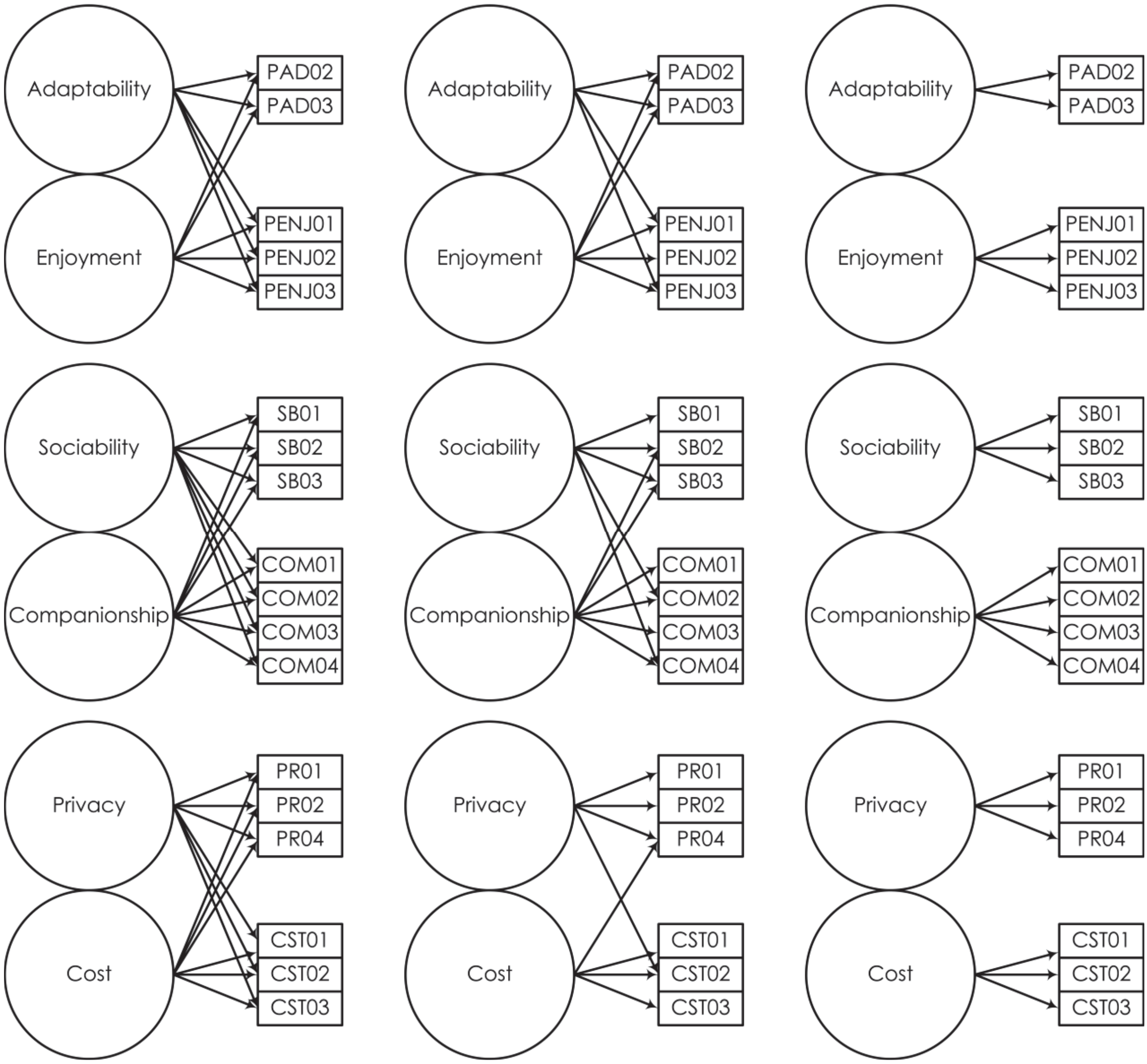

Figure 5.2: From left to right: the EFA model, the intermediate model, and the CFA model

When the measurement model is considered to be robust based on the model fit indices, it is acceptable to continue with a confirmatory SEM approach. As continuing with the confirmatory approach is preferred for reasons of simplicity, the confirmatory model is chosen when the change in AIC and BIC values, compared to the exploratory and intermediary model, is relatively small and the model fit indices show an acceptable to a good fit. Table 5.6 presents the results of the robustness tests. The robustness analysis shows that the model fit indices overall decrease from the exploratory to the confirmatory setting. Nevertheless, they still indicate a good to acceptable model fit and the change in AIC and BIC are relatively small. The baseline of this research is the theoretical background as hypothesized in the conceptual model as described in chapter 4. Statistical analysis is used as a means to confirm (or reject) the theoretical based hypotheses. Thus, with the notion that the constructs of adaptability and sociability need further attention and development in future research (further discussion on this will be presented in chapter 12), it is decided to continue with confirmatory approach.

Table 5.6: Model Fit Indices of Robustness Testing

Fit Indices	Exploratory Model	Intermediate Model	Confirmatory Model
RMSEA	.033	.032	.066
RMSEA CI	.026 - .041	.026 - .037	.061 - .070
CFI	.992	.987	.935
TLI	.979	.981	.917
SRMR	.008	.023	.051
AIC	60706	60720	61301
BIC	61355	61148	61648

FINALIZING THE FIRST ORDER MEASUREMENT MODEL

The final measurement model from the exploratory setting was rerun in a confirmatory setting. With confirmatory factor analysis, the indicated relations of the observed items are specified to the latent variables in advance allowing for correlations between the various latent variables (Anderson & Gerbing, 1988). The pre-specified factors solution is evaluated in terms of how well it reproduces the sample correlation or covariance matrix of the measured items, and thus requires a strong empirical or conceptual foundation to guide the specification and evaluation of the factor model (Brown, 2006). As the constructs are both defined by theory (conceptual foundation) and emerged from the exploratory factor analysis (empirical foundation), carrying on with confirmatory factor analysis was deemed appropriate. Table 5.7 shows that the model fit indices of the confirmatory factor analysis model are acceptable.

Table 5.7: Model Fit Indices of the First Order Confirmatory Factor Analysis

Fit Indices	Values
RMSEA	.039
RMSEA CI	.037 - .040
CFI	.927
TLI	.917
SRMR	.054
AIC	205667
BIC	207455

ESTABLISHING THE SECOND ORDER MEASUREMENT MODEL

Once the first order confirmatory factor analysis had been completed, the next step was to examine the magnitude and pattern of correlations among the factors in the first order solution before trying to fit the second order factor analysis (Kline, 2011). In the first order factor analysis correlations among the factors were assumed based on the theory as hypothesized in the conceptual model, hence the use of an oblique rotation in the first order factor analysis. One goal of second order factor analysis is to provide a more parsimonious theory-based account for the correlations among the first order factors (Brown, 2006). These specifications assert that the second order factors have direct effects on the first order factors. These direct effects and correlations within the second order factors are responsible for the covariation among the first order factors. According to Chen, Sousa, and West (2005), a second order factor model has several potential advantages over a first order factor model. First, the second order model can test whether the hypothesized higher order factor actually accounts for the pattern of relations between the first order factors. Second, a second order factor model puts a structure on the pattern of covariance between the first order factors, explaining the covariance in a more parsimonious way with fewer parameters, which has also been denoted by Gustafsson and Balke (1933) and Rindskopf and Rose (1988). Third, a second order factor model separates variance due to specific factors from measurement error, leading to a theoretically error-free estimate of the specific factors. Finally, second order factor models can provide useful simplification of the interpretation of complex measurement structures.

VALIDITY TESTS FOR THE SECOND ORDER FACTOR MODEL

Tests of validity for a second order factor model follow the same rules of identification as for a first order factor model. Thus, similar thresholds for model fit will be applied here. The first step of validating the second order factor structure is to determine if the implicit constrains are realistic (Chin, 1998). This can be done by examining the correlations among the different first order factors included in the model. Table 5.8 presents these correlations along with its expected second order factor structure. According to Taylor (1990) correlation coefficients below or equal to .35 are considered as weak correlations, between .36 to .67 as moderate correlations, and greater than .67 as strong correlations. The second order factor structure can be validated by the observation of high correlations between the first order factors that are expected to form a second order factor together, and weak correlation between those first order factors that are not expected to be part of the same second order factor. Table 5.8 on the next page shows that no clear pattern for a second factor structure can be derived from the correlations. Although some moderate to strong correlations exist for the hedonic attitude beliefs structure, other correlations in these groups are weak. Moreover, the correlations among the personal normative and control beliefs structure are mostly weak to non-significant. Based on these results it is probably impossible to obtain acceptable fit indices for the second order factor model as hypothesized in the conceptual model.

Table 5.8: Correlations between the first order factors

	UI	PEOU	PAD	PENJ	PA	AN	SP	SB	COM	PR	TR	SOCI	SI	ST	SE	PIIT	RAS	SAFE	COST
UI	-																		
PEOU	.667	-																	
PAD	.727	.686	-																
PENJ	.866	.680	.769	-															
PA	.291	.392	.406	.347	-														
AN	.666	.494	.573	.734	.235	-													
SP	.370	.371	.377	.452	.706	.406	-												
SB	.561	.630	.693	.608	.446	.597	.481	-											
COM	.692	.489	.528	.808	.202	.745	.413	.564	-										
PR	-.307	-.191	-.188	-.350	-.089	-.266	-.218	-.151	-.384	-									
TR	.263	.405	.403	.280	.875	.163	.571	.416	.102	-.032	-								
SOCI	-.289	-.303	-.249	-.297	-.233	-.198	-.206	-.217	-.217	.406	-.259	-							
SI	.763	.648	.760	.771	.395	.606	.373	.621	.586	-.206	.362	-.229	-						
ST	.518	.284	.328	.524	.055	.556	.221	.322	.609	-.169	-.024	-.036	.450	-					
SE	.732	.608	.718	.730	.308	.676	.360	.656	.629	-.152	.279	-.174	.753	.473	-				
PIIT	.405	.551	.372	.447	.202	.300	.226	.360	.315	-.221	.229	-.260	.363	.176	.293	-			
RAS	-.208	-.356	-.287	-.224	-.248	-.115	-.123	-.233	-.062	.226	-.287	.725	-.246	.118	-.134	-.350	-		
SAFE	.531	.681	.569	.573	.359	.435	.305	.548	.422	-.217	.365	-.382	.543	.176	.448	.458	-.431	-	
COST	.004	.126	.185	-.036	.211	-.078	.016	.162	-.212	.392	.252	.157	.124	-.162	.037	-.058	-.013	.041	-

Note: Second order factors as hypothesized in the conceptual model are displayed in boxes

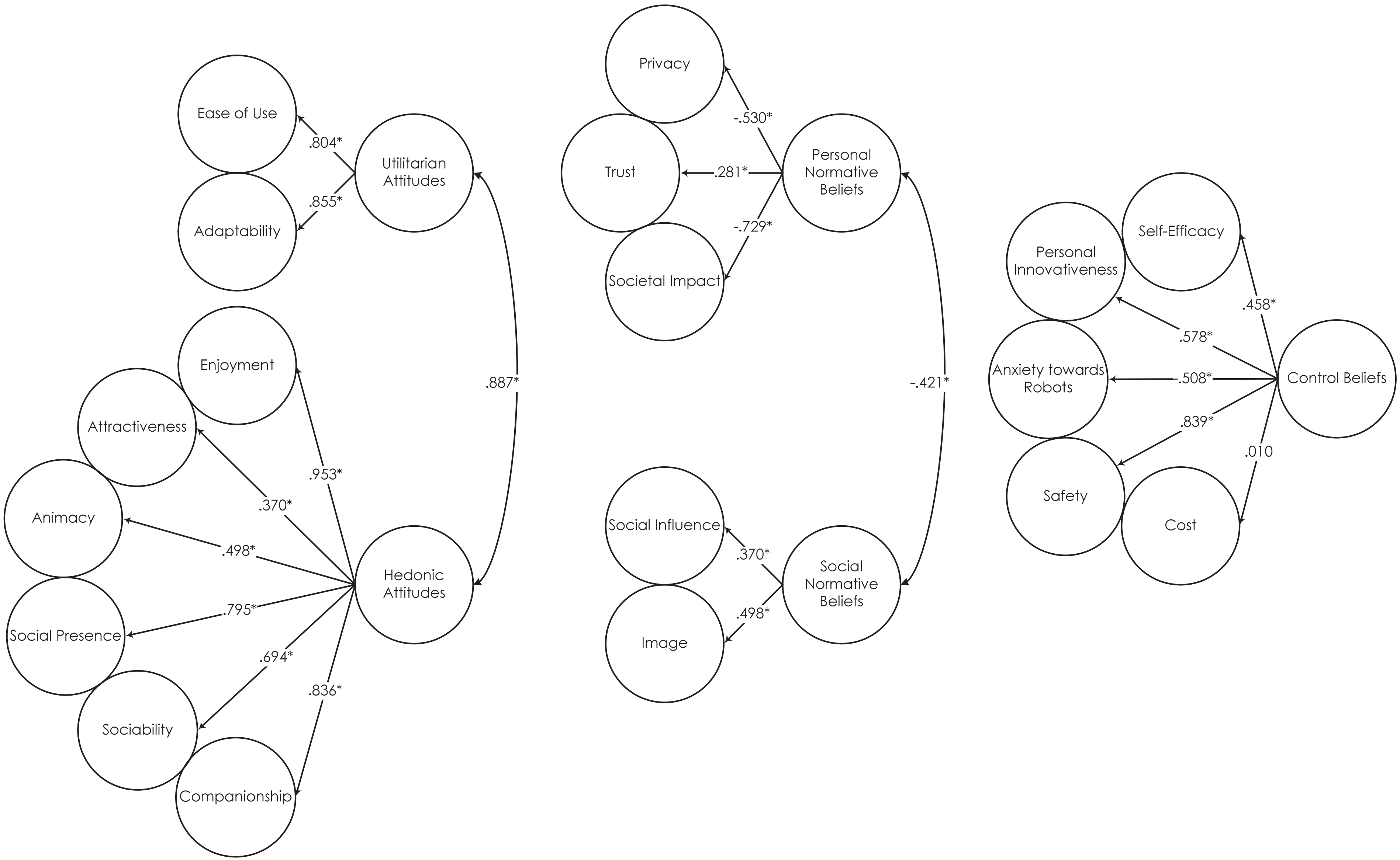

Figure 5.3: Second order factor structures separately (including path loadings with * for significance level at $p < .05$)

The next step to validate the second order factor structure is to demonstrate the convergent validity of the first order factors by examining the strength of the paths connecting the second order factors to the first order factors (Chin, 1998). As the measurement model should theoretically contain more than two second order factors (e.g., utilitarian attitudes, hedonic attitudes, personal norms, social norms, and control beliefs) and correlations among the second order factors are assumed, at least two first order factors per second order factor are necessary to be able to identify the model (Rindskopf & Rose, 1988). As a first step, the three second order factor structures were run independently. The final results are presented in table 5.9 below and figure 5.3 on the previous page.

Table 5.9: Model Fit indices of the second order factor structures separately

Fit indices	Attitudinal beliefs	Normative beliefs	Control beliefs
RMSEA	.067	.054	.067
RMSEA CI	.064 - .070	.049 - .059	.061 - .072
CFI	.910	.938	.904
TLI	.898	.926	.881
SRMR	.071	.076	.061
AIC	80675	61856	54024
BIC	81087	62138	54276

To increase the model fit indices of the attitudinal beliefs structure, it was necessary to allow a correlation between the first order factors of attractiveness and animacy. There are many sources (Byrne & Nelson, 1965; Dion, Berscheid, & Walster, 1972; Epley et al., 1991; van der Heijden, 2004; Norman, 2004; Schenkman et al., 2003) that indicate that attractiveness influences different types of other evaluations of the same object, so a correlation between attractiveness and animacy could be defended in that way. The RMSEA (i.e., .067), CFI (i.e., .910) and SRMR (i.e., .071) all indicate a good model fit, however, the TLI (i.e., .898) is slightly lower than aimed for (Kenny & McCoach, 2003). Nevertheless, as there were no other suggested modification indices with sufficient impact on the model fit, it was decided to continue with fitting the normative beliefs structure. Table 5.9 shows that all model fit indices for the normative beliefs structure indicate a good model fit, with respectively a RMSEA of .054, a CFI of .938, a TLI of .926, and a SRMR of .076. Last, for control beliefs structure the model fit indices of RMSEA (i.e., .067), CFI (i.e., .904) and SRMR (i.e., .061) show a good model fit, however, the TLI (i.e., .881) is slightly lower than hoped for (Kenny & McCoach, 2003). Nevertheless, as again there were no suggested modification indices with sufficient impact on the model fit, it was decided to continue with testing the model fit of the full second order factor model.

As final step to validate the second order factor structure, the paths and model fit should still hold when applied in a nomological network of other factors (Chin, 1998). Table 5.10 shows that the model fit indices of the second order factor model. Although the RMSEA shows a good fit, all other model fit indices are not at an acceptable level. The poor model fit could be a result of low data quality or simply the lack of fit between the data and the conceptual model based on theory. Especially based on the high value of the SRMR, one reason could be that, as the three beliefs structures indicated (nearly) acceptable model fits individually, the interrelations between the separate beliefs structures result in misspecification of the model when put together. This argument is supported by the presence of correlations among the second order factors greater than one (see table 5.11 on the next page). Empirical underidentification can occur in case of near zero or near unity correlations among the second order factors (Rindskopf & Rose, 1988). One option could be to constrain the correlations between utilitarian attitudes and control beliefs and between social norms and control beliefs to 1. However, this is only allowed when the confidence interval of the correlation contains 1 (Múthen & Múthen, 1998-2012). The correlation between utilitarian attitudes and control beliefs is 1.086 (CI: 1.031 - 1.141) and the correlation between social norms and control beliefs is 1.011 (CI: .935 - 1.087). As the confidence interval of the correlation between social norms and control beliefs includes 1, an option is to constraint this correlation to 1. However, this would not solve the problem with the correlation between utilitarian attitudes and control beliefs.

Table 5.10: Model fit indices of the second order factor model

Fit indices	Values
RMSEA	.051
RMSEA CI	.049 - .052
CFI	.866
TLI	.858
SRMR	.101
AIC	208441
BIC	209537

Table 5.11: Correlations between the second order factors

	Utilitarian attitudes	Hedonic attitudes	Personal norms	Social norms	Control beliefs
Utilitarian attitudes	-				
Hedonic attitudes	.893	-			
Personal norms	-.602	-.571	-		
Social norms	.966	.971	-.477	-	
Control beliefs	1.086	.934	-.782	1.011	-

FINALIZING THE SECOND ORDER MEASUREMENT MODEL

Based on the above results, it can be concluded that the second order factor structure as hypothesized in the conceptual model does not fit the collected data. A discussion on the theoretical implications of this result follows in the overall discussion of this dissertation (chapter 14). To pursue with data analysis without completely abandoning the conceptual model of social robot acceptance, it was decided to continue with testing the same interrelations as hypothesized between the second order factors but then directly between the underlying first order factors. This enables the identification of the specific components that account for the users' acceptance of social robots in domestic environments. The results of testing this model will be presented in section 5.5. The corrected means of the acceptance variables were obtained from the final first order factor analysis for further analysis (see table 5.12).

Table 5.12: Corrected means of the acceptance variables

Variable	*M*	*SD*
Attitudinal beliefs		
Ease of use	4.47	1.00
Adaptability	3.69	1.41
Enjoyment	3.60	1.71
Attractiveness	4.24	1.31
Social presence	4.23	1.41
Animacy	3.71	1.35
Sociability	3.40	1.58
Companionship	3.23	1.52
Normative beliefs		
Social influence	3.88	1.44
Status	2.66	1.41
Trust	4.15	1.19
Privacy concern	5.91	1.13
Societal impact	5.05	1.25
Control beliefs		
Self-efficacy	4.26	1.23
Personal innovativeness	2.74	1.46
Anxiety towards robots	4.99	1.43
Safety	5.45	1.44
Cost	3.75	1.52
Outcome variables		
Use intention	4.22	0.98

5.4 RESULTS 1: COMPARING THE DIFFERENT CONDITIONS

Before testing the hypotheses and the theoretical model, this section presents the results of the survey concerning the different conditions. First, the participants' preferences of the robot's appearance for the different roles will be presented. Second, the differences in evaluation on the acceptance variables in the different conditions will be described.

ROBOT ROLES AND PREFERRED APPEARANCES

Examining table figure 5.3, it can be observed that, in all the conditions, a humanoid appearance was favored by the participants, i.e., 53.9% of the participants choose a humanoid robot. In addition to these quantitative data, the participants were also asked to provide a reason for their choice for a category of robot appearances (see figure 5.4). The results show that, regardless of the condition, 50.3% of the participants who choose a humanoid robot stated that they favored this robot because it looked most humanlike. Moreover, 10.2% of the participants who choose a humanoid robot indicated that a humanoid appearance looks familiar, that such an appearance suits best when a robot is built to be social (9.9%), and that such an appearance is the most attractive one (8.1%). Unfortunately, quite some participants did not provide a reason for choosing a humanoid appearance (10.7% of the participants who choose a humanoid appearance).

The caricatured and functional appearance were almost equally chosen by the participants, i.e. 18.9% and 17.3% respectively. The participants choose a caricatured appearance, because this appearance does not look all too humanlike (22.7%), clearly looks like a robot (20.5%), or was the most competent for its role (13.6%). The choice for a functional appearance made by the participants was either because this appearance clearly looks like a robot (17.9%), because robots should not act as if they are alive or resemble humans (13.4%), because they don't want a humanoid robot in their home (12.4%), or because they thought this appearance would be most competent (12.4%). A smaller number of participants (n= 115) choose a zoomorphic appearance. The most provided reason for choosing this appearance was because the participants thought such a robot looks cuddly (14.8%). Other reasons provided by the participants who choose a zoomorphic robot were either that this appearance looks attractive (8.7%), that it looks friendly (7.8%), or that they just love animals in general (7.8%). Unfortunately, a comparatively large group of participants who choose a zoomorphic appearance (16.5%) did not provide a reason for their choice.

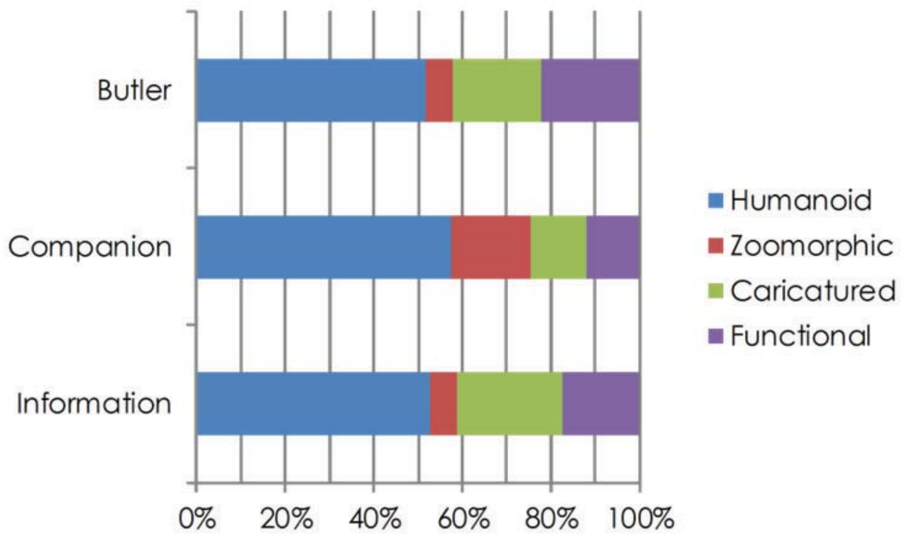

Figure 5.3: Preferred robot appearance for the different roles (n= 1162)

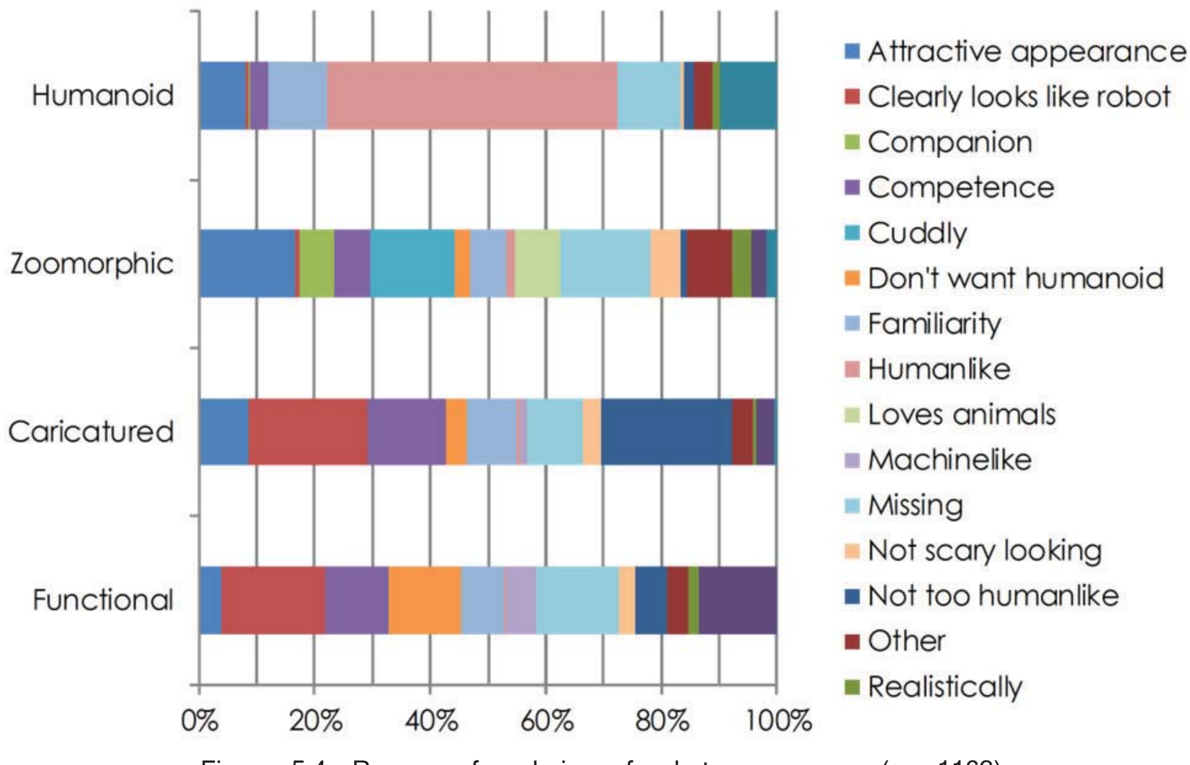

Figure 5.4: Reasons for choice of robot appearance (n= 1162)

A Chi-square test was performed to see if the condition (i.e., the robot's role as butler, companion or information source) had an effect on the appearance of robot (i.e., humanoid, zoomorphic, caricatured, or functional) the participants preferred (see table 5.13). The results show that there is a significant association between the assigned condition and chosen appearance of robot ($\chi^2(6) = 62.689$, $p < .001$). The values of the standardized residuals are used to further interpret the results of the Chi-square test. The standardized residuals represent the error between the observed frequency (i.e., what the data actually observes) and expected frequency (i.e., what the model predicts). A positive value indicates an overrepresentation and a negative value points to an underrepresentation. A value higher than 1.96 or lower than -1.96 for either the over- or underrepresentation is considered to be significant at $p < .05$ (Fields, 2013).

Table 5.13: Effect of condition on robot appearance

			Condition		
Robot appearance		Butler	Companion	Information	Total
Humanoid	Count	204.0	213.0	205.0	622
	Expected	213.3	199.8	208.9	
	Std. residual	-0.6	0.9	-0.3	
Zoomorphic	Count	24	68	23	115
	Expected	39.4	36.9	38.6	
	Std. residual	-2.5	5.1	-2.5	
Caricatured	Count	81	45	94	220
	Expected	75.4	70.7	73.9	
	Std. residual	0.6	-3.1	2.3	
Functional	Count	87	45	66	198
	Expected	67.9	63.6	66.5	
	Std. residual	2.3	-2.3	-0.1	

The results show that, in the butler condition, there is a significant underrepresentation for the zoomorphic appearance (*z*= -2.5) and a significant overrepresentation for the functional appearance (*z*= 2.3) of the robot. Examining the provided reasons (see figure 5.5) given by the participants in the butler condition, the reasons why the participants choose a functional appearance (total n= 87) was either because this one looked most competent (12.6%), because this clearly looks like a robot (12.6%), because they don't want a human-shaped robot (12.6%), or because they thought that robots should never resemble human beings (11.5%). Again, quite some participants in this group did not provide a reason (13.8%).

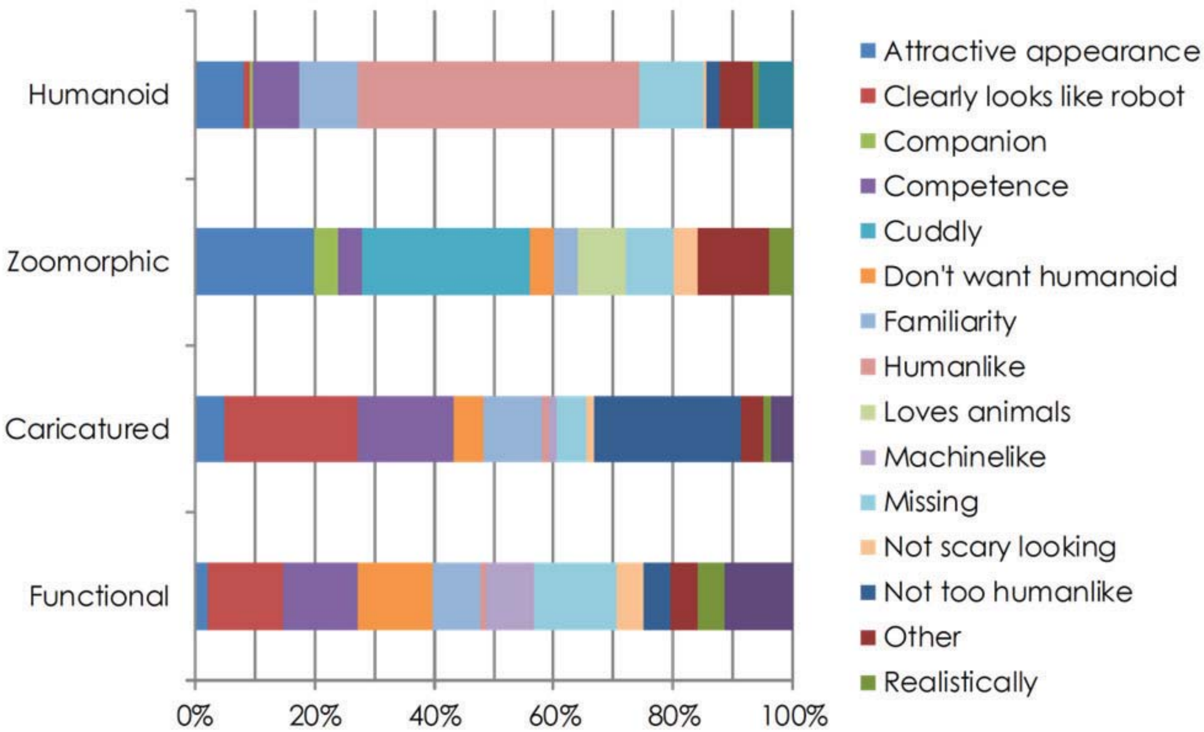

Figure 5.5: Reasons for choice of robot appearance for the butler role

In the companion condition, there is a strong significant overrepresentation for the zoomorphic appearance (z= 5.1) and a significant underrepresentation for both the caricatured appearance (z= -3.1) and the functional appearance (z= -2.3). Examining the provided reasons (see figure 5.6) given by the participants in the companion condition, from the total of participants who choose a zoomorphic appearance (n= 68), some did this because they thought this appearance looked cuddly (13.2%) or just attractive in general (13.2%). Other participants in the companion condition who choose a zoomorphic appearance connected this appearance to the familiarity with pet companions (8.8%) or they just loved animals in general (8.8%). Unfortunately, again, a larger group of participants did not provide a reason for their choice (14.7%).

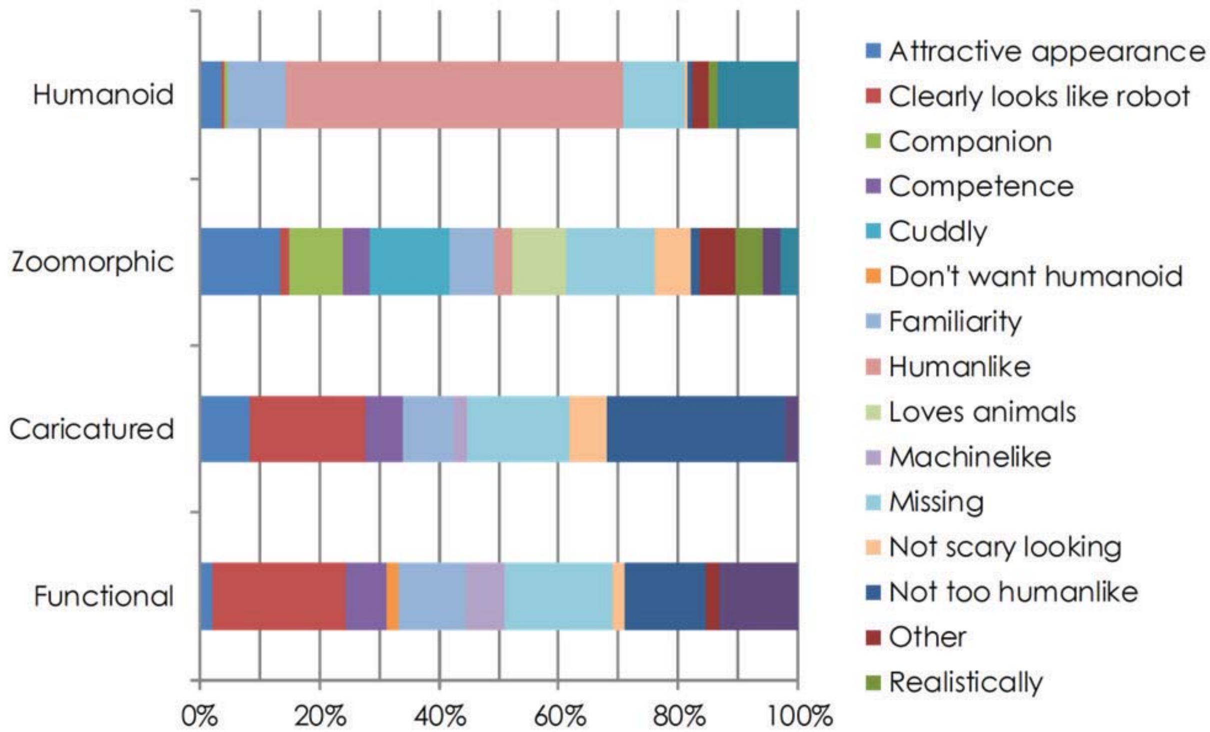

Figure 5.7: Reasons for choice of robot appearance for the companion role

And in the information source condition, there is a significant underrepresentation for the zoomorphic appearance (*z*= -2.5) and a significant overrepresentation for the caricatured appearance (*z*= 2.3). Examining the provided reasons (see figure 5.7) by the participants in the information source condition, the reasons why the participants choose a caricatured appearance (total n= 94) was either because with this appearance clearly looks like a robot (19.1%), because this appearance is not too humanlike (17.0%), because this appearance looked most competent for its role (15.0%), or because this appearance was the most attractive one (11.7%).

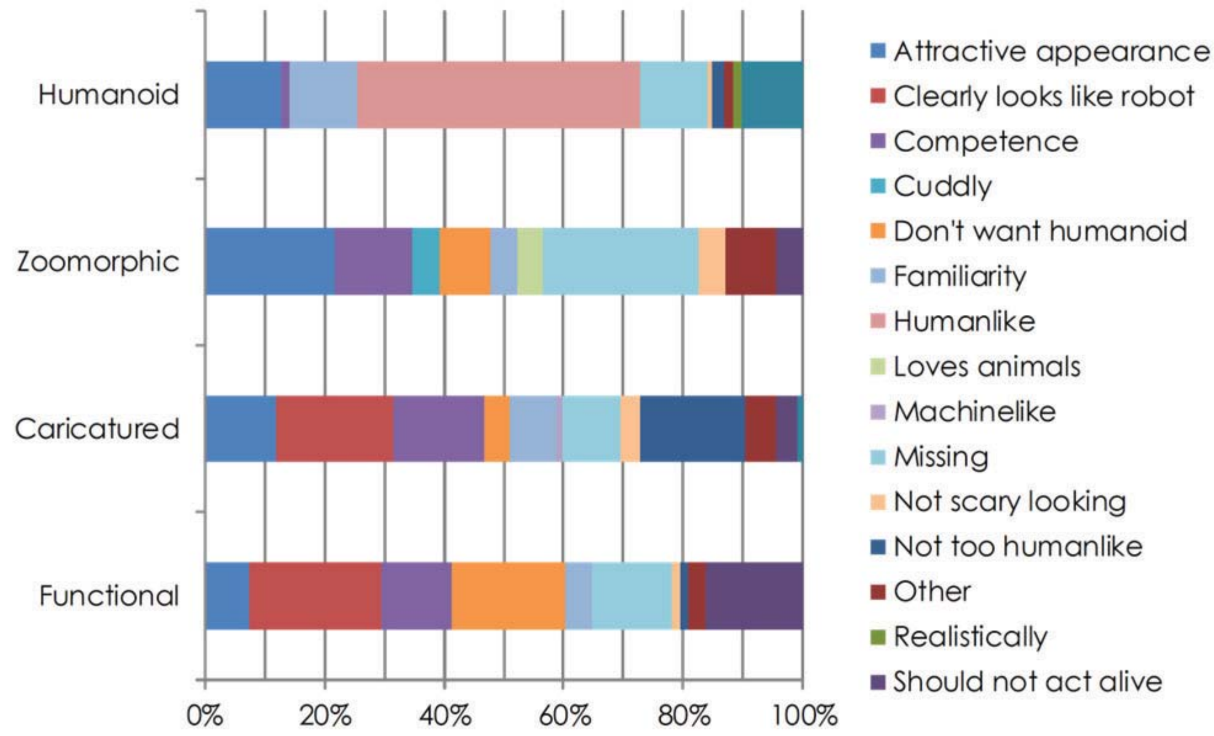

Figure 5.6: Reasons for choice of robot appearance for the information source role

EVALUATION DIFFERENCES AMONG THE DIFFERENT ROBOT ROLES

With several one-way ANOVA tests, it was investigated if participants evaluated the acceptance variables differently among the three conditions (i.e., butler, companion, and information source). Table 5.14 shows that the attitudinal beliefs of enjoyment (F(2, 1152)= 22.17, p < .001), attractiveness (F(2, 1152)= 7.95, p < .001), social presence (F(2, 1152)= 13.39, p < .001), animacy (F(2, 1152)= 10.62, p < .001), and sociability (F(2, 1152)= 10.68, p < .001) were significantly different between the three conditions. Additionally, the normative beliefs of social influence (F(2, 1152)= 10.62, p < .001), status (F(2, 1152)= 5.16, p= .006), trust (F(2, 1152)= 5.44, p= .004), privacy concern (F(2, 1152)= 5.97, p= .003), and societal impact (F(2, 1152)= 3.45, p= .032) were significantly different between the three conditions. And last, the control beliefs of self-efficacy (F(2, 1152)= 3.33, p= .036) was significantly different between the three conditions.

To further analyze these significant results, a series of Bonferoni test was performed. Examining the attitudinal beliefs, the results show that the participants indicated that they would enjoy a butler and an information robot more than a companion robot (p < .05). Moreover, they have pointed out that both a butler robot and an information robot would be more attractive (p < .05), more socially present (p < .05), more animate (p < .05) and more sociable (p < .05) than a companion robot. Examining the normative beliefs, the results show that the participants reported that they would experience higher social influence (p < .05) to use a butler robot or an information robot than to use a companion robot. Additionally, they stated that having either a butler robot or an information robot would increase their status more (p < .05) than having a companion robot. Moreover, the participants indicated that they would trust (p < .05) a butler robot or an information robot more than a companion robot. Examining the control beliefs, the results show that the participants reported that they would feel more competent (i.e., self-efficacy, p < .05) to use an information robot than a butler robot. Additionally, the participants in the condition of the information robot perceived themselves as more innovative (p < .05) than the participants in the condition of the companion robot.

Table 5.14: Effect of condition on the evaluation of the robot

	Condition						ANOVA	
	Butler		Companion		Information			
Acceptance Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*(2, 1152)	*p*
Attitudinal beliefs								
Ease of use	4.48	1.03	4.52	0.97	4.42	1.00	0.94	.392
Adaptability	3.65	1.40	3.79	1.45	3.65	1.36	1.33	.265
Enjoyment	3.95[a]	1.74	3.15[ac]	1.65	3.67[c]	1.66	22.17	.000
Attractiveness	4.36[a]	1.34	4.01[ac]	1.34	4.32[c]	1.31	7.95	.000
Social presence	4.40[a]	1.43	3.92[ac]	1.44	4.35[c]	1.31	13.39	.000
Animacy	3.85[a]	1.33	3.45[ac]	1.40	3.81[c]	1.28	10.62	.000
Sociability	3.56[a]	1.57	3.09[ac]	1.59	3.54[c]	1.53	10.68	.000
Companionship	3.19	1.48	3.09	1.59	3.37	1.52	2.64	.072
Normative beliefs								
Social influence	4.05[a]	1.45	3.60[ac]	1.47	3.97[c]	1.38	10.62	.000
Status	2.76[a]	1.45	2.46[ac]	1.35	2.73[c]	1.41	5.16	.006
Trust	4.20[a]	1.18	3.98[ac]	1.19	4.24[c]	1.18	5.44	.004
Privacy concern	6.06[b]	1.04	5.90	1.15	5.78[b]	1.18	5.97	.003
Societal impact	5.13[b]	1.23	5.10	1.26	4.91[b]	1.26	3.45	.032
Control beliefs								
Self-efficacy	4.17[b]	1.19	4.25	1.31	4.39[b]	1.23	3.33	.036
Personal innovativeness	2.71	1.43	2.61[c]	1.45	2.89[c]	1.49	3.52	.030
Anxiety towards robots	5.02	1.42	5.00	1.55	4.95	1.32	0.22	.804
Safety	5.47	1.43	5.42	1.54	5.48	1.34	0.11	.894
Cost	3.70	1.51	3.79	1.63	3.76	1.42	0.34	.714
Outcome variables								
Use intention	4.22	1.00	4.20	0.97	4.25	0.96	0.27	.762

Bonferoni significance between two conditions at $p < .05$
[a]= between butler and companion
[b]= between butler and information
[c]= between companion and information

5.5 RESULTS 2: MODEL TESTING

Based on the measurement model, this section will test the structural model of social robot acceptance and reports on the proposed hypotheses in the conceptual model as described in chapter four. The intended structural model (see figure 5.8 on the next page) was tested in Mplus. The original model showed that the model fit was acceptable for the RMSEA and SRMR with values of .045 and .071 respectively, but not quite acceptable for the CFI and the TLI with values of .899 and .887 respectively (see table 5.15). Post-hoc modification indices suggested that specifying six correlations between first order factors would increase the model fit. These were three correlations of factors from the hedonic attitudes (e.g., enjoyment with sociability, enjoyment with companionship, and attractiveness with animacy) and three correlations of factors from the control beliefs (e.g., personal innovativeness with anxiety towards robots, personal innovativeness with safety, and anxiety towards robots with safety). The theory, as outlined in chapter 4, suggested that each correlation would be part of a second order factor structure as hypothesized in the conceptual model. Therefore, it was decided to add these six suggested correlation in a second run of the model and the model fit increased to an almost acceptable level (see table 5.15). To further increase the model fit, a last correlation pair as suggested in the post-hoc modification indices, was added (i.e., societal impact with anxiety towards robot). Although these two concepts were not hypothesized as belonging to the same second order factor, its inclusion in the model can be supported by the high correlation between the two concepts that has been reported in multiple studies (e.g., Dautenhahn & Saunders, 2011; de Graaf & Ben Allouch, 2013b; Nomura et al., 2008). With the inclusion of this correlation the model fit increased to an acceptable level in the final model (see table 5.15).

Table 5.15: Model fit indices of the structural model

Fit indices	**Original model**	**Second model**	**Final model**
RMSEA	.045	.043	.042
RMSEA CI	.044 - .046	.042 - .045	.040 - .043
CFI	.899	.906	.915
TLI	.887	.895	.904
SRMR	.071	.071	.068
AIC	206929	206591	206208
BIC	208495	208188	207809

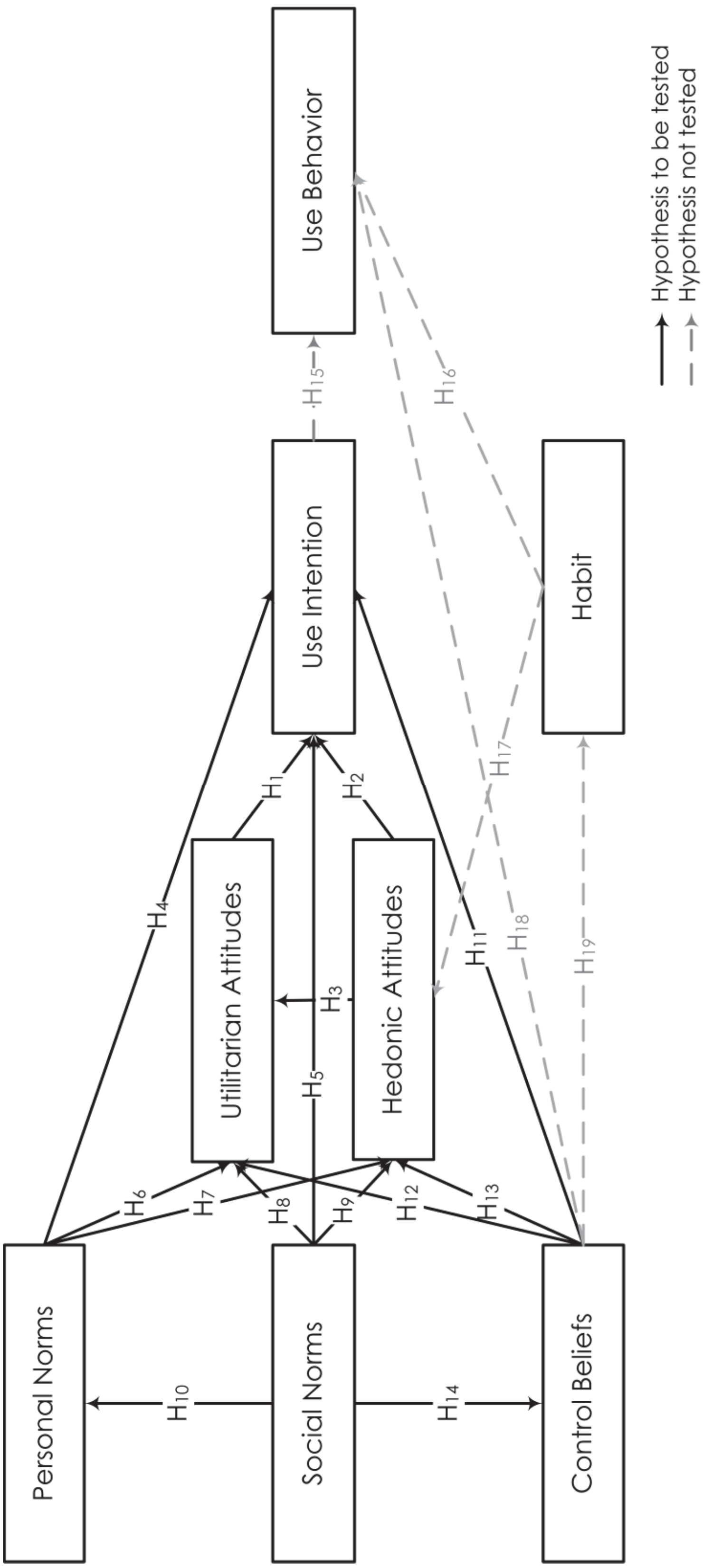

Figure 5.8: Structural model of social robot acceptance

INTERPRETTING THE EFFECTS OF THE ATTITUDINAL BELIEFS

Once a good model fit was established, the hypothesized regression paths were interpreted. Examining the attitudinal beliefs structure, it was hypothesized that utilitarian attitudes influence use intention (H_1). The results indicate that use intention cannot be explained by either one of the utilitarian attitudes (see table 5.16). These results lead to the rejection of hypothesis 1.

Table 5.16: Results of H_1: Utilitarian attitudes affect use intention

Hypotheses			*β*	*p*
Ease of use	affects	Use intention	.089	.112
Adaptability			.034	.519

On the other hand, Examining the results in table 5.17, two of the six hedonic attitudes could significantly explain use intention (H_2). When the participants expected to enjoy having a social robot in their home (β= .531, p < .001), and expected that robot to be less sociable (β= -.099, p= .029), they had higher intentions to use it. These results partially support hypothesis 2.

Table 5.17: Results of H_2: Hedonic attitudes affect use intention

Hypotheses			*β*	*p*
Enjoyment	affects	Use intention	**.531**	**.000**
Attractiveness			-.094	.125
Animacy			-.024	.490
Social presence			-.024	.657
Sociability			**-.099**	**.029**
Companionship			-.072	.194

Furthermore, the conceptual model hypothesized that hedonic attitudes affected utilitarian attitudes (H_3). Examining the results in table 5.18, it is shown that almost half of the regression paths were significant. When participants expected they would enjoy having a social robot in their home, they believed that the robot would be easier to use (β= .307, p= .018) and more adaptive to their personal needs (β= .532, p < .001). Additionally, when the participants expected a social robot to be more sociable (β= .211, p= .002) but offers less companionship (β= -.239, p < .001), they thought such a robot would be more capable to adapt to their personal needs. These results partially support hypothesis 3.

Table 5.18: Results of H_3: Hedonic attitudes affect utilitarian attitudes

Hypotheses			β	p
Enjoyment	affects	Ease of use	**.238**	**.023**
		Adaptability	**.532**	**.000**
Attractiveness	affects	Ease of use	-.067	.458
		Adaptability	-.049	.521
Animacy	affects	Ease of use	-.014	.776
		Adaptability	-.057	.265
Social presence	affects	Ease of use	-.137	.060
		Adaptability	-.068	.325
Sociability	affects	Ease of use	.096	.220
		Adaptability	**.211**	**.002**
Companionship	affects	Ease of use	-.107	.132
		Adaptability	**-.239**	**.000**

INTERPRETTING THE EFFECTS OF THE NORMATIVE BELIEFS

Examining the normative beliefs structure, it was hypothesized that personal norms influence use intention (H_4). The results show that use intention could only be significantly explained by one personal norm (see table 5.19). Participants who expected less privacy concerns when having a social robot in their home had higher intentions to use such a robot (β= -.059, p= .022). These results weakly support hypothesis 4.

Table 5.19: Results of H_4: Personal norms affect use intention

Hypotheses			β	p
Privacy concern	affects	Use intention	**-.059**	**.022**
Trust			.076	.119
Societal impact			-.079	.064

A similar pattern was found for the influence of social norms on use intention (H_5), where also only one regression path was significant (see table 5.20). Participants who expected that having a social robot increased their status had higher intentions to use such a robot (β= .100, p= .001). This leads to partially support for hypothesis 5.

Table 5.20: Results of H_5: Social norms affect use intention

Hypotheses			β	p
Social influence	affects	Use intention	.098	.206
Status			**.100**	**.001**

Furthermore, the conceptual model of social robot acceptance hypothesized that personal norms influenced utilitarian attitudes (H_6). Examining the results in table 5.21, it is shown that none of the regression paths are significant, which leads to a rejection of hypothesis 6.

Table 5.21: H_6: Personal norms affect utilitarian attitudes

Hypotheses			***β***	***p***
Privacy concern	affects	Ease of use	-.024	.537
		Adaptability	-.035	.309
Trust	affects	Ease of use	.141	.062
		Adaptability	.100	.120
Societal impact	affects	Ease of use	-.016	.773
		Adaptability	.032	.517

Additionally, it was hypothesized that personal norms would have an effect on hedonic attitudes (H_7). The results show that almost half of the regression paths are significant (see table 5.22). When the participants expected less privacy concerns when having a robot in their home, they believed they would enjoy that robot more (β= -.151, p < .001), would find the robot more attractive (β= -.057, p= .025), more animate (β= -.151, p < .001), more socially present (β= -.104, p= .003), and that the robot would provide more companionship (β= -.193, p < .001). Additionally, when participants expected they could trust a social robot in their home, they would find that robot more attractive (β= .885, p < .001), more animate (β= .552, p < .001), and more sociable (β= .178, p < .001). These results partially support hypothesis 7.

Table 5.22: H_7: Personal norms affect hedonic attitudes

Hypotheses			***β***	***p***
Privacy concern	affects	Enjoyment	**-.151**	**.000**
		Attractiveness	**-.057**	**.025**
		Animacy	**-.154**	**.003**
		Social presence	**-.104**	**.003**
		Sociability	-.052	.185
		Companionship	**-.193**	**.000**
Trust	affects	Enjoyment	.002	.921
		Attractiveness	**.850**	**.000**
		Animacy	**.552**	**.000**
		Social presence	-.021	.502
		Sociability	**.178**	**.000**
		Companionship	-.038	.147
Societal impact	affects	Enjoyment	-.085	.123
		Attractiveness	.000	.997
		Animacy	-.096	.228
		Social presence	-.067	.362
		Sociability	-.016	.830
		Companionship	-.115	.101

The conceptual model also hypothesized that social norms affect utilitarian attitudes (H_8). Examining the results in table 5.23, it is shown that none of the social norms could significantly explain any of the utilitarian attitudes, which leads to the rejection of hypothesis 8.

Table 5.23: H_8: Social norms affect utilitarian attitudes

Hypotheses			***β***	***p***
Social influence	affects	Ease of use	-.324	.746
		Adaptability	.121	.282
Status	affects	Ease of use	.046	.301
		Adaptability	-.016	.702

Additionally, it was hypothesized that social norms would have an effect on hedonic attitudes (H_9). The results show that three of the regression paths are significant (see table 5.24). When the participants expected that having a social robot in their home would increase their status, they thought the robot would be more enjoyable (β= .135, p < .001), more socially present (β= .230, p < .001) and offer more companionship (β= .273, p < .001). These results somewhat weakly support hypothesis 9.

Table 5.24: H_9: Social norms affect hedonic attitudes

Hypotheses			*β*	*p*
Social influence	affects	Enjoyment	.163	.145
		Attractiveness	-.020	.745
		Animacy	-.247	.094
		Social presence	-.207	.238
		Sociability	-.176	.224
		Companionship	-.148	.341
Status	affects	Enjoyment	**.135**	**.000**
		Attractiveness	.040	.220
		Animacy	.094	.064
		Social presence	**.230**	**.000**
		Sociability	.044	.369
		Companionship	**.273**	**.000**

Additionally, the conceptual model hypothesized that social norms would affect personal norms (H_{10}). Examining the results in table 5.25, it is shown that all regression paths are significant. When the participants expected to experience more social influence, they thought that having a social robot in their home would involve less privacy concerns (β= -.168, p= .002), that they could trust that such a robot more (β= .511, p < .001), and they expect smaller societal impact from such robots (β= -.318, p < .001). Moreover, when the participants expected that having a social robot in their home would increase their status, they thought that such a robot would involve less privacy concerns (β= -.098, p= .028), but could be trusted less (β= -.264, p < .001) and would elicit a greater societal impact (β= .108, p= .031). These results fully support hypothesis 10.

Table 5.25: H_{10}: Social norms affect personal norms

Hypotheses			*β*	*p*
Social influence	affects	Privacy concern	**-.168**	**.002**
		Trust	**.511**	**.000**
		Societal impact	**-.318**	**.000**
Status	affects	Privacy concern	**-.098**	**.028**
		Trust	**-.264**	**.000**
		Societal impact	**.108**	**.031**

INTERPRETTING THE EFFECTS OF THE CONTROL BELIEFS

Examining the control beliefs, the conceptual model hypothesized that control beliefs directly influence use intention (H_{11}). The results show that only one control belief could significantly explain use intention (see table 5.26). When participants expected to have the necessary skills to use a social robot in their home, they had higher intentions to use such a robot (β= .267, p= .034). These results weakly support hypothesis 11.

Table 5.26: H_{11}: Control beliefs affect use intention

Hypotheses			β	p
Self-efficacy	affects	Use intention	**.267**	**.034**
Personal innovativeness			.019	.484
Anxiety towards robots			.065	.114
Safety			.043	.334
Cost			.027	.292

Additionally, it was hypothesized that control beliefs influence utilitarian attitudes (H_{12}). Examining the results in table 5.27, it is shown that almost half of the regression paths are significant. Participants who evaluated themselves as more innovative (β= .214, p < .001), expected that using such a robot would be more safe (β= .318, p < .001), that such a robot would be more expensive (β= .067, p= .033), expected that a social robot would be easier to use. Moreover, participants who thought that such a robot would be more expensive (β= .079, p= .002), expected that a social robot would be able to better adapt to their personal needs. These results demonstrate that hypothesis 12 is partially supported.

Table 5.27: H_{12}: Control beliefs affect utilitarian attitudes

Hypotheses			β	p
Self-efficacy	affects	Ease of use	.343	.059
		Adaptability	.298	.075
Personal innovativeness	affects	Ease of use	**.214**	**.000**
		Adaptability	-.019	.578
Anxiety towards robot	affects	Ease of use	-.028	.642
		Adaptability	-.043	.388
Safety	affects	Ease of use	**.318**	**.000**
		Adaptability	.068	.225
Cost	affects	Ease of use	**.067**	**.033**
		Adaptability	**.079**	**.002**

The conceptual model of social robot acceptance also hypothesized that control beliefs would affect hedonic attitudes (H_{13}). Examining the results in table 5.28, it is shown that almost half of the regression path is significant. When the participants felt more capable of using a social robot, they expected to enjoy using such a robot more (β= .465, p < .001), to find it more animate (β= .383, p= .007), more socially present (β= .370, p < .001), more sociable (β= .645, p < .001), and that such a robot could provide more companionship (β= .601, p < .001). Moreover, when participants evaluated themselves as more innovative, they expected that using a social robot in their home would be more enjoyable (β= .123, p < .001). Also, when participants indicated that they would feel less anxiety towards talking to a social robot, they expected to experience more companionship from such a robot (β= .165, p= .014). Additionally, when participants stated they would feel safe being around a social robot, they thought such a robot would be more enjoyable (β= .173, p < .001), and could provide more companionship (β= .165, p= .014). Finally, when the participants evaluated a social robot as more expensive, they thought such a robot would be more sociable (β= .127, p < .001) but should provide less companionship (β= -.102, p= .002). These results partially support hypothesis 13.

Table 5.28: H_{13}: Control beliefs affect hedonic attitudes

Hypotheses			***β***	***p***
Self-efficacy	Affects	Enjoyment	**.465**	**.000**
		Attractiveness	.080	.185
		Animacy	**.383**	**.007**
		Social presence	**.730**	**.000**
		Sociability	**.645**	**.000**
		Companionship	**.601**	**.000**
Personal innovativeness	affects	Enjoyment	**.123**	**.000**
		Attractiveness	-.031	.289
		Animacy	.046	.318
		Social presence	.037	.359
		Sociability	.073	.146
		Companionship	.060	.102
Anxiety towards robots	affects	Enjoyment	.078	.151
		Attractiveness	.008	.864
		Animacy	.150	.059
		Social presence	.066	.350
		Sociability	.018	.812
		Companionship	**.165**	**.014**
Safety	affects	Enjoyment	**.173**	**.000**
		Attractiveness	.038	.320
		Animacy	.060	.279
		Social presence	**.170**	**.001**
		Sociability	**.252**	**.000**
		Companionship	**.190**	**.000**
Cost	affects	Enjoyment	.002	.937
		Attractiveness	.030	.269
		Animacy	-.027	.489
		Social presence	-.012	.707
		Sociability	**.127**	**.000**
		Companionship	**-.102**	**.002**

Finally, the conceptual model hypothesized that social norms influence the control beliefs (H_{14}). With the exception of one, the results show that all regression paths are significant (see table 5.29). When the participants expected to experience more social influence, they thought they would be more capable to use a social robot ($\beta = .733$, $p < .001$), they evaluated themselves as more innovative ($\beta = .376$, $p < .001$), they were less anxious to talk to a robot ($\beta = -.418$, $p < .001$), they would feel more safe around a robot ($\beta = .617$, $p < .001$), and they would perceive such a robot as more expensive ($\beta = .234$, $p < .001$). Moreover, when the participants expected that having a social robot in their home would increase their status, they thought they would be more capable to use such a robot ($\beta = .163$, $p < .001$), they would feel more anxious to talk to such a robot (β= .309, p < .001), they would feel less safe when being around such a robot (β= -.108, p= .008), and they expect that such a robot would be less expensive (β= -.284, p < .001). These results suggest almost fully support hypothesis 14.

Table 5.29: H_{14}: Social norms affect control beliefs

Hypotheses			β	p
Social influence	affects	Self-efficacy	**.733**	**.000**
		Personal innovativeness	**.376**	**.000**
		Anxiety towards robots	**-.418**	**.000**
		Safety	**.617**	**.000**
		Cost	**.234**	**.000**
Status	affects	Self-efficacy	**.163**	**.000**
		Personal innovativeness	.005	.906
		Anxiety towards robots	**.309**	**.000**
		Safety	**-.108**	**.008**
		Cost	**-.284**	**.000**

5.6 REFLECTION ON THE RESULTS OF THE ACCEPTANCE SURVEY

This chapter investigated people's anticipated acceptance of social robots for domestic use. An online survey was conducted to investigate the role of several acceptance variables in the acceptance of three different roles for domestic social robots.

ROBOT ROLES AND PREFERRED APPEARANCES

In all the different conditions more than half of the participants favored a humanoid appearance over the other types of appearances for a social robot that would operate in their own homes. The main reason provided by the participants for choosing a humanoid appearance was that such an appearance looks most like humans, which they found more attractive and better suited for robots build to interact socially with their users. This is in line with earlier findings that a robot designed for social interaction with humans must project some amount of humanness so that the user feels comfortable to socially engage with the robot (Fong, Nourbakhsh, & Dautenhahn, 2003).

However, the findings presented here show that the role for which a social robot is built affects the choice for a robotic appearance made by future users. When a social robot is built to be a butler, people deem to find a functional appearance more suitable and a zoomorphic appearance less suitable for this role. The division of the choice for appearance in the butler role showed an overrepresentation for the functional appearance, because the participants found this appearance more competent and more clearly looking like a robot. Some other participants specifically stated that they did not want a human-shaped robot or that robots should never resemble humans. When a social robot is built to be a companion, people deem to find a zoomorphic appearance more suitable and a functional and caricatured appearance less suitable for this role. The division of the choice for appearance in the companion role showed an overrepresentation for the zoomorphic appearance, because the participants found this appearance cuddly and attractive. Some other participants related this appearance to the familiarity with human-pet relationships or they just loved animals. When a social robot is built to be an information source, people deem to find a caricatured appearance more suitable and zoomorphic appearance less suitable for this role. The division of the choice for appearance in the role as information source showed an overrepresentation for the caricatured appearance, because the participant found this appearance not too humanlike and clearly looking like a robot. Some other participants found this appearance more competent and more attractive. These findings support other researchers that people expect robots to look and behave appropriately, given the task in context (Goetz, Kiesler, & Powers, 2003). Thus, a robot’s appearance must match its intended role.

Examining the evaluation of the three different roles for social robots, it is shown that overall the companion robot evaluated more negatively in the different acceptance variables. Rather surprising was that the participants evaluated the companion role for social robots as less sociable. An explanation could be that people expect robots to be social enough for the role as butler of information source, but not for the role as companion. Another explanation could be that, at this stage of diffusion, robots as companions are not socially accepted yet in the Dutch society.

ANTICIPATED ACCEPTANCE OF DOMESTIC SOCIAL ROBOTS

The analysis in section 5.3 indicated that the data of the Acceptance Survey did not fit the second order factor structure of the proposed conceptual model of social robots acceptance. Hence it was chosen to continue with the analyses of direct regression paths between the first order factors in a similar way as hypothesized between the second order factors in the original conceptual model. The conceptual model of social robot acceptance with the direct regression paths could be confirmed using the data of the Acceptance Survey among the general Dutch population. Two hypotheses were fully supported, nine hypotheses were partially supported and three hypotheses were rejected by the data. Figure 5.9 (see next page) provides an overview of the hypotheses in the conceptual model and whether or not they are (partially) supported according to the findings.

The direct effects on use intention show that the acceptance of a social robot for domestic use increases when future users ascribe themselves the necessary skills to use a social robot, when they believe that having such a robot enhances their status, and when they expect that such a robot provides more enjoyable interactions, behaves less sociable, and causes less privacy concerns.

Utilitarian attitudes are tied to usability and emphasize the extrinsic motivations to accept or use a technology, and included the factors of ease of use and adaptability. The utilitarian attitudes of potential users of social robots seem to be influenced by both the hedonic attitudes and the control beliefs, but are not directly affected by the personal or social norms. The direct effect of hedonic attitudes on utilitarian attitudes support earlier findings in both the information systems literature (e.g., Agarwal & Karahanna, 2000; Lee, Kozar, & Larsen, 2003) and the human-robot interaction literature (e.g., Heerink et al., 2010; Lee, Jung, Kim, & Kim, 2006; Shin & Choo, 2011). The direct effect of control beliefs has been reported before in studies on information systems (e.g., Hackbarth et al., 2003; Karahanna & Limayem, 2000) and human-robot interaction (e.g., Bartneck, Suzuki, Kanda et al., 2007b). The participants expected that a social robot will be more easy to use, when these users perceive themselves as more innovative, and when such a robot is more enjoyable, more safe, and costs more. Moreover, they expected that such a robot will be more adaptable to their personal needs, when such a robot is more enjoyable, more sociable, provides less companionship, and costs more.

Hedonic attitudes are related to the users' experience while performing the task and emphasize the intrinsic motivations in technology acceptance, and included the factors of enjoyment, attractiveness, animacy, social presence, sociability, and companionship. The hedonic attitudes of potential future users of social robots seem to be influenced by the control beliefs as well as both the personal and social norms. The direct effects of normative beliefs on attitudinal beliefs has been reported in both the information systems literature (e.g., Ben Allouch, Van Dijk, & Peters, 2009; Lee, Kozar, & Larsen, 2003; Yu et al., 2005) and the human-robot interaction literature (e.g., Heerink et al., 2010; Shin & Choo, 2011). First, the participants expected that a social robot will be more enjoyable, when they perceived themselves as more innovative and more capable to use a social robot, and when such a robot causes less privacy concerns, enhances their status, and feels more safe to use. Second, the participants expected that a social robot will be more attractive, when such a robot causes less privacy concerns and can be trusted more. Third, the participants expected that a social robot will be more animate, when these users perceive themselves as more capable to use a social robot, and when such as a robot causes less privacy concerns and can be trusted more. Fourth, the participants indicated that they expect a social robot to be more socially present, when these users perceive themselves as more capable to use such a robot, and when such as a robot causes less privacy concerns, could enhance the users' status, and feels more safe to use. Fifth, the participants believed that a social robot should be more sociable, when the participants perceive themselves as more capable to use such a robot, and when they expected that such as a robot could be trusted more, could enhance their status, and costs more. Sixth, the participants indicated that a social robot should provide more companionship, when the participants perceived themselves as more capable to use such a robot, and when they expected that such as a robot causes less privacy concerns, could enhances the users' status, feels more safe to use, and costs less.

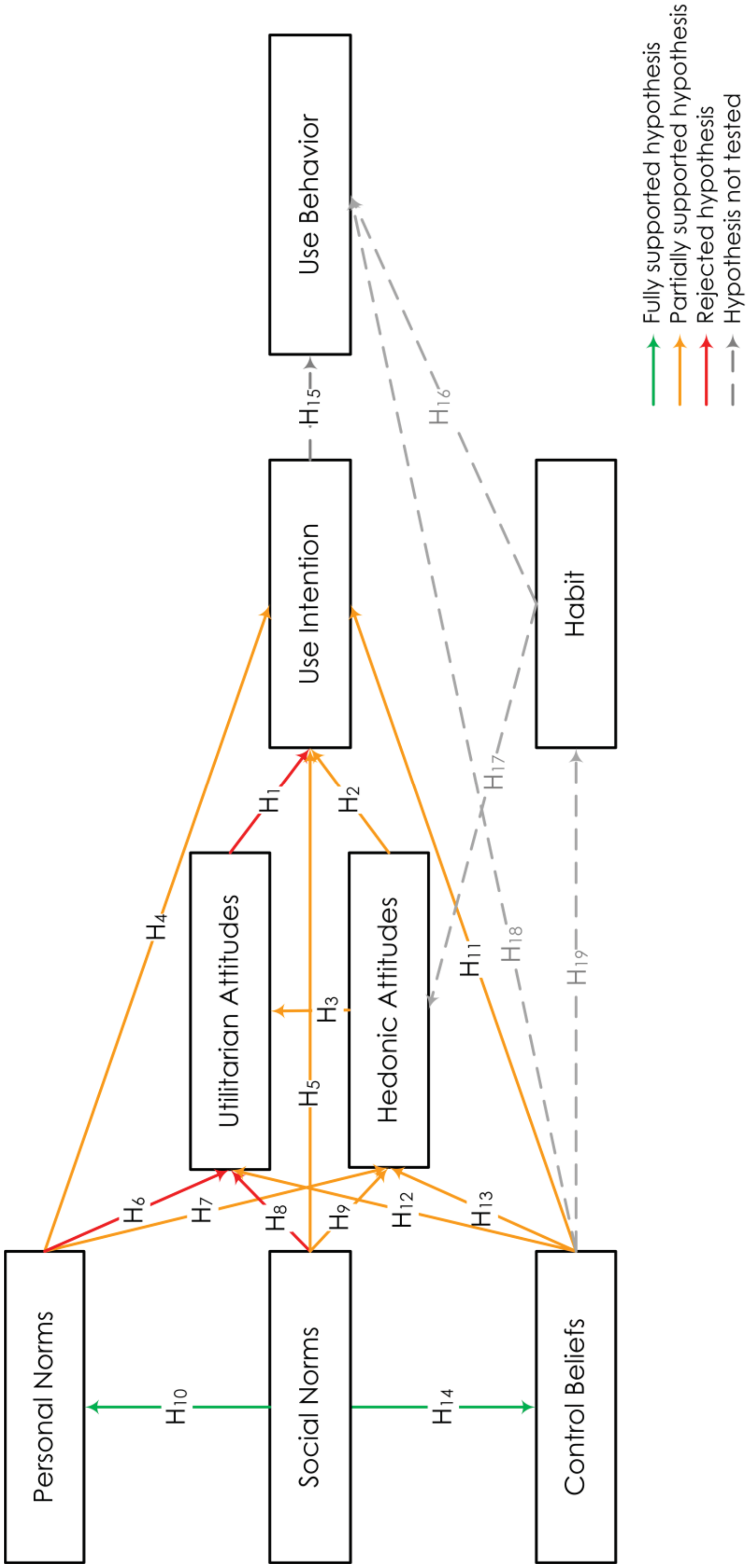

Figure 5.9: Overview of the tested hypotheses of the social robot acceptance model

Personal norms contain an individual's beliefs that engaging in a particular behavior leads to salient personal beliefs, and included the factors of privacy, trust and societal impact. To my knowledge, this is the first time that the distinction between personal and social norms is made in social robotics research. As personal norms arise from beliefs that are considered to be the norm in one's social environment, it was assumed that social norms affect one's personal norms. The results suggest that the personal norms indeed seem to be influenced by the social norms. The participants indicated that having a social robot in their own home would cause less privacy concerns, when they expect to experience more social influence to use such a robot and when they expect that owning such a robot enhances their status. Moreover, the participants believed to trust a social robot more, when they expected to experience more social influence to use such a robot and when they expected that owning such a robot could not increase their status. Additionally, the participants thought that social robots will cause more societal impact, when they expected to experience less social influence to use such a robot and when they expected that such a robot could enhance their status.

Social norms encompass an individual's beliefs about the likelihood and importance of the social consequences of performing a particular behavior, and included the factors of social influence and image. The conceptual model did not hypothesize any predictors for the social norms. Social norms functions as the core of the conceptual model as it not only theoretically influences use intention and all other factors in the model directly, but also theoretically indirectly influences use intention through all these other factors as well. The results show that the direct effects of social norms on personal norms and control beliefs were fully supported, and that only the direct effect of social norms on utilitarian attitudes was not supported with this data. However, social norms do affect utilitarian norms indirectly both via hedonic attitudes and control beliefs. The direct effects of social norms on all other factors in the model were partially supported. This means that social norms remains to have a core function in our empirical model of social robot acceptance.

Control beliefs consists of the user's beliefs about the presence or absence of resources, opportunities and obstacles that may facilitate or impede performance of the behavior, and included the factors of self-efficacy, personal innovativeness, anxiety towards robots, safety and cost. The control beliefs of potential future users of social robots seem to be influenced by the social norms. Both the theory of planned behavior (Ajzen, 1991) and the social cognitive theory (Bandura, 1977) indicate that control beliefs are affected by opinions form one's social network. First, the participants perceive themselves as more capable to use a social robot, when they expected to experience more social influence to use such a robot and when they expected that such a robot could enhance their status. Second, the participants indicated themselves as more personal innovative, when they expected to experience more social influence to use such a robot. Third, the participants believed to be less anxious to talk to a social robot, when they expected to experience more social influence to use such a robot and when they expected that such a robot could increase their status. Fourth, the participants believed to be more safe in the presence of a social robot, when they expected to experience more social influence to use such a robot and when they expected that such a robot could enhance their status. Fifth, the participants would evaluate a social robot as more expensive, when they expected to experience more social influence to use such a robot and when they expected that such a robot could not increase their status.

The theoretical and practical implications of these results will be attended to in the main discussion chapter of this dissertation (chapter 12). As acceptance is not a static decision but perceived in this dissertation as a decision-making process that evolves over time, the next part of this dissertation will, therefore, address the long-term acceptance of social robot. By presenting the findings from the long-term home study, it is investigated how the evaluation of acceptance variables changes over time.

PART III

USE

6

RELEVANCE AND METHOD OF THE KAROTZ HOME STUDY

"Be stubborn about your goals, and flexible about your methods."
– Unknown –

So far, this dissertation has investigated the anticipated acceptance social robots using the theory of planned behavior as the basis of the theoretical background of this dissertation and therefore, up until now, the main focus was on psychological elements of acceptance. However, actual and preferably long-term use is necessary to investigate the full acceptance of social robots in domestic environments. Moreover, when social robots are utilized in home settings, a sole reliance on psychology alone may not be sufficient. The domestic environment involves the complete household which often consists of more than one person. Here, the partially sociological theories of the domestication theory and diffusion of innovations presented in chapter 3 may provide some additional insights for investigating the long-term acceptance of social robots in domestic environments.

Social robotics research is increasingly paying attention to the domestic environment as a context of use. However, this area of research is still in its infancy as only recently robotics technology has become robust enough to allow for employment of long-term evaluations in home settings (Ferneaus et al., 2010; Nguyen et al., 2013). Moreover, an extra challenge for research in these setting lies within privacy issues and a consequent lack of control over users' activities with the robot. Nevertheless, domestic use of robots is at present a reality with the arrival of commercial products such as robotic vacuum cleaners and robotic toys.

This chapter first outlines the relevance of long-term home studies for human-robot interaction research. Thereafter, the description of the phases of long-term acceptance will denote that acceptance is broader than adoption and that adoption is only one part of the long-term acceptance process. This chapter ends with an outline of the research design of the Karotz Home Study. The descriptions of the different acceptance phases presented in section 6.2 are part of an existing publication:

Graaf, M.M.A. de, Ben Allouch, S., & Dijk, J.A.G.M. van (2014). Long-term evaluation of a social robot in real homes. *Paper presented at the AISB Workshop on New Frontiers in Human-Robot Interaction, London, UK*.

6.1 RELEVANCE OF LONG-TERM USER ACCEPTANCE STUDIES

Although there are many human-robot interaction studies researching people's initial reactions and attitudes towards robots, the temporal dimension of the acceptance process is underexposed. Even today, little is known about the long-term acceptance and use of robots in domestic environments. Earlier research denotes that when users develop experiences with a technology or their own skills, this might change the user's attitudes towards that technology (Venkatesh & Davis, 2000). Thus, people's perceptions on social robot acceptance are likely to change over time when they gain user experiences with such technologies. Long-term interaction with social robots can be considered as a sub-area of HRI research that investigates the development of interaction patterns between users and social robots over time (Leite, Martinho, & Paiva, 2013). It is scientifically acknowledged that long-term effects exist in technology usage and that usages patterns change over time (Sung et al., 2009). Despite this recognition, there is still a lack of knowledge about these long-term effects in the field of social robotics.

Up until now, only a few studies investigated the domestic use of robots over a longer period of time (e.g. de Graaf & Ben Allouch, 2014; Ferneaus et al., 2010; Fink et al., 2013; Sung et al., 2009; Sung et al., 2010). However, studying long-term use and use patterns is necessary to provide insight into how social robots become part of people's daily routines and to inform designers how to create robots that remain useful beyond the initial adoption (Forlizzi & DiSalvo, 2006). Moreover, studies within people's natural environments can provide practical insights into the continuous use of and user experiences with these robotic products. Longitudinal studies are extremely fertile to explore changes in use behavior and user experience over time.

Even traditional technology acceptance literature lacks a profound body of long-term research, even despite its long history within the information systems literature (Taylor & Todd, 1995). While earlier technology acceptance research has mainly focused on explaining why people initially adopt technologies, only a minority of these studies have paid attention to what happens in the post-adoption stage. This is where people decide between continuing and discontinuing the use of the technology. The consideration of different antecedents for pre-adoption and post-adoption beliefs have been argued for by earlier researchers (Davis, Bagozzi & Warshaw, 1989; Rogers, 2003; Thompson, Higgens, & Howell, 1991). Attitudinal beliefs are formed based on three types of information: past behavior, affective information and cognitive information (Zanna & Rempel, 1988). A reasonable assumption is to propose that pre-adoption beliefs are mainly shaped by affect or cognition through indirect experiences with a technology (i.e., by watching others using the technology or via media), and that post-adoption beliefs are mainly created based on past experience (Karahanna, Straub, & Charvany, 1999). Consequently, beliefs after using a product may not be the same as the set of beliefs that have led to the initial adoption. Only when people are willing to continue to use a technology after initial adoption, one could assume that the acceptance of that technology is a success.

6.2 THE PROCESS OF LONG-TERM ACCEPTANCE

An alternative to the commonly used adoption models in technology acceptance literature is offered by the domestication theory and the diffusion of innovations theory. The domestication theory is essentially about giving technology a place in everyday life. Acceptance is not assumed as a rational, linear, mono-causal and technologically determined process. The domestication theory acknowledges the complexity of everyday life and the place of technology within its dynamics, rituals, rules, routines and patterns (Silverstone & Haddon, 1996). This initially enables researchers to understand media technology use in the complex structures of everyday life settings, with attention to interpersonal relationships, social background, changes and continuities. Moreover, it takes into account the increasingly complex interconnection between different media, and the convergence of different media technologies and media texts (Hynes & Richardson, 2009).

The diffusion of innovations theory also comprises a process of long-term acceptance. It describes acceptance as the sequence of activities an individual passes from gaining initial knowledge of a technology, to forming an attitude towards that technology, making the initial adoption decision which could lead to the implementation of that technology and, eventually to continuing the use of that technology (Rogers, 2003). While the diffusion of innovations theory is useful as it explains how technologies are appropriated, the domestication theory is more valuable in the ways it provides insights into the intricate processes whereby the user assigns meaning and significance to the artefact, and how this is experienced by domestic users during the acquisition and consumption of the technology.

Mainly based on these two visions on long-term acceptance, together with findings from earlier long-term studies on technology use in the home (e.g., Demiris et al., 2008; Karapanos et al., 2009; Sung et al., 2009; Sung et al., 2010), six acceptance phases were formulated: expectation, confrontation, adoption, adaptation, integration and identification. These acceptance phases are linked to the experiences of acceptance from the users' perspective, and are not linked to the phases of technology diffusion as is the case in, for example, Roger's (2003) the diffusion of innovations theory. In the following, we will describe these acceptance phases and enrich these descriptions with findings from earlier long-term human-robot interaction research.

EXPECTATION PHASE

In the expectation phase, people learn about the technology, determine its value and form expectations and attitudes towards it before they invite the technology into their homes (Sung et al., 2009; Sung et al., 2010). People seek for information about the technology (Rogers, 2003). They want to learn about the purpose of the technology, than try to understand the functionality of the technology, and finally they pursue to rationalize its internal processes. After rationalization comes affection and people will form their interpersonal attitude towards the technology (Rogers, 2003). This is where people become emotionally involved with the technology and actively try to gain knowledge about the technology and judges this knowledge. However, people who are typically unsure are more likely to seek reinforcement in the opinions of others (Rogers, 2003). This may indicate that people who are hesitant to use robots are more sensitive for social influence. Another study exploring the long-term use of mobile phones describes a expectations phase, although the researchers call it pre-adoption, in which people anticipate on future experiences by establishing expectations (Karapanos et al., 2009).

CONFRONTATION PHASE

In the confrontation phase, people are confronted with the technology in real life for the first time. This can be in a store, but also when one encounters other people who are using the technology. It is possible that people have their first trials of using the technology. Most people prefer having some first trials before starting their actual use of a technology (Rogers, 2003), i.e. adopting it. Moreover, this is also the first opportunity for people to reevaluate their prior expectations of the technology and the benefits or user experiences it has to offer. It might be that the formed prior expectations do not match with what the technology actually seems to be about. This is where an expectation gap might occur (Lohse, 2011), and where some people start showing the first signs of not entering the next acceptance phase.

ADOPTION PHASE

The adoption phase contains the decision that leads to the adoption (or rejection) of a technology. This is where people decide to actually start using the technology in their private environments and have their first use trials with the technology (Sung et al., 2009; Sung et al., 2010). However, uncertainty still exists about the expected consequences of the use of the technology. This is why people want to learn more about the technology and are trying familiarize themselves with it (Karapanos et al., 2009), if they are still positive about the potential outcomes of technology use.

ADAPTATION PHASE

The adaptation phase begins directly after the initial adoption so people are still obtaining their initial user experiences, but have a broad idea of what the technology is all about. People are still pervaded by feelings of excitement as well as frustration as they experience novel features and encounter learnability flaws (Karapanos et al., 2009). People familiarize themselves with the technology, identify any issues or concerns and show the technology to others (Demiris et al., 2008). People will experiment with the technology's complexities and compatibilities in their personal spaces and make necessary changes to adapt the technology to their personal needs (Rogers, 2003; Sung et al., 2009; Sung et al., 2010). As people keep being curious about and aware of the presence of the technology (Demiris et al., 2008) and trying to appropriate to the technology (Silverstone & Haddon, 1996), they will finally come to determine reaffirmation of their initial adoption or rejection of further use (Silverstone & Haddon, 1996; Sung et al., 2009; Sung et al., 2010).

INTEGRATION PHASE

In the integration phase people are feeling a functional dependency on the technology (Karapanos et al., 2009), have created routines of use (Silverstone & Haddon, 1996; Sung et al., 2009; Sung et al., 2010) and have fully integrated the technology in their everyday lives (Demiris et al., 2008). During the integration phase the technology has been changed or modified by the user (Rogers, 2003) and the technology has become meaningful in people's everyday lives (Karapanos et al., 2009). They do not longer notice the presence of the technology in their homes as long as it does not have their primary attention any more (Demiris et al., 2008). When the technology allows its users to personalize this shaping, the probability of long-term acceptance increases (Backer, 2000). However, it could be that the technology in this phase is used differently from the way it was intended by designers (Silverstone & Haddon, 1996). The meanings of technologies are not solely connected to the technology itself, but are shaped and reshaped through the interactions between designers, social groups and policy makers (Bijker, Hughes, & Pinch, 1987; Fulk, 1993). This is called the mutual shaping of technology.

IDENTIFICATION PHASE

In the identification phase, the technology exceeds its functional purpose and becomes a personal object as people get emotionally attached to it. We accept the technology in our everyday lives, it participates in our social interaction, communicates parts of our self-identity that serve to either differentiate us from others or connects us to others by creating a sense of community (Karapanos et al., 2009). In this phase, the domestic environment reconnects with the public values (Silverstone & Haddon, 1996). The technology can become a tool for making status claims or for expressing a specific lifestyle to family, friends and neighbors. The personal side of identification, e.g. personalizing it and creating daily routines of use, increases over time. The social side of identification, e.g. enabling self-expression and creating a sense of community, initially decreases but also shows a gradual and sustained increase (Karapanos et al., 2009). People, again, seek reinforcement for the initial adoption, and may even reverse this decision if exposed to conflicting messages about the technology (Rogers, 2003). However, as people try to avoid or at least reduce a stage of dissonance, they will either change their conflicting knowledge, attitudes or behaviors. Dissonance is the uncomfortable feeling an individual experiences when incongruence occurs between attitude and behavior (Festinger, 1957). This uncomfortable feeling can be resolved by either altering personal beliefs (e.g. attitude towards the technology) or performed behavior (e.g. use of the technology). This means that, when users obtain information that argues not to adopt the robot, they will either advocate reasons why they would continue to use the robot or they will stop using the robot. During the conformation stage, users want supportive information that prevents the occurrence of dissonance.

6.3 EXISTING LONG-TERM HOME STUDIES IN HUMAN-ROBOT INTERACTION

A few studies have been performed on long-term use of robots in home environments. Most of these studies employ commercially available robots. For example, Sung et al. (2009, 2010) and Fink et al. (2013) evaluated how people used and accepted the Roomba vacuum cleaner in their homes, with thirty and eleven participating households respectively. During their visits at five times during a 6-month ethnographic study, several methods besides questionnaire and interview data were used, such as drawings, probing techniques and checklists of activities with the Roomba. Sung et al. (2009) argue that two months will be enough to study stable technology use after the novelty effect has faded away. The novelty effect consists of the user's first responses to a technology and are not the sustained use patterns that are established over time. Stable or sustained use, consisting of returning use routines, occurs when the novelty effect ends. And the researchers from both studies (Fink et al., 2013; Sung et al., 2009; Sung et al., 2010) argue that a combination of multiple types of data is preferred to capture people's routines of use and acceptance of the robot. A framework of long-term domestic use was drawn by Sung et al. (2010) and confirmed by Fink et al. (2013) containing the key interaction patterns when households accept robots: pre-adoption (similar to the expectation phase), adoption, adaptation, and use and retention (similar to the integration phase). On several evaluation measures, participants rated the vacuum cleaner robot more negatively after the introduction (Fink et al., 2013), but those people who still used the robot after six months were more positive than those who stopped earlier.

Fernaeus et al. (2010) reported on a study evaluating the Pleo dinosaur robot with six families with children. As the families were allowed to stop using the robot at their own terms, the use duration varied from two to six months. The researchers used interviews and video-material recorded by the families, and focused on whether the evaluation of the robot would be affected by prior expectations. Results show that high prior expectations were not met, which caused some participants to stop using the robot when the novelty-effect wear off. Even though the participants initially regarded the robot as a real pet (e.g., petting it, giving it a name and displaying emotions towards it), the disappointing interaction capabilities of the robot resulted in it being treating as a regular toy. The researchers provided a set of design challenges which are relevant for robotic toys but also for long-term technology use in general.

The SERA (Social Engagement with Robots and Agents) project employed the rabbit-shaped Nabaztag robot, the predecessor of Karotz, and video-taped the interaction between three to six elderly users and the robot in three consecutive iterations of each ten days. The robot initiated several dialogs per day with the goal to stimulate physical activity. At the beginning of each dialog, the robot asked permission to video record the interaction and it was up to the participants to agree on that using a button on the system. Our project partners analyzed the verbal and nonverbal behavior of the users based on this video data (von der Pütten et al., 2011). The results show that there are inter-individual differences with regard to all categories of behavior. Whereas verbal behavior was stable for some participants, this changed over time with other participants. However, a pattern of decreased amount of smiling was observed among the participants who used the robot for more than one iteration. Me and my colleagues have analyzed the users' experiences with the robot obtained via the interview data in this study (de Graaf, Ben Allouch, & Klamer, 2015). Examining the use experiences over time, it seems that these are somewhat similar to those described in the domestication theory (Silverstone & Haddon, 1996). With respect to the acceptance variables, it was concluded that the social interactions with the robot was an important factor for continued use. Participants who talked to the robot and gave it a name evaluated the robot more positively and intended to use the robot after the study if that was possible. However, the utilitarian attitudinal belief of usefulness functioned as an fundamental base for engaging in long-term use with a social robot. Finally, a lack of self-efficacy and privacy concerns were main reasons why two of the six participants did not want to continue the use of the robot.

The rabbit-shaped Karotz robot was used in a study to compare weather information provided by this robot and a tablet display (Mirlacher et al., 2009). In total, 32 participants used and evaluated the tablet in week one, the robot in week two, the tablet again in week three, and the robot again in week four. Results show that the users' capabilities of using both systems increased over time, but they liked and used the robot more than the tablet. Moreover, although not significantly different, the participants had higher preferences for the personalized information provided by the robot rather than the tablet.

LESSONS LEARNED FROM EXISTING LONG-TERM RESEARCH

The existing studies described above each provide interesting findings on long-term human-robot interaction. However, two of these studies (Mirlacher et al., 2009; de Graaf, Ben Allouch, & Klamer, 2015; von der Pütten et al., 2011) interrupted the users' experiences and studied acceptance in separate use periods. Some researchers suggests that longitudinal studies must last for at least two interconnected months, if one aims for observing sustained use after initial adoption and beyond the novelty effect. Stable or sustained use, consisting of returning use routines, occurs when the novelty effect ends, which is around two months of use according to Sung et al. (2009). The end of the novelty effect around two months of use has been confirmed in other long-term robot studies (Kanda et al., 2007; Fink et al., 2013). Additionally, not all studies included robots that offer both utilitarian and hedonic interaction experiences. Fernaeus et al. (2010) employed the Pleo robot, which is a rather toy-like robot and does not have a utilitarian purpose. And Sung et al. (2009, 2010) and Fink et al. (2013) reported on user experiences with the Roomba vacuum cleaner, which is a utilitarian product. Moreover, half of these studies did not focus on individual user acceptance, but took a more sociological perspective by looking into the general opinion of the household (Ferneaus et al., 2010; Fink et al., 2013; Sung et al., 2009; Sung et al., 2010). As there are only a few existing long-term studies that focus on domestic robot use, more research is necessary in this domain.

6.4 DESIGN OF THE KAROTZ HOME STUDY

The aim of the Karotz Home Study is to investigate the existence of different phases of technology acceptance as described in section 6.2 and to see whether and how a longer, uninterrupted period of use of a social robot in a domestic environment affects the long-term use of social robots. In addressing this goal, we employed an commercially available domestic robot with some social features. Studying an existing commercial robot has been successfully applied to study people's experiences and perceptions of human-robot interaction and was argued to be favored over robotic research prototypes which are often not suitable for long-term studies in naturalistic environments (Fernaeus et al., 2010). Therefore, studying long-term acceptance of a social robot with an existing commercially available domestic robot was deemed appropriate for our research goal. The following sections will provide the details of the method used in the Karotz Home Study. First, the details of the employed robot will be provided, followed by a description of the procedure and data collection of the home study. Subsequently, some insights are provided on the procedure of data analysis and how missing data was handled. This section ends with the details of the participants of the home study.

THE KAROTZ ROBOT

The robot used in this study is Karotz (see figure 6.1), which is a 30-cm high internet-enabled activated smart rabbit-shaped ambient electronic device. Communication occurs via verbal communication, the LED-light in its belly, the moveable ears, and by detecting the presence of other objects nearby. As the Karotz is permanently connected to the internet, it is able to react on, transmit, broadcast all types of content available on his network, for example news, messages, music, texts, alerts, and radio. The build-in webcam enables users to communicate with family members at home or to keep an eye on their homes when away. More information on the robot can be found at http://store.karotz.com/en_WW/. In total, 70 Karotz robots were placed into people’s own homes with the intention to being used for up to 6 months.

Figure 6.1: The Karotz robot deployed in the Karotz Home Study

Each robot was installed with a basic set of applications, such as daily news broadcasts, daily local weather reports, favorite radio stations, personalized reminders, and randomly spoken phrases to make the robot being perceived as more autonomous and animate. This basic set of applications ensured us that the user experience was somewhat similar among the participants, or at least initially as some participants chose to adjust these applications to their own needs. Besides the required applications, participants were free to install additional applications as they thought would be useful or fun for their households. Except for a few, all participants positioned the robot somewhere in their living room. According to the classification of social robots by Breazeal (2003), Karotz would be a socially evocative robot which fully relies on the users' tendency to anthropomorphize the robot and capitalizes on feelings evoked when humans nurture, care, or get involved with objects.

DATA COLLECTION AND PROCEDURE

Our goal was to explore people's ordinary routines of technology use and natural acceptance processes. This requires a holistic understanding of the household's everyday routines, their domestic technology use, as well as their expectations of domestic social robots. However, we choose not to employ logging mechanisms or extensive video recording as this would create an unnatural setting and therefore would not meet our goal. Moreover, this infringes the participants privacy, which would add additional methodological challenges above the practical ones. Yet, the downside of moving to these self-reports focuses on assessing their accuracy. Where possible, we sought to triangulate our data with multiple methods using both qualitative and quantitative data. Moreover, when depending on quantitative data alone, it is impossible to capture the insights as to why people have certain attitudes and show behavior which cannot be seized by a numerical score on a scale. And this understanding is particularly important for autonomous and embodied systems, which can invoke complex mental models and social-affective reactions (Tsui et al., 2011). Therefore, both quantitative and qualitative data were conducted and analyzed together to get a richer insight into the long-term acceptance of social robots in people's own homes.

The Karotz Home Study ran from October 2012 to October 2013 and consisted of seven moments of data collection which were aligned to the seven acceptance phases as described in section 6.2. At the beginning of each acceptance phase, both the interview and the questionnaire data was collected. In both instruments, the participants were clearly informed that the goal of the study was to gather their own personal opinions. All members of the households above the age of nine were asked to complete the questionnaire. For the interviews, a representative of that household reported on their own individual user experiences with some additional questions about the opinion of other household members. In the pre-adoption phase, the data was used to explore the participants' prior expectations. The first questionnaire also had additional questions about the participants demographics. In addition to the participants expectations of the robot, the first interview was also used to get to know the household, their daily routines and domestic technology use. In the confrontation phase, after installation and a first interaction with the robot for about 15 minutes, the data was used to catch the participants' initial impressions and their initial reactions. The data obtained in the remaining acceptance phases (e.g., adoption, adaptation, integration, identification) was used to investigate how the participants evaluated the robot over time, how it was deployed and how their use patterns changed and how the participants (tried to) integrate the robot into their everyday lives. From now on, each questionnaire started with the question if the robot was still in use and why or why not. Table 6.1 presents the number of questionnaires and interviews collected in the acceptance phases and their associated time point with regard to the moment the participants were introduced to the robot (i.e., in the confrontation phase).

Table 6.1: Distribution of sample sizes among the acceptance phases

Acceptance phase	Time points*	Questionnaires	Interviews
Expectation	2 weeks before	102	21
Confrontation	1^{st} day	102	21
Adoption	2 weeks	100	18
Adaptation	1 month	98	17
Integration	2 months	75	13
Identification	6 months	55	7

*Time points with regard to introduction of the robot

QUESTIONNAIRE
Similar constructs as those used in the Acceptance Survey presented in chapter 5 were employed here, however the complete set of original items were included in this study. These were the utilitarian attitudinal beliefs of usefulness, ease of use and adaptability, and the hedonic attitudinal beliefs of enjoyment, attractiveness, animacy, social presence, sociability and companionship. For the social normative beliefs these were social influence and status, and for the personal normative beliefs this was trust. Finally, for the control beliefs these were self-efficacy, anxiety towards robots and cost.

In addition to these factors, for the long-term study, also the utilitarian attitudinal beliefs of intelligence and the social normative belief of media influence were included. Moreover, as actual robots were employed in this study, the dependent variables of actual use and habit were added. To be believable and realistic, robots must be perceived as intelligent (Cuijpers et al., 2011). Therefore, the intelligence scale from Bartneck et al. (2009) was included in the questionnaire. Additionally, as most participants did have not encountered robots in real life, it was expected that their opinions about the robot were also shaped by the media. Media influence especially occurs in the case of early adoption (Rogers, 2003), when the media is the main source of information (Young et al., 2007). Therefore, the items of social influence from Brown and Venkatesh (2005) were adapted to measure the participants' media influence. For actual use, the scale was adopted from Adams et al. (1992) to administer how often, how long and for what purposes the robot was used. However, when people perform the same behavior on a regular basis, habitual use patterns might occur (Limayem, Hirt, & Cheung, 2007). Therefore, the scale of habit was obtained from LaRose and Eastin, 2004) to measure the participants habitual use of the robot.

All used scales were indicated as reliable, as the internal consistency reached the satisfactory level of >.70 (Nunnally, 1978). The used constructs, their source and the level of internal consistency obtained in this study are presented in table 6.2. The full list of all items can be found in appendix A.

Table 6.2: Internal consistency of the acceptance variables in all acceptance phases

	Internal consistency (α)					
Acceptance variables	Expectation	Confrontation	Adoption	Adaptation	Integration	Identification
Attitudinal beliefs						
Usefulness	.91	.94	.98	.94	.94	.96
Ease of use	.72	.71	.75	.74	.83	.70
Adaptability	.67	.63	.76	.78	.88	.87
Intelligence	.86	.90	.91	.92	.93	.87
Enjoyment	.88	.92	.92	.94	.88	.96
Attractiveness	.90	.93	.95	.95	.94	.91
Animacy	.79	.81	.83	.85	.90	.79
Social presence	.80	.77	.75	.75	.79	.86
Sociability	.81	.66	.76	.68	.87	.80
Companionship	.85	.86	.87	.88	.92	.88
Social normative Beliefs						
Social influence	.82	.75	.89	.94	.93	.91
Media influence	.63	.71	.87	.79	.88	.77
Image	.88	.92	.89	.96	.98	.96
Trust	.86	.92	.94	.96	.96	.95
Attitude tw. robots	.65	.70	.70	.72	.72	.64
Control beliefs						
Self-efficacy	.74	.84	.93	.92	.91	.92
Anxiety tw. robots	.81	.74	.80	.68	.80	.83
Pers. innovativeness	.89	-	-	-	-	-
Cost	.74	.90	.91	.90	.89	.92
Outcome variables						
Use intention	.92	.95	.98	.97	.98	.97
Actual use			.81	.76	.83	.71
Habit			.71	.74	.79	.79

INTERVIEWS

During each acceptance phase as described in section 6.2, the participants were interviewed. In total, 21 participants started the study who consented on being part of the interview sessions. Semi-structured interviews, conducted at the participants' own homes, were used to obtain detailed user experiences with the robot. Questions were asked about the following topics: evaluation of the robot (e.g., Can you describe some advantages / disadvantages of the robot?), evaluation of the use behavior and acceptance (e.g., how often have you used the robot in the last period? Do you consider to continue the use of the robot, why / why not?), user experiences related to and depending on the current acceptance phase (e.g., What does a regular day of using the robot look like? Are you still excited about the robot / Have you become familiar with all aspects of the robot? How would you compare the robot with other devices in your home? Have you adjusted the robot to your personal preferences? Do you usually use the robot on similar moments?), and the sociability and relationship development with the robot (e.g., Can you describe how you perceive the robot? How are the interactions with the robot similar to / different from interactions with other persons? Does the robot seems to have its own will / personality? Does the robot offer some kind of companionship?). A complete list of the interview questions can be found in appendix X.

DATA ANALYSES

A total of 97 interviews were conducted over a time period of six months. The interviews were recorded and transcribed verbatim with the participants' approval. The transcriptions were done as soon as possible after conducting the interviews to guarantee information clearance and solve problems with interpretation quickly (Taylor & Bogdon, 1984). Based on the transcriptions of the interviews, key concepts were identified and translated into a coding scheme by the primary coder. The final coding scheme is presented in appendix D. Next, for each interview section, at least one code from the coding scheme to interview sections. In total, 32 of the 97 interviews were also coded by a second scientist, which resulted in almost 33% of double-coded data. Intercoder reliability, which involves testing the extent to which the independent coders agree on the application of the codes to the different interview sections, has found to be substantial with a Cohen's Kappa of .73 (Landis & Koch, 1977). In the results, which will be presented in the next two chapters, from every interview transcript, 'striking' or 'typical' quotes (Hansen et al., 1998) were selected which illustrated, confirmed or enhanced our understanding of the experiences of the participants with the social robot as explained through the emerged key concepts from the coding scheme.

MISSING DATA

One of the main methodological problems in longitudinal studies is attrition, which is the situation in which not all *N* subjects have data on all *T* repeated measurements. Even in well-controlled situations, missing data invariably occurs in longitudinal studies (Hedeker & Gibbons, 1997). A traditional, but naïve approach might be to ignore subjects with incomplete data and model only those subjects measured at all time-points. Clearly, this approach can only be reasonable when the two groups, those with and those without missing data, are systematically comparable. However, subjects with missing data are often quite different from those subjects with complete data (Hedeker & Gibbons, 1997). However, a major drawback of statistical analyses on longitudinal data is that if one of the repeated measurements is missing all other available data of that subject will be excluded from the analysis as well. This means that an analysis on only those subjects with complete data suffers from a selection problem.

To overcome the problem of missing data, sophisticated imputation methods have been developed to calculate the data for a particular item at a particular point in time based on the available data. Contemporary approaches to attrition in longitudinal studies include multiple imputation strategies and maximum likelihood estimation methods (Newsom Jones, & Hofer, 2012). Maximum likelihood techniques estimate the summary statistics ‘as if’ selective attrition was measurable, either through single-stage (or ‘integrated’) models that use full information maximum likelihood procedures, or using two-stage (or ‘nonintegrated’) procedures such as the expectation-maximization algorithm. Multiple imputation replaces each missing value with a set of plausible values that represents random errors in the imputation process, so that the standard statistical models of interest (e.g. general linear models) can be estimated based on each imputed (or “complete”) dataset, and the parameter estimates along with their standard errors are combined eventually (Newsom Jones, & Hofer, 2012).

Both methods, when applied to data missing at random, tend to produce similar results and have proven superior to single imputation procedures (Newman, 2003; Graham & Schafer, 1999; Schafer & Graham, 2002). Multiple imputation has been shown to produce unbiased parameter estimates which reflect the uncertainty associated with estimating missing data. Additionally, multiple imputation has been shown to be robust to departure from normality assumptions and provides adequate results in the presence of low sample size or high rates of missing data. Moreover, multiple imputation performs very well in small sample sizes (as low as *N*=50), even with very large multiple regression models (as large as 18 predictors) and even with a lot of missing data (as much as 50%).

In my complete dataset, consisting of all the questionnaires from all the acceptance phases, approximately 25% of the data was missing not at random because of wave nonresponse. Wave nonresponse occurs when respondents are unreachable or refuse to participate. Some subjects missed a particular measurement wave, which resulted in subjects providing data at some, but not all, study time points. Alternatively, some subjects dropped out of the study, thus did not provide data beyond a specific point in time. Missing data caused by wave nonresponse affects sample size, comprises the estimation of population parameters and statistical inferences, and leads to selection bias when the distribution of covariates and the dependent variables is determined by the respondents' continued participation in the study. This bias may lead to a spurious relationship among the variables of unpredictable magnitude and direction.

Multiple versions of the dataset were produced, each containing its own set of imputed values. When statistical analyses are performed, the parameter estimates for all of the imputed datasets are pooled, providing estimates that are generally more accurate than they would be with only one imputation. The multiple imputation approach includes three steps: (1) the imputation step; (2) the complete data analysis step; and (3) the pooling step. Although five to ten imputations are considered sufficient to yield highly efficient inferences for decades (Allison, 2001), more recent research suggests that up to twenty imputations are necessary to yield sufficient statistical power with the friction of missing values less than 50% (Enders, 2010; Graham, Olchowski, & Gilreath, 2007). As my dataset has 25% missing data, I estimated twenty imputed datasets in the imputation step. I used Markov Chain Monte Carlo method to create random draws of parameters from Bayesian posterior distributions and took each 1000th iteration for the imputed values with a convergence criterion of .05. In the complete data analysis step, these data sets were repeatedly analyzed in substantive hypothesis testing. Finally, in the pooling step, results were then combined, and the average of the estimates is reported as the final result. So not only imputed values are generated based on existing data, but also an error component drawn randomly from the residual distribution is simulated.

PARTICIPANTS

Participants were recruited with various methods, such as word of mouth, advertising in public locations (e.g., libraries, leisure centers and supermarkets), and snowball sampling by asking assigned participants for referrals to other people who might participate. During recruitment, we tried to balance out the households' demographic profiles to seek diversity. Therefore the participants were divided into four different types of homes (see table 6.3 for the distribution within the sample): singles, couples, young families (children younger than 12 years old) and mature families children older than 12 years old). The goal was to equalize the participants within each household type. In the end, 28 participants were single, 26 participants lived with a spouse, 23 participants were part of a young family, 15 participants were part of a mature family, and for 10 participants did not provide their household type. Furthermore, to facilitate the interactions with the robot, participants were required to have at least a limited working proficiency in either English or German as the Katorz robot does not provide interactions in Dutch. Tightly specifying the participant group provides more reliability given the group size. We compensated our participants who participated with both the questionnaires and the interviews by allowing them keep their robot after study completion. Moreover, to increase both homogeneity and convenience, most participants lived within 10 square kilometer around our university, the University of Twente in The Netherlands.

Table 6.3: Distribution of household types within the sample

	Sample	
Household	***n***	**%**
Single	28	27.5
Couple	26	25.5
Young family	23	22.5
Mature family	15	14.7
Missing	10	9.8
Total	**102**	**100**

In total, 70 robots were placed into people's own homes. Together, in these 70 homes lived 160 participants. Of these participants, 102 were able or willing to complete the questionnaires. There were 48 males and 54 females, and their age ranged from 8 to 77 (M= 37.74, SD= 16.87). Our participants were skewed towards those with higher education (see table 6.4 for the distribution within the sample): 17 had a low educational level, 31 had a middle educational level, and 48 had a higher educational level. As the robot used in this study is shaped like a rabbit, we also asked participants about their pets. Almost all participants liked pets (N= 87), and almost half of them currently had a pet (N= 47).

Table 6.4: Distribution of educational level within the sample

	Sample	
Educational level	***n***	**%**
Low	17	16.7
Middle	31	30.4
High	48	47.1
Missing	6	5.9
Total	**102**	**100**

USER GROUPS

Not all participants finished the complete study, as some stopped using the robot before the end of the project. Therefore, participants were divided in three groups based on the duration of use. Rejecters (n= 23) are those participants who stopped using the robot within the adoption, i.e. before month of use. Adopters (n= 32) are those participants who stopped using the robot in the adaptation or integration phase, i.e. around two months of use. And users (n= 47) are those participants who were still using the robot in the identification phase, i.e. after six months of use, and indicated an intention to continue the use the robot after the study.

6.5 STUDYING LONG-TERM SOCIAL ROBOT ACCEPTANCE

The temporal dimension of acceptance is underexposed in human-robot interaction research. Today only a few studies have investigated the long-term use of a robot in home environments (e.g. de Graaf & Ben Allouch, 2014;

Ferneaus et al., 2010; Fink et al., 2013; Sung et al., 2009; Sung et al., 2010). Yet, even the traditional technology acceptance literature lacks a profound body of long-term research, even despite its long history in information systems research (Taylor & Todd, 1995). This chapter proposed a sequence of acceptance phases mainly based on the domestication theory (Silverstone & Haddon, 1996) and the diffusion of innovations (Rogers, 2003), together with findings from earlier long-term studies on technology use in the home (e.g., Demiris et al., 2008; Karapanos et al., 2009; Sung et al., 2009; Sung et al., 2010), which consists of six acceptance phases: expectation, confrontation, adoption, adaptation, integration and identification. The sequence of the acceptance phases is believed to be fundamental and could thus be applied to other technological devices for domestic use. However, the duration of each phase could differ between technologies as the frequency and the habit formation (Lally et al., 2009) varies among different behaviors. The following two chapters (i.e., chapter 7 and 8) will present the results of the Karotz Home Study which explored people user experiences of a social robot in their own homes up to six months of use.

7

USER EXPERIENCES DURING LONG-TERM USE

“People are quite traditional in their way of living, at least when it comes to daily routines and chores in the household, which are not necessarily easily pervaded by technology.”
– Leppänen and Jokinen –

This chapter presents the qualitative results of the participants' acceptance experiences based on the descriptions of the acceptance phases presented in chapter 6.2. First, the acceptance experiences gained from the interviews in each phase are presented. However, not all participants continued the use of the robot until the end of the study. Therefore, the second part of this chapter focusses on non-use and the reasons why participants stopped using the robot at different stages in the acceptance process.

7.1 ACCEPTANCE EXPERIENCES FROM PHASE TO PHASE

According to the participants' stories in the interviews, the overall acceptance experience living with a social robot was mostly about exploring what one could do with the robot (e.g., exploration), getting familiar with it (e.g., familiarization), and trying to recognize possible benefits of its applications (e.g., recognize benefits). The results of the acceptance experiences from phase to phase are presented in table 7.1 on the next two pages. In the upcoming sections, I will present the acceptance experiences in more detail from phase to phase ordered by the frequency in which participants discussed the particular acceptance experience.

THE EXPECTATION PHASE

In the expectation phase, people want to know more about the technology and its purposes and therefore seek information about the technology. Based on the gathered information, people will form an initial opinion about the technology and establish initial expectations. The expectation phase concerns the anticipation and preparation of obtaining a technology. The interviews for the expectation phase were conducted two weeks before being introduced to the robot. At this point, the participants only knew that a robot was going to be part of their households for the upcoming months, but no details were provided about what type of robot nor its functionalities.

Table 7.1: User experiences (n=1663) as coded in the interviews for all the acceptance phases

User Experiences	Expectation phase % of all reported experiences (n= 104)	Confrontation phase % of all reported experiences (n= 262)	Adoption phase % of all reported experiences (n= 374)
Expectation experiences			
- Anticipation	36	15	0
- Association	12	11	8
- Attitude formation	3	6	1
- Discuss with others	1	2	13
- Information seeking	13	8	10
- Preparation	14	1	0
Adoption experiences			
- Adjustment	0	1	8
- Curiosity	9	5	4
- Excitement	3	1	2
Adoption/Adaptation experiences			
- Exploration	0	13	21
- Novelty	3	4	4
- Trial and error	0	9	9
Adaptation experience			
- Personalization	0	1	3
Adaptation/Integration experiences			
- Familiarization	0	1	2
Integration experiences			
- Incorporation	0	0	0
- Reinvention	0	1	4
- Use routines	0	0	0
Identification experiences			
- Promotion to others	0	1	0
- Confirmation	0	0	0
- Emotional attachment	0	0	1
- Identification	0	0	0
- Maintenance	0	0	0
- Personality attribution	0	1	1
- Recognize benefits	6	19	9
Total	100	100	100

Adaptation phase % of all reported experiences (*n*= 399)	**Integration phase** % of all reported experiences (*n*= 330)	**Identification phase** % of all reported experiences (*n*= 194)	**All phases combined** % of all reported experiences (*n*= 1663)
0	0	0	5
9	7	7	9
1	0	1	2
9	6	10	8
2	1	0	5
0	0	0	1
3	1	0	3
3	0	1	3
1	0	0	1
15	7	1	12
1	0	0	2
3	3	0	5
11	11	8	7
13	21	22	10
9	13	10	6
2	7	6	4
2	10	9	4
0	1	1	0
0	0	0	0
2	2	8	0
1	1	3	1
1	0	0	0
3	1	3	2
8	8	11	10
100	100	100	100

ANTICIPATION

In the expectation phase, the participants talked most about their expectations about using the robot (e.g., anticipation). The participants, not knowing all the details of the robot yet, tried to image what it would be like to have the robot in their homes and whether or not things would change.

> "It depends on what [the robot] can do, …but I don't think it would make any difference [when the robot comes]." – female, 22, living in student dorm
>
> "Such a robot obviously has influence, …the influence is difficult to predict. But I don't expect it to have a big impact." – male, 32, living alone
>
> "First I must know how and what. And then it is waiting for what is going to happen." – female, 19, living in student dorm

PREPARATION

Moreover, the participants were preparing for the arrival of the robot (e.g., preparation). Although this also comes down to thinking about what it would be like to have the robot, preparation contains more details about specific use scenarios. The participants tried to prepare themselves for the kind of functionalities the robot had to offer and which effects that could have on their attitudes towards the robot or their technology use behavior in general.

> "If [the robot] can provide me with information that I normally look up on my computer or tablet, then I can keep sitting down. …I am all about the practical and convenience." – male, 31, living alone
>
> "That is difficult to say [what the robot would mean to me]. I don't know exactly how it will all go." – male, 24, living alone

INFORMATION SEEKING

Additionally, the participants discussed looking up information about the robot and its usages (e.g., information seeking). Before the interviews, most participants explained that they already tried to find information online or that they would prefer to have more information about the robot.

> "I had seen the [recruitment] leaflet in the supermarket. Later I went back to take it with me, because I wanted to read it all over. But it was gone thus I tried to Google it, but most of what I found was in English and I did not feel like reading all that." – female, 57, living alone
>
> "I find it all very interesting, but I don't know enough about it. I need more time to dive into that, to read about it." – female, 19, living in student dorm
>
> "I have checked the internet and YouTube before… I think it said that [the robot] could help you perform daily household tasks?" – female, 33, living alone

ASSOCIATION

And, finally, the participants were associating the robot's purposes with other technologies (e.g., association). Because the participants had never used robot technologies before, they tried to make sense of it by comparing it to other objects they are familiar with such as personal computers and smart phones.

> "For me, [the robot] is some type of computer, something that is programmed." – female, 22, living in student dorm
>
> "I think of it as some type of tool, media-player like, something from which you can obtain the news or that it could serve as an alarm clock." – female, 27, living with spouse
>
> "Some type of tool that can support you, …that takes care of your things." – male, 64, living with spouse

THE CONFRONTATION PHASE

In the confrontation phase, people encounter the technology for the first time. This is where people may try out the technology if possible or just observe others using the technology. In the confrontation phase, the interviews took place on the same day that the participants were introduced to the robot and had their first usage trials.

RECOGNIZE BENEFITS

the participants talked most about the possible benefits of the robot (e.g., recognize benefits). Most participants perceived the applications of the robot as beneficial, such as the reminders or the weather forecast. Other participants looked at the bigger picture and explicitly said that the robot could safe them time or that they would not must use their computer anymore. A few participants explained that they perceived some interaction modes as beneficial and appreciated the lifelike features of the robot.

> "That you can install a reminder to make you be on time for appointments, to be able to leave on time." – female, 22, living in student dorm
>
> "It will bring some liveliness. You could call that a benefit." – male, 32, living alone
>
> "You don't have to turn on the computer anymore. Because you can push the button and ask for example for the weather forecast or the news." – male, 24, living alone

ANTICIPATION

Moreover, the participants were still anticipating on their possible uses of the robot (e.g., anticipation). They were trying to picture how living with the robot would look like and explained that only time could tell how it all would work out in the upcoming weeks. Some participants expected that the robot could become an important part of their lives. Others discussed how the robot could be of use for their household.

> "Maybe he becomes more important in my daily life… I have to see first what he can do." – female, 22, living in student dorm
>
> "To see what fits me and how I can incorporate a learning moment together with the children. That kind of things. It is just a totally different pastime. Just something extra." – female, 32, living with young family
>
> "It takes time and adjustment. I mean, you will learn that in time [how to deal with the robot]." – female, 55, living with spouse

EXPLORATION

Additionally, the participants started to discover how to use the robot (e.g., exploration). Most participants said that, in the upcoming weeks, they would explore the different purposes of the robot and would discover how it all works. The participants explained that they just had to try some features and experience it themselves. Some participants expected that this would be fun and that the robot could surprise them with what it can do.

> "That I will explore funny things with [the robot]. Discover what you can do with it." – female, 24, living with mature family
>
> "I would actually take a day to fully work with [the robot] and to find out what it can do and how it all works." – female, 55, living with spouse
>
> "That we discover new stuff over and over again… and that I am surprised by what [the robots] is going to do." – female, 38, living with mature family

TRIAL AND ERROR

While exploring what the robot has to offer, the participants explained that this goes along with a lot of trying to see what works for them (e.g., trial and error). They were testing the different available applications, uninstalling those that did not fit, and explained that some of the applications did not seem to work at all. For some participants, trying different applications was something that was discussed among family members before going forward with it.

"I see it as a challenge to try it all out… That you say [to a family member] shall we try this or that." – female, 32, living with young family

"I think it will mainly be just testing a lot of things in the beginning." – female, 33, living alone

"I still find it a bit difficult how you can install new apps in a proper manner. For example, I haven't managed to actually hear the weather forecast yet." – female, 55, living with spouse

ASSOCIATION

Also, the participants were still associating the robot with other technologies (e.g., association). Most participants saw the similarities between the applications of the robot and those of a smartphone or tablet. Other participants took the animated appearance of the robot into account by comparing the robot with a rabbit or just by acknowledging it social abilities.

"Just like you say good morning to your pet." – female, 24, living with mature family

"In principle, it is somewhat the same as a iPad or iPhone, but more humanlike and a little less like an appliance." – female, 27, living with spouse

"If I had to describe the robot to someone who hasn't seen or used it before, I would say it is a plastic rabbit with turning ears and glowing lights that can do a little bit more than a smartphone." – male, 31, living alone

INFORMATION SEEKING

Additionally, the participants discussed looking up additional information about the robot (e.g., information seeking). Most participants tried to Google information about the robot. Some other participants watched movies on YouTube or talked with others about the robot to learn what they could do with the robot. Even during the interview, the participants were asking me questions about how to use the robot and what kind of things they could or could not do with it.

"I have to look it up on the website to know what I can do with [the robot]. That I will have to read through it all." – female, 57, living alone

"When we had all seen it [in our household], I have taken a look into what [the robot] could do. Watched some YouTube movies, stuff like that." – female, 38, living with mature family

"I have discussed [the robot] with some colleagues of mine who also have this robot. That was before I had installed it. And I asked them what I could do with it, what kind of object is it. And gathered some information from that." – male, 38, living with young family

THE ADOPTION PHASE

The adoption phase is where people actually start using the technology in their privacy environment and gain their first serious user experiences with the technology. The interviews for the adoption phase were conducted two weeks after the robot was installed in the participants homes. This was to make sure that the participants had actually started to use the robot.

EXPLORATION

the participants mostly discussed discovering the purposes of the robots and how it works (e.g., exploration). Where exploration in the confrontation phase dealt with intentions to explore the functionalities of the robot, this time the participants had some stories about their first discoveries of the robot.

> "I have used [the robot] rather a lot in the first week. The commands such as the weather forecast and news." – female, 33, living alone
>
> "I have tried to search for a radio station, but that did not work out. I have used the webcam. And the app with which you can turn the ears and change the colors…. I have played some music, which worked the first time but later it did not." – male, 32, living alone
>
> "The next day [after the installation] we have sat down on the couch with the iPad and looked up what kind of apps there are. Tried it out a bit." – female, 27, living with spouse

DISCUSS WITH OTHERS

Moreover, the participants said that they had discussed having the robot with friends and co-workers (e.g., discuss with others). Especially when visitors came to their house, the participants liked to show the robot to them and to talk about it. Other participants also discussed the robot when meeting people outside their homes or some even shared pictures of the robot on social media.

> "My roommates and some friends came over and they thought [the robot] was funny and tried some commands… My parents are also curious. So I have made them a video and send it to them, to see what it looks like and what it can do." – female, 22, living in student dorm
>
> "On FaceBook… I want to make a picture [of the robot] and post what it can do. Or maybe make a small movie." – female, 32, living with young family
>
> "I have talked a lot about [the robot]. A friend of mine has a similar robot. It is a nice conversation topic at parties… Other people are curious about it, they like it." – male, 32, living alone

INFORMATION SEEKING

The participants still felt a must seek more information about (using) the robot (e.g., information seeking). The information seeking behavior was quite similar to that in the previous period with the participants rereading the manual, or searching the internet for ideas of useful applications of the robot. A few participants even asked the researcher for more information.

> "I am not sure yet what I can to with [the robot] I thought I should ask you first if I can install more applications. If you can explain to me what I can do with it, I would like to try that." – female, 57, living alone
>
> "I must go through the manual one more time, … because I have scanned it a little bit but I haven't read it all yet." – female, 24, living with mature family
>
> "I don't think I have seen it all. I think I will take a look on the internet. I have seen some homepages from which you could download some apps. I think I will snoop around to fulfill my needs." – female, 19, living in student dorm

TRIAL AND ERROR

Additionally, the participants explained that they were trying out several tasks with the robot and sometimes failed at it (e.g., trial and error). This differed from the trial and error experiences in the confrontation phase as this time the errors were not because of a lack of user experience but mostly because the robot did not worked that well.

> "That wouldn't work in the beginning. I was like, haven't I done that right? Then I tried it in the same menu as the garbage reminder and it worked." – female, 24, living with mature family
>
> "I have tried to control it with my phone. Sometimes it worked, other times not. Actually, [the robot] does not always works so good, but often it does." – male, 32, living alone
>
> "Some frustration when not everything works that well." – female, 19, living in student dorm

RECOGNIZE BENEFITS

Nonetheless, the participants still acknowledged possible benefits of having the robot (e.g., recognize benefits). This time, the participants particularly welcomed the information provided by the robot and the remembrance function. Using the robot seem to safe time for some participants, whilst others appreciated the robot to remember them to take out the trash or catch the bus on time.

> "I is just easier to use [the robot] as an alarm clock and for listening to music… And asking for today's weather forecast to the robot. I used to do that on my mobile phone, but that takes longer." – female, 22, living in student dorm
>
> "For taking the garbage out. That was quite useful. Otherwise I would have forgotten it." – female, 33, living alone
>
> "[The robot] is very useful. I have installed a shopping list on it. All kinds of stuff. I take my medications in time." – male, 55, living alone

ADJUSTMENT

Finally, the participants were trying to adjust how the robot should be handled with success (e.g., adjustment). The participants experimented with some personal settings on the robot and tried to adjust their behavior to better interact with the robot. Some participants said they were learning to better understand what the robot says. Other participants felt the must make adjustments to makes everything work better such as moving the robot to a different spot, switching it off when leaving the house, or silence it when it is time for bed.

> "In the beginning, you don't understand anything [the robot says], because you are not focused on it. But now I am very tentative to what it says." – female, 24, living with mature family
>
> "I usually have [the robot] switched on when I am at home. When I leave the house or go to bed, I switch him off." – female, 33, living alone
>
> "I have to get a longer flex from somewhere. [The robot] is standing against an inclined wall and I am not sure if it all goes well with the turning ears. I have to relocate that a little bit." – female, 19, living in student dorm
>
> "[The robot] was annoying at night, because it made noise. But I have learned that I can make him be quiet." – male, 31, living alone

THE ADAPTATION PHASE

In the adaptation phase, users have a broad idea of what the technology is all about. However, they still encounter novel features and this might come along with some learnability flaws such as incorrect usage. Yet, while exploring the functionalities of the technology and making attempts to adapt these to their personal needs, the users are increasingly getting familiarized with the technology. The interviews for the adaptation phase were conducted one month after the participants were introduced to the robot.

EXPLORATION

The participants were still mainly exploring how to use the robot (e.g., exploration). This time, for the participants, exploration is more in terms of being sure that they have discovered all the possibilities the robot has to offer.

> "I still have the feeling that I haven't, that I can install more functions on [the robot]. I haven't tried it all yet." – female, 57, living alone
>
> "I have used some of the applications, but there are more of them to install… but I have not looked into that yet. I have to explore that some more." – female, 24, living with mature family
>
> "I have tried to search for a radio station, but that did not work out. I have used the webcam. And the app with which you can turn the ears and change the colors…. I have played some music, which worked the first time but later it did not." – male, 32, living alone

FAMILIARIZATION

Additionally, most participants explained that the novelty effect had begun to fade away (e.g., familiarization). The participants were becoming familiar with what the robot does. They learned how to set the robot and the robot had no more surprises for them.

> "A little bit of astonishment… when it first arrived here… But that is getting used to, that is just a habituation process." – female, 57, living alone
>
> "Obviously, in the beginning it is interesting to see what [the robot] can do, but we know that by now." – female, 27, living with spouse
>
> "The children won't even react to [the robot] anymore. They just know that he interrupts us incidentally." – female, 59, living alone
>
> "New things are fun, but, at a certain point, you know how [the robot] works. And that is okay." – male, 64, living with spouse

PERSONALIZATION

Also, the participants have appropriated the robot to fit their needs (e.g., personalization). They have adjusted the setting according to their needs. Some participants installed some additional spoken words into the robot, for example to make it great them on certain times. Other participants actually reduced the social features of the robot to a minimum. A few participants programmed the robot in such a way that it would turn on the radio, the news or the weather forecast at set times.

"To sit on the chair for a short time and pleasantly listen to some music. I can image to do that more often." – female, 57, living alone
"I have installed [the robot] to say good morning and good night." – female, 24, living with mature family
"[The robot] used to say stuff every half an hour. Well, I have reduced that as much as possible." – female, 33, living alone
"I have programmed [the robot] to automatically provide the weather forecast in the morning and evening." – male, 32, living alone
"To arrange that [the robot] switches on just before the news bulletin so that you automatically gain the news at 6 o'clock." – female, 19, living in student dorm

ASSOCIATION

Yet, the participants were still associating the purposes of the robot to those of other technologies they use (e.g., association). However, this time they focus more on the differences between the robot and other technologies instead on the similarities, which was more the case during the adoption phase.

"The robot is a bit like a connection… more interactive than a radio or smartphone." – female, 22, living in student dorm
"What I like about [the robot] is that he reminds us about things. That is something unique. That does not exist for me, except for an alarm clock maybe." – female, 24, living with mature family
"That would possibly be the radio, but differently… you see personal things in the rabbit [robot]." – female, 55, living with spouse

INCORPORATION

Moreover, some participants were making amends to make the robot parts of their everyday lives (e.g., incorporation). They used the robot for purposes for which they used other technologies before, such as listening to music on the robot instead of on the radio. Other participants integrated the (uses of) the robot into daily routines, such as listening to weather forecast every morning or making the use of robot part of their daily activities.

"I listen to the weather forecast every day… directly after I get up… That is something constant." – female, 57, living alone
"It is something pleasant in our home. A nice part with which we can do a lot. Not only me, but also my husband and children. All of us together." – female, 32, living with young family
"I used to turn on the juke box or the radio on my laptop or on the television, but I use the robot for that now." – male, 24, living alone

DISCUSS WITH OTHERS

Furthermore, the participants were still taking to others about the robot and its purposes (e.g., discuss with others). The robot still causes some family discussions, or when visitors come to the house and want to know more about the robot after they noticed it. And a few participants want to share their experiences on social media.

> "I would like to tell more people about [the robot] on FaceBook or something." – female, 32, living with young family
>
> "With each other. That you say like well that is funny what [the robot] says… You laugh together because he is grumbling." – female, 24, living with mature family
>
> "I think that at least five other friends of mine have a similar robot… It is usually about what the others do with it, exchanging experiences." – male, 32, living alone

RECOGNIZE BENEFITS

Finally, the participants still realized that the robot has potentials (e.g., recognize benefits). Especially the diversity of use, the reminders and the social aspects were evaluated as a benefit. However, some participants indicate that the true benefits of the robot will only become visible after further improvement or they point to other use groups for which the robot could be of use.

> "Because you can use [the robot] in different ways. And because it looks cute… That is what makes it a supplement." – female, 32, living with young family
>
> "I think [the robot] is a supplement to our household... I like it that he reminds us of things… And that he says funny things." – female, 24, living with mature family
>
> "I think that, if you don't have a smartphone, then I see some benefits." – female, 26, living with young family
>
> "Younger people don't see [the robot's] potentials. Those people have their phones… it goes a lot faster and digitally. That is fine, everybody should decide for himself. But we like it and I can imagine that at a certain point for some age categories that it has some benefits." – male, 64, living with spouse

THE INTEGRATION PHASE

In the integration phase, a used technology has become meaningful in a person's life. The technology is modified or personalized by the user to adapt to their preferences. The users do no longer notice the presence of the technology and have fully integrated its use into their everyday lives. The interviews for the integration phase were conducted two months after the installation of the robot.

FAMILIARIZATION

The robot had no more surprises (e.g., familiarization) for the participants in the integration phase. The participants explained that they have explored all the options of the robot and picked their favorites. Also, the participants were no longer continuously aware of the fact that the robot was there and the novelty was completely gone by now.

> "That is going its course and we are totally used to [the robot] now… You have tried and looked at all the options. The newness is gone." – female, 32, living with young family
>
> "In the beginning [the robot] attracts a lot of attention and that is lovely too. And now… you are not fully conscious of him anymore. It becomes normal. That is habituation, having him here." – female, 32, living with young family

INCORPORATION

Moreover, the robot had become part of the participants' everyday lives (e.g., incorporation). In some occasions the favorite use purposes of the robot have become part of the participants daily activities. The usage of the robot has become a fixed set of activities. The participants were using the same applications on a regular basis or replaced other home technologies with one of the robot's functionalities.

> "I use the same programs almost every day… In the morning, I don't even watch television anymore, because I get the news bulletin and weather forecast from the robot." – female, 22, living in student dorm
>
> "When [the robot's] alarm clock goes off, my son immediately says 'ears ears'. That is how he call him. And he instantly knows that it is time to wake up." – female, 32, living with young family
>
> "For the radio I already had [the robot] switched on. And that hasn't changed. And I use the alarm clock once and a while when I must get out of bed. I actually use it for the same things again and again." – male, 24, living alone

PERSONALIZATION

Yet, the participants were still adapting the robot to their personal preferences (e.g., personalization). The participants explained that they kept changing the settings for some of the applications or installed additional applications to make better use of the robot. It was really about selecting the right set of applications that best suit their needs. But, adapting the robot also entails the of its appearance with the supplementary set of ears or the stickers the participants received at times of the installation.

"I just looked at all the programs I found useful. In the beginning I also tried out the funny programs, but… those are more a distraction… so I uninstalled those." - female, 22, living in student dorm

"In the morning, [the robot] wakes up at 8 o'clock and I think in the weekends this is even at 9 o'clock, because you can hear him pretty good upstairs… And in the evening at 10 o'clock he switches off again. I have programmed all that." - female, 24, living with mature family

"I have used those [the extra set of ears]. Because I liked the black ones more than the white ones." - female, 19, living in student dorm

USE ROUTINE

Nevertheless, the participants were already creating their daily use routines with the robot (e.g., use routine). Despite the ongoing alteration of the settings, the participants were already able to create daily use routines with the robot. For some participants, the robot has become a part of their morning rituals or the use of the robot has become a special moment during the day.

"Often in the afternoon, between 2 and 4 p.m., that is the time fully dedicated to my youngest son. And in the morning, when my husband is still busy, we listen to the radio. And then again, when my older son gets home from school, we use [the robot] again. And once more at 6 or 7 o'clock, the quiet pastime between dinner and bedtime." - female, 32, living with young family

"Every morning, when I wake up between 7 o'clock of half past seven, [the robot] makes some noises and I recognize that now. It serves like a second alarm clock, when I hear him from my bedroom. And at a quarter to 8, he reads the weather forecast aloud… That is something I got used to." - male, 32, living alone

"There is a pattern in it. It might be that the exact time differs, but that won't be much. I basically do the same things at a certain time." - male, 55, living alone

RECOGNIZE BENEFITS

Moreover, the participants still discussed the possible benefits of the robot (e.g., recognize benefits). This time, with the rejecters of the robot gone, the remaining participants were more positive about the benefits of the robot. They appreciated several functionalities of the robot, such as the radio and the reminders, which had made changes in the everyday lives of the participants.

"Listening to the radio, installing some stuff to be a reminder that he says out loud. It is a very useful object once and a while." - female, 32, living with young family

"The advantage is that [the robot] is entertaining." - male, 32, living alone

"The advantage is definitely that I don't forget parts anymore, that without any doubt an advantage. The second advantage is that I listen more to music… But also, this may sound a bit weird, but it brings me ideas. It keeps my brain working. You could see that as an advantage as well." - male, 55, living alone

REINVENTION

And the participants had begun to think about possible new applications of the robots (e.g., reinvention). The participants seem to agree that especially the reminder function if the robot is most beneficial. And some participants put the effort into thinking about or even making some first attempts in creating new applications for the robot.

> "I want to explore if I can change the language… because it is very artificial, very robot-like. So I will try to get something off the internet, and that I record something myself." - female, 22, living in student dorm
>
> "I know that [the robot] can make sounds. And that he has a camera, that you can record something. But how you can profit the most from that, I am still curious to figure that out." - male, 32, living alone
>
> "I have downloaded the software [to create new apps]. I want to try to create a third group for the audio… for people who has difficulties to read. Audiobooks, that could be useful." - male, 55, living alone

THE IDENTIFICATION PHASE

In the identification phase, a technology exceeds its functional purpose and becomes a personal object. People may use a technology to express a certain lifestyle, to differentiate or connect to other groups. Moreover, in this phase, users seek supportive information that approves continuance of use and therefore confirms their initial decision to adopt the technology. The interviews for the identification phase were conducted six months after the participants were introduced to the robot.

FAMILIRIZATION

The participants were fully accustomed to the robot (e.g., familiarization). They knew what the robot had to offer and how they could make use of that. However, familiarization was not always something positive at this point, for some participants it resulted in boredom and they expected that the robot would offer some new applications.

> "I have seen and used most programs already… For me it is more like a toy and at a certain point it becomes boring." - female, 22, living in student dorm
>
> "You know what [the robot] is capable of and what it does. The newness is gone. You have a need for something new. Because with a robot, … you expect that it can update itself and that new stuff will come." - female, 32, living with young family

RECOGNIZE BENEFITS

Moreover, some of the participants continued to talk about the possible benefits the robot provides them (e.g., recognize benefits). These participants that discussed the potentials of the robot were positive about the advantages the robot had offered. Surprisingly, most participants explained that it was not the robot's utility that they indicated as most beneficial, but it was the robot's sociability that they appreciated the most.

> "Every time [the robot] says something, you get involved with it or you are laughing at what is says… That is still nice. And that he calls the time, that is also very useful." – female, 24, living with mature family
>
> "Not because of its functions, because I rather use my phone for that kind of stuff… But as I said, I would regret it if I did not have him anymore. So in that sense it has a benefit in some way." – female, 27, living with spouse
>
> "When I am extremely tired… I tend to forget things. And then it is very useful that it reminds me to take my medication or to go get some groceries." – male, 55, living alone

DISCUSS WITH OTHERS

Although sharing experiences of the robot with other people (e.g., discuss with others) was still a topic of interest during the interviews, the participants explained that they had talked less about the robot. Being familiarized with the robot resulted in less triggers from the participants to share their experiences with others. A few participants explained to me that they would like to have an online community with other Karotz users to share their experiences with.

> "I used to do that in the beginning [showing the robot to visitors]. But at a certain time everyone knew the robot already. So I stopped doing that." – female, 22, living in student dorm
>
> "You don't see other people on FaceBook who also has such a device or who talks about it. I missed that." – female, 32, living with young family
>
> "Basically every visitor asks about [the robot] and most of the time we give a little demonstration of what he can do. But people who have seen it before, they won't ask for it again." – female, 27, living with spouse

INCORPORATION

The remaining participants integrated the use of the robot into their everyday lives (e.g., incorporation). They felt that the robot just belonged in their home as if it would be incomplete without the robot standing in its place doing what it does.

"[The robot] belongs with us now." - female, 24, living with mature family
"[The robot] was just there and did what he had to do." - male, 32, living alone

USE ROUTINE

Daily routines of using the robot (e.g. use routine) were created by the remaining participants. There were standard times at which the participants used the robot, and most of the time they used the robot for the same purposes.

"Usually at nights to listen to music, and in the morning mainly for information about the weather and the news." - female, 22, living in student dorm
"Especially because [the robot] calls the time every hour. On Wednesday evening, we have the reminder for the garbage. You are basically waiting for him to say that." - female, 24, living with mature family
"I used the camera when I am at work, to take a look if everything was going okay back home. And the dairy function on Sunday evening. That were all things on the same moment." - male, 31, living alone

PERSONALIZATION

The participants had the robot fully adapted to their personal needs (e.g., personalization). They were done exploring the programs and settings and they had spent quite some time doing that before they were completely satisfied with how the robot works best for them.

"I constantly searched for better programs… He is completely adjusted to me. That is useful." - female, 22, living in student dorm
"I have studied that quite intensively, what [the robot] can do. But also talking to him, that you pronounced everything in the right way… I have unraveled all that." - female, 32, living with young family
"That are your personal needs. That is what I like about it. We have it exactly how we like it to be." - female, 24, living with mature family

EMOTIONAL ATTACHMENT

For most of the remaining participants, the robot has become something special that is just there. Most participants even expressed that they still liked to keep the robot and that they would miss the robot if someone had to take it away from them (e.g., emotional attachment). Most participants expected that they would miss the robot if I had to take it away. Some participants compared the robot with having pets. Other participants just felt that they owned the robot now that is has been in their homes for so long.

"You get used to having it… It is just like having a pet, when you talk about it like that… He has become a part of our family… I still like him. I would not want to miss him.." – female, 24, living with mature family

"He has been standing in the living room for quite some time now, so it feels as if it is your possession." – male, 32, living alone

"I would regret it if I did not have him anymore… I think of [the robot] as some type of pet. Like having fish. You know they are there, you have the feeling they are there, but you cannot do much with it… anyway a little bit attached to it… It would make a difference if you would take him away. I would miss him." – female, 27, living with spouse

REINVENTION

Finally, most of the remaining participants came up with ideas to further develop the usability of the robot (e.g., reinvention). Some participants tried to program their own application or led others them with that. Other participants just shared their ideas for further development of the robot with me during the interviews.

"I have tried to look up how you could make an English speaking robot says stuff in Dutch. I Googled that, but that is quite difficult to do." – male, 32, living alone

"I have given [the robot] to someone else who is a technology expert. He is figuring out if it is possible to put the robot on a turning platform, so that you can use him for more purposes. For example the camera, you can't overlook the whole living room with it… In that way you'll create more possibilities, such as surveillance… or for home care." – male, 55, living alone

A REFLECTION ON THE RESULTS

In chapter 6.2, a long-term perspective of long-term technology use in home environments was presented that consisted of six acceptance phases along with a theoretical time line. It was suggested that the expectation phase started before the participants had ever seen the robot. The confrontation phase should start at the moment was the robot is introduced, after which the adoption phase will start. However, to make sure that each participant had had the opportunity to have some first explorations with the robot, the interviews for the adoption phase were conducted two weeks after the introduction of the robot. The adaptation phase for social robot acceptance was hypothesized after one month of use and the integration phase was expected to start around two months of use. Finally, the identification phase should hypothetically begin around six months after the introduction.

The conceptualization and timeframe of the acceptance phases were based on two prominent theories (i.e., the domestication theory and the diffusion on innovations theory) complemented with research results from other long-term home studies focusing on technology acceptance and use (e.g., Demiris et al., 2008; Karapanos et al., 2009; Sung et al., 2009; Sung et al., 2010). The results indicate that the acceptance experiences, to a large extent, correspond with the time line suggested for these phases (see figure 7.1). One exception is the identification phase, in which the participants talked more about adapting the robot to their personal needs and trying to incorporate the use of the robot into their everyday lives. This suggests that, at six months after being introduced to the robot, the participants were still in the integration phase. The most likely explanation for this, is that only three of the seven remaining participants in this last round of interviews were still using the robot at that point and intended to continue the use of the robot after the study.

Some additional remarks on a few acceptance experiences that deviated from this time line are necessary. First, only one participant had discussed the robot once with someone else outside the household in the expectation phase. Instead, the topic of discuss with others mostly occurred in the interviews two weeks after the introduction, which is theoretically the adoption phase. Second, the participants continued to seek information about the robot until two weeks after the introduction, which is theoretically the adoption phase. However, the topic of information seeking did peak in the interviews two weeks before the introduction (i.e., the expectation phase), as was conceptualized theoretically. Third, even after two months of use, the participants still talked a lot about appropriating the technology to their own needs, which theoretically should have been finalized at two months of use where the integration phase begins. Finally, the topic of recognize benefits was part of all the interviews, but was of especial interest to the participants at the day of the introduction to the robot (i.e., confrontation phase). Yet, the topic reoccurred during the interviews after six months of use (i.e., identification phase), which was conceptualized theoretically.

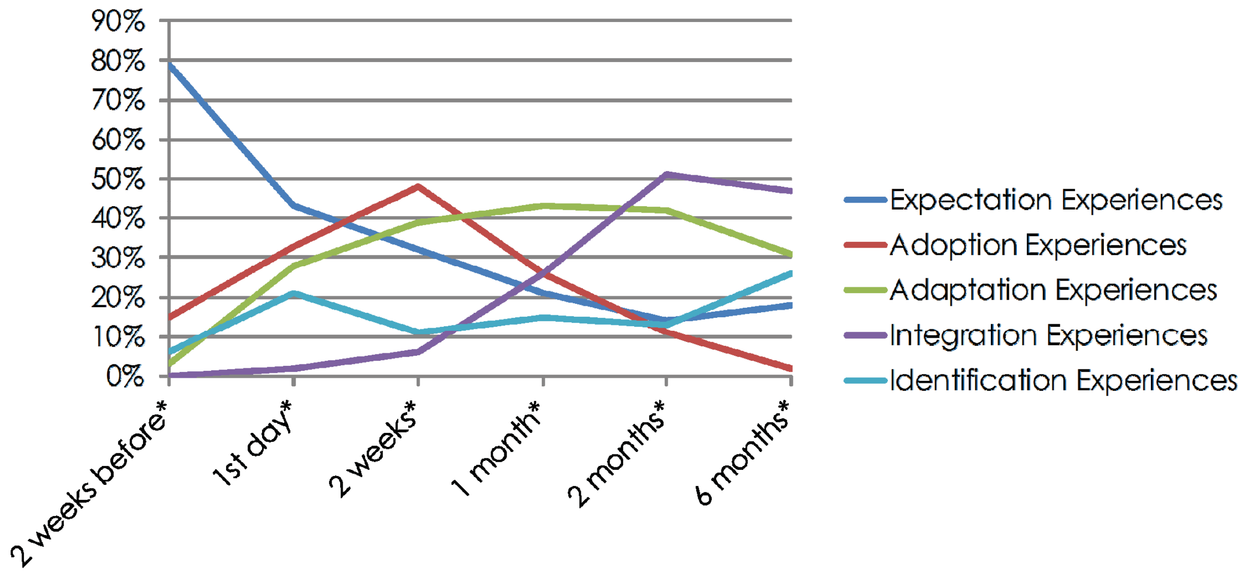

Figure 7.1: Visualization of the user experiences (*n*=1663) as coded in the interviews
Note: *Time points with regard to introduction of the robot

7.2 EXPERIENCES OF NON-USE

So far, the reasons why and the ways in which the participants have used the robot in their own homes have been discussed. The role of users has been increasingly addressed within the technology acceptance literature, especially during the mid-1990s, and some researchers have argued for the recognition of active users as important actors in shaping technology (Silverstone & Hirsch, 1992; Lie & Sørenson, 1996; Wyatt, 2007). By including the user, an attempt is made to overcome problems associated with approaches that focus on the actors that produce the technologies such as scientists, engineers, politicians, financers and marketers (Wyatt, Thomas, & Terranova, 2002).

However, defining people only as users and (re-)shapers of technology confirms the “technocratic vision of the centrality and normativity of technology” (Wyatt, Thomas, & Terranova, 2002, p. 25). An important and often overlooked topic in technology acceptance research is about those people who do not use a technology or stopped using it after initial adoption (Satchell & Dourish, 2009; Selwyn, 2004). Users need to be evaluated in relation to the more invisible group, the non-users. Moreover, the reasons for non-use may affect the creation of new (applications for) technologies, and could, in that way, also be considered as shapers of future technologies (Satchell & Dourish, 2009; Wyatt, 2007).

A large body of academic research over the past decades points towards the expansion of the digital divide between users and non-users of technology (van Dijk, 2006). Most studies on non-use so far report high rates of people not using the technological devices under study (Wessels et al., 2003). However, comparing these results is challenging because they all use different definitions, various measures, unequal devices and have tested these within diverse populations (Selwyn, 2004). Therefore, a solid theoretical framework of non-use of technological devices remains absent (Wessels et al., 2003), and consequently, the academic understanding of non-use of technology remains weak.

The Karotz Home Study aimed at providing more insight in the reasons why people stop using a social robot in domestic environments. In the interviews as well as in the questionnaires the participants were asked to provide reasons why they stopped using the robot. Non-use can be divided into resisters, rejecters, excluded and expelled (Wyatt, Thomas, & Terranova, 2002). Resisters are those people who never really used a technology simply because they did not want to. In this dissertation, this group will be referred to as non-adopters. Rejecters are those people who voluntarily stopped using a technology for several reasons. Rogers (2003) further splits this group into rejecters and discontinuers. Rejection is the active rejection of a technology, and discontinuance is the decision to stop using a technology after having previously adopted it (Rogers, 2003). This dissertation will implement this distinction between rejecters and discontinuers. The excluded are those people that never used a technology because they cannot get access for a variety of reasons and they do not have the choice to adopt or not. And finally, the expelled are those people who have had access at some point but have lost it involuntarily for whatever reason. These last two groups of non-users, however, are beyond the scope of the Karotz Home Study and could be further investigated when robotic technology has become more widespread in society. Additionally, some researchers denote that there may be demographic differences between users and non-users of technologies (e.g., Rogers, 2003; Wyatt, Thomas, & Terranova, 2002). This section is divided by the different groups of non-use (i.e., non-adoption, rejection and discontinuance) and provides the demographic profiles of these groups as well as their motivations and the influential acceptance variables for non-use.

NON-ADOPTION

Non-adoption is the passive rejection of a technology, whereat the user never really considered the use of the technology just because they do not want to (Rogers, 2003; Wyatt, Thomas, & Terranova, 2002). In total, 16 persons initially signed up for the Karotz Home Study, but later withdraw from the study. Among these people were 8 males and 8 females, their age ranged from 22 to 80 (M= 45.9, SD= 18.4). Table 7.2 provides the demographics of these non-adopters along with the main reasons for non-use. Most of them (n= 6) did not respond to my follow-up messages for participation, and two others did not provide a reason why they did not want to participate anymore. Among those who did provide a reason, the most given one for non-adoption was the fact that the robot could not speak Dutch (n= 6). It was either the participant or one of their children that could not speak English or German, which resulted in their decision to quit. Another reason for non-adoption was privacy concerns (n=2). These persons explicitly asked several questions about the embedded camera and which user data would be collected by the robot or the researchers. They expressed their concern about the violation of their privacy. One person could not participate in the study, because he was worried that the robot would exceed the data limit of his internet connection. And the last person dropped out because she said that she was too busy.

Table 7.2: Demographics of non-adopters and their main reason for non-use

Gender	Age	Household type	Reason for non-use
Male	?	Young family	No reaction
Female	22	Single	No reaction
Male	?	Mature family	No reaction
Male	23	Single	No reaction
Female	40	Young family	No reaction
Female	22	Single	No reaction
Male	52	Couple	Not given
Male	56	Mature family	Not given
Female	39	Young family	Language
Female	34	Young family	Language
Female	70	Single	Language
Male	80	Couple	Language
Female	38	Young family	Privacy
Male	55	Mature family	Privacy
Male	43	Single	Limited data for internet
Female	68	Couple	Too busy

REJECTION

Rejection is the active rejection of the robot, whereat the user has considered the adoption of the technology, including one or more trial interactions, but then decided not to adopt it (Rogers, 2003; Wyatt, Thomas, & Terranova, 2002). In total, 23 participants stopped using the robot before or in the adoption phase and are categorized as rejecters. Among these rejecters were 12 males and 11 females, and their age ranged from 12 to 77 (*M*= 34.7, *SD*= 15.8) Five of these rejecters lived alone, seven of them lived with a spouse, three were part of a young family, and seven rejecters lived in a mature family. One rejecter did not provide its household type. The educational level of two rejecters was low, six rejecters had middle education, and fourteen rejecters had higher education. One participant did not provide its educational level. Twelve rejecters had an income equal to or less than one times the modal income. Two rejecters had an income between one and two times the modal income, and the modal income of eight rejecters was above two times the modal income. One rejecter did not provide its income. Twelve rejecters owned a pet and 9 rejecters did not. Two rejecters did not indicate whether or not they owned a pet.

REASONS FOR REJECTION

When the participants indicated during the interviews that they had stopped using the robot in the last period and did not intend to restart using the robot in the upcoming period, a semi-structured exit interview was conducted. Questions were asked about what the main reasons were for not wanting to use the robot anymore, and in-depth follow-up questions were asked to unravel the concrete reasons for non-use. Those participants that only took part in the study through the questionnaires were asked each time to indicate whether or not they stopped using the robot and if so, to provide a description of their reasons why. Based on these two sources of information, reasons for non-use were coded. The reasons for non-use for rejecters are presented in table 7.3. The following sections will further describe these reasons.

Table 7.3: Reasons for rejection

Reasons for non-use	**Rejection reasons** % of all reported reasons (*n*= 51)
Disenchantment	37.3
End of novelty	2.0
Lack of motivation	9.8
Need not satisfied	9.8
Reliance on others	2.0
Replaced by other device	9.8
Restrictions and problems	29.4
Total	100.0

Replaced by other device. The most noted reasons for rejection was that the participants had replaced (functionalities of) the robot by other devices. Replacement occurs when something else, such as another technology, offers a better solution or provides more satisfaction in performing the same task or fulfilling the same need. Most participants who had a smart phone indicated that the robot offered similar functionalities, but that their smart phone was easier to use and more often within reach.

> "I did not turn [the robot] on during the last period, because I do not see the added value… compared to my smartphone." - male, 38, living with young family
>
> "He [the robot] cannot do much and what he can do my smartphone does as well, and more." - female, 29, living with spouse

Restriction and problems. The second most noted reason for rejection were occurring restrictions and problems for the use of the robot. There are many restrictions and problems people might encounter before adopting a technology. One such restriction the participants registered was a lack of time and another that the technology was too difficult to master how to use the device. A few participants indicated that they encountered a language barrier, even though they indicated before the study that they had a limited working proficiency in either English or German.

> "Too difficult in English." - female, unknown age, living with mature family
> "I have not have the time yet." - female, 37, living alone
> "Too difficult to make it [the robot] understand what to do." - female, 21, living with mature family

Lack of motivation. On the third place, although much less noted than the other two reasons, came lack of motivation, disenchantment and replaced by other device as reasons for rejection. Regarding lack of motivation, some participants were just part of the households of which other family member had signed up for the study. And a few of these participants were just not interested in what the robot had to offer.

> "He [the robot] is standing in de living room, but I am not doing anything with it myself." - female, 21, living with mature family
> "I do not know what to do with it." - male, 15, living with mature family

Disenchantment. It might be that people just dislike some aspect of the technology, including not liking to use the technology, or not liking the service or supplier. Most participants who rejected the robot for dissatisfaction reasons indicated that the robot was not fun to use or interact with. One participant specified that she did not appreciate the autonomous, unaccountable actions of the robot.

> "[The robot] is annoying." - male, 29, living with spouse
> "Often acts weird. Awake when I do not want it." - female, 25, living with spouse

Need not satisfied. Some of the participants felt that the robot could not satisfy a certain need. Not having a need satisfied by a technology is somewhat related to having a lack of motivation, but involves a more empathic evaluation of non-use. The participants had based their decision of non-use on some type of assessment that the technology is irrelevant, not good enough, or that there were better alternatives. Sometimes these participants made this decision without a thorough exploration of the robot's potentials.

> "I think it is a combination of software and hardware. If it was just the software, then my potential killer app could become available in the future… But the hardware is also mediocre, so he [the robot] does not provide any benefits." male, 38, living with young family

End of novelty. On the last place, and only a few times noted, were the reasons of end of novelty and reliance on others. The end of novelty effect occurs when the newness of a technology is gone, and for some people this is where technology use ends because there is nothing left to explore. For one participant, this already happed before he had actually adopted the robot.

> "The novelty is gone." - male, 65, living with spouse

Reliance on others. A very few participants indicated that using the robot was just too difficult for them and that they often must depend on others to use it. These participants thought that this was not really convenient and stopped using the robot for that reason.

> "I have not installed everything yet. I cannot do it myself and am waiting for my daughter to have time for it." - female, 70, living alone

INFLUENTIAL FACTORS FOR REJECTION

Based on the questionnaire data, several binary logistic regression analyses were performed to determine which factors explained non-use in each acceptance phase. Unlike linear regressions, which is used to classify or predict values on a continuous variable, logistic regression attempts to classify or predict a discrete, categorical variable from among continuance and/or discrete predictors. The goal of logistic regression is to predict the likelihood of falling into one of the outcome categories based on a set of predictors. The interest here is to explain why people stopped using the robot, which is an answer to the dichotomous question whether or not they were still using the robot, based on the defined acceptance variables, which are all continuous variables. The forward selection method (likelihood ratio) was chosen to determine the best predictors (Garson, 2011). All variables are entered into the regression at the beginning, which are then scanned and only the best predictors are selected for the model (Agrestic & Finlay, 2009).

A first analysis is done for rejection in the confrontation phase (e.g., within two weeks after the introduction). Table 7.4 displays the results of the analysis that provides insight into the acceptance variables for the probability that a participant rejected the use of the robot. The results of the residual Chi-square statistic (χ^2= 19.86, p > .001) suggests that the addition of one or more of the acceptance variables significantly affect the predictive power of the model (Field, 2014). Two steps were needed to realize the final model. The addition of the variables resulted in an improved prediction of rejection, as the -2 Log Likelihood decreased in value (from 82.76 to 74.42) with each step. The Cox and Snell R-square (.18) and the Nagelkerke R-square (.30) both provide an indication of the proportion of variance explained by the regression model. These values can vary from 0 to 1, with higher values indicating a better proportion of the variance explained by the regression model (Agrestic & Finlay, 2009). The Hosmer and Lemeshow test showed an insignificant result ($\chi^2(8)$= 13.54, p= .094), from which can be concluded that the model adequately fits the data and the interpretation of the results can be continued. Table 7.4 shows a negative effect for enjoyment (b= -1.44, p > .001). When the participants evaluate the robot as less enjoyable, they are more likely to reject the use of the robot. In contrast, there is a positive effect for intelligence (b= 1.13, p= .007). When the participants evaluated the robot as more intelligent, they were more likely to reject the use of the robot.

Table 7.4: Influential variables for rejection in the confrontation phase

Variables	***β***	**SE**	***p***	**Odds Ratio**	**CI for Odds Ratio**
Enjoyment	-1.43	0.38	.000	0.24	0.11 - 0.50
Intelligence	1.13	0.42	.007	3.11	1.35 - 7.13

Another binary logistic regression analysis was performed for rejection in the adoption phase (e.g., between two weeks and one month after the introduction). The results are shown in table 7.5. The results of the residual Chi-square statistic (χ^2= 31.89, p < .001) suggest that the addition of one acceptance variable significantly affects the predictive power of the model (Field, 2014). One step was needed to realize the final model. The Cox and Snell R-square (.28) and the Nagelkerke R-square (.48) both provided an indication of the proportion of variance explained by the regression model. These values can vary from 0 to 1, with higher values indicating a better proportion of the variance explained by the regression model (Agrestic & Finlay, 2009). The Hosmer and Lemeshow test shows an insignificant result ($\chi^2(7)$= 3.66, p= .819), from which can be concluded that the model adequately fits the data and the interpretation of the results can be continued. Table 7.5 shows a negative effect for usefulness (b= -2.33, p < .001). When the participants evaluated the robot as less useful, they were more likely to reject the use of the robot.

Table 7.5: Influential variables for rejection in the adoption phase

Variables	β	SE	p	Odds ratio	CI for odds ratio
Usefulness	-2.33	0.56	.000	0.10	0.03 - 0.29

DISCONTINUANCE

Discontinuance is a decision to stop using a technology after having previously adopted it (Rogers, 2003). In total, 32 participants stopped using the robot in the adaptation phase or the integration phase and are therefore categorized as discontinuers. Among these discontinuers were 16 males and 16 females, and their age ranged from 20 to 71 (M= 34.2, SD= 13.0). Eleven of these discontinuers lived alone, six of them lived with a spouse, none were part of a young family, and none of the discontinuers lived in a mature family. Six discontinuers did not provide their household type. The educational level of four discontinuers was low, 10 discontinuers had middle education, and eighteen discontinuers had higher education. The income of 24 discontinuers was equal to or less than one time the modal income. Four discontinuers had an income between one and two times the modal income, and the modal income of four discontinuers was above two times the modal income. Sixteen discontinuers owned a pet and sixteen discontinuers did not.

REASONS FOR DISCONTINUANCE

Based on the information from the interviews and questionnaires also reasons for non-use were coded for discontinuers. These reasons are presented in table 7.6. The following sections will further describe these reasons.

Table 7.6: Reasons for discontinuance

Reasons for non-use	Discontinuance reasons % of all reported reasons (*n*= 51)
Disenchantment	11.3
End of novelty	11.3
Lack of motivation	4.8
Need not satisfied	27.4
Reliance on others	1.6
Replaced by other device	27.4
Restrictions and problems	16.1
Total	100.0

Replaced by other device. By far, the two most noted reasons for discontinuance were need not satisfied and replaced by other device. Sometimes, people stop using a technology because something else, such as another technology, offers a better solution or provide more satisfaction in performing the same task or fulfilling the same need. For discontinuers in this study, the robot offered many functionalities that other devices in their homes, such as the television, radio of smart phone, also had to offer, and that they preferred using these devices instead off the robot.

> "If I want to listen to the radio I can easily turn on internet radio or just the regular radio in the living room." - female, 22, living in student dorm
>
> "If I want to hear the news I can also look it up on teletext." - female, 57, living alone
>
> "If I had just a desktop PC than I may have used it [the robot] more often. But my laptop is always on when I am at home." - female, 33, living alone
>
> "It the beginning it seems useful for medication reminders, but I have that on my cellphone and that one I always carry with me. So I find that more useful." - female, 26, living with young family

Need not satisfied. The category of need not satisfied is related to lack of motivation, but involved a more empathic evaluation of non-adoption. Based on some type of assessment that the technology is irrelevant, not good enough, or that there were better alternatives. Sometimes people make these decisions without even trying the technology, or that a trial or investigation had shown that it was not right for them.

> "I cannot do anything with [the robot]… I had expected to be able to do more things with it." - female, 57, living alone
> "I have him [the robot] switched off more often, because it has no benefits for me." - male, 30, living with spouse
> "We heard what we had programmed… we did not use [the robot] actively… It was standing in the way and has no added value." - female, 26, living with young family
> "I was a bit disappointed. Like I said the last time, I cannot do anything with it [the robot]. Just what he [the robot] is saying on its own, and I know what he is going to say because he has said that before." - female, 59, living alone

Restriction and problems. Second, although much less noted, was the reason of restriction and problems. There are many restrictions and problems people might encounter before adopting a technology. Some of the discontinuers in this study had problems with understanding the robot because of the speech function of the robot was not always optimal according to them. The robot of some participants sometimes failed to connect to their wireless internet connection, and for a few of these participants, this was the reason why they stopped using the robot.

> "If you request the news and you cannot understand what he [the robot] says. Then you just look at an online news page." - female, 33, living alone
> "Better understanding speech function [would be an improvement]. In that way you could actually understand the news and other stuff which would make it [the robot] interesting again." - male, 30, living with spouse
> "She [the robot] cannot find the internet connection despite several attempts." - female, 77, living alone

End of novelty. A shared third place was for the discontinuance reasons of disenchantment and end of novelty. When some participants were done exploring the applications of the robot and could not find a useful purpose, they stopped using the robot for that reason. When the newness is gone, there is nothing left to explore.

> "The novelty is gone. You just use it a lot less." - female, 57, living alone
> "It does not intrigue me as much as it did. […] I liked it in the beginning to discover new stuff." - female, 24, living with mature family
> "No more new stuff to discover." - female, 22, unknown living situation

Disenchantment. Some participants disliked aspects of the robot or did not enjoy the use of it. For one participants, this was because she became ill and could not handle all the talking from the robot any longer. However, she said that she and her family had explored all the application options of the robot, and they could not find a purpose for it any more.

> "I became ill and then I did not find it funny anymore what he [the robot] said… So I removed the plug." - female, 38, living with mature family
> "The ongoing noises are disturbing." - male, 43, living with young family

Lack of motivation. Fourth, the participants who discontinued the use of the robot explained that a lack of motivation was the reason to stop using the robot. In these instances, people either had not heard about the particular technology, avoided finding out about them in general, or had no interest in following up and adopting a known technology.

> "I was planning to take him [the robot] upstairs, but then I was thinking that I would have to take him upstairs each night. And he would probably just say it once that I must get out of bed. And then I thought that I would not do all that." - female, 59, living alone
> "I wanted to try the agenda, but then I thought that it might tell me something when I am not in the room. So I did not have the energy for it, so I did not continue to use it." - female, 38, living with mature family
> "Not interesting." - female, 30, living alone
> "I think he [the robot] is utterly boring." - male, 32, living alone

Reliance on others. Last, and only noted by a few participants, was the reason of reliance on others. Some people benefit from a technology indirectly, even though they did not or would not adopt, because they could pass responsibility for using the technology on to others.

> "[My son] had stopped sending me messages [via the robot] because I did not always react on it. At that moment I was not in the living room… and there is no repeat function so I did not know that I had missed something." - female, 38, living with mature family

INFLUENTIAL FACTORS FOR DISCONTINUERS

Another binary logistic regression analysis was performed for discontinuance in the adaptation phase (e.g., between one and two months after the introduction). Unfortunately, the Hosmer and Lemeshow test shows a significant result ($\chi^2(7)$= 52.50, p < .001), from which can be concluded that the model does not fit the data and the interpretation of the results cannot be continued. In other words, the acceptance variables could not explain why participants discontinued the use of the robot in the integration phase.

A fourth and last binary logistic regression analysis was performed for discontinuance in the identification phase (e.g., between two and six months after the introduction). The results are shown in table 7.6. The results of the residual Chi-square statistic (χ^2= 19.86, p > .001) suggests that the addition of one or more of the acceptance variables significantly affect the predictive power of the model (Field, 2014). Two steps were needed to realize the final model. The addition of the variables resulted in an improved prediction of discontinuance, as the -2 Log Likelihood decreased in value (from 33.24 to 25.77) with each step. The Cox and Snell R-square (.31) and the Nagelkerke R-square (.54) both provide an indication of the proportion of variance explained by the regression model. These values can vary from 0 to 1, with higher values indicating a better proportion of the variance explained by the regression model (Agrestic & Finlay, 2009). The Hosmer and Lemeshow test shows an insignificant result ($\chi^2(7)$= 9.84, p= .198), from which can be concluded that the model adequately fits the data and the interpretation of the results can be continued. Table 7.7 shows that there is a negative effect for adaptability (b= -0.76, p= .049). When the participants evaluate the robot as less adaptable to their needs, they are more likely to discontinue the use of the robot. There is also a negative effect for sociability (b= -1.19, p= .041). As the participants evaluate the robot as less sociable, they are more likely to discontinue its use in the integration phase.

Table 7.7: Influential variables for discontinuance in the integration phase

Variables	β	SE	p	Odds ratio	CI for odds ratio
Adaptability	-0.76	0.39	.049	0.47	0.22 - 0.99
Sociability	-1.19	0.58	.041	0.30	0.10 - 0.95

COMPARING THE GROUPS OF NON-USERS

Some researchers denote that the demographic profiles of users and non-users of technologies differ from one another (e.g., Rogers, 2003; Selwyn, 2006; Wyatt, Thomas, & Terranova, 2002). Non-users are most likely older of age, live in households without children, have less years formal education, and are part of lower socioeconomic groups (Rogers, 2003;Selwyn, 2006). Therefore, separate Chi-square analyses were ran for gender, household type, educational level, income and pet ownership, and a one-way ANOVA was performed to investigate the demographic differences between the user groups of rejecters, discontinuers and users. As the non-adopters did not provide information about their educational level or their income, these two test could only be performed among the rejecters, discontinuers and users.

There was no significant gender effect for user group ($\chi^2(2)= 0.736$, $p= .692$). Males and females were equally distributed over the different user groups (see table 7.8). Thus, gender did not have an effect on the use duration of the robot.

Table 7.8: User group vs. gender

		User group			
Gender		Non-adopters	Rejecters	Discontinuers	Users
Males	Count	8	12	16	20
	Expected	7.6	10.6	15.2	22.3
	Std. residual	0.1	0.3	0.2	-0.5
Female	Count	8	11	16	27
	Expected	8.4	12.1	16.8	24.7
	Std. residual	-0.1	-0.3	-0.2	0.5
Total		**16**	**23**	**32**	**47**

A one-way ANOVA indicated that there was no significant effect for age between the four user groups ($F(3,112)= 2.502$, $p= .062$). Age was equally distributed among the user groups. The mean age and standard deviations of the user groups are presented in table 7.9.

Table 7.9: User group vs. age

	User group			
Age	Non-adopters	Rejecters	Discontinuers	Users
Mean	45.9	34.7	34.2	41.6
SD	18.4	15.8	13.0	19.0

There was no significant effect of household type for user group ($\chi^2(9)$= 12.318, p= .196). The different household types were equally distributed over the different user groups (see table 7.10). Thus, household type did not have an effect on the use duration of the robot.

Table 7.10: User group vs. household type

Household type		User group			
		Non-adopters	Rejecters	Discontinuers	Users
Singles	Count	5	5	11	12
	Expected	4.9	6.7	7.9	13.4
	Std. residual	0.1	-0.7	1.1	-0.4
Couples	Count	3	7	6	13
	Expected	4.3	5.7	7.0	11.8
	Std. residual	-0.6	0.4	-0.4	0.2
Young families	Count	5	3	9	11
	Expected	4.1	5.7	6.7	11.4
	Std. residual	0.4	-1.1	0.9	-0.1
Mature families	Count	3	7	0	8
	Expected	2.7	3.7	4.3	7.3
	Std. residual	0.2	1.7	-2.1	0.2
Total		**16**	**22**	**26**	**44**

There was no significant effect for educational level for user group ($\chi^2(4)$= 5.713, p= .222). Participants with low, middle and higher education were equally distributed over the different user groups (see table 7.11). Thus, educational level did not have an effect on the duration of use of the robot.

Table 7.11: User group vs. educational level

Educational level		User group		
		Rejecters	Discontinuers	Users
Low	Count	2	4	11
	Expected	3.9	5.7	7.4
	Std. residual	-1.0	-0.7	1.3
Middle	Count	6	10	15
	Expected	7.1	10.3	13.6
	Std. residual	-0.4	-0.1	-0.4
High	Count	14	18	16
	Expected	11.0	16.0	21.0
	Std. residual	0.9	0.5	-1.1
Total		**22**	**32**	**42**

There was no significant effect for income for user group ($\chi^2(10)$= 12.628, p= .245). Income was equally distributed among the user groups (see table 7.12). Thus, educational level did not have an effect on the duration of use of the robot.

Table 7.12: User group vs. income

		User Group		
Income		Rejecters	Discontinuers	Users
Less than 1x modal	Count	8	16	17
	Expected	9.3	13.5	18.2
	Std. Residual	-0.4	0.7	-0.3
Between 1x and 2x modal	Count	6	12	17
	Expected	7.9	11.5	15.5
	Std. Residual	-0.7	0.1	0.4
More than 2x modal	Count	8	4	9
	Expected	4.8	6.9	9.3
	Std. Residual	1.5	-1.1	-0.1
Total		**22**	**32**	**43**

There was no significant effect of pet ownership for user group ($\chi^2(3)$= 0.593, p= .898). Pet owners and participants without a pet were equally distributed over the different user groups (see table 7.13). Thus, pet ownership did not have an effect on the duration of use of the robot.

Table 7.13: User group vs. pet ownerships

		User group			
Pet Ownership		Non-adopters	Rejecters	Discontinuers	Users
No	Count	8	12	16	21
	Expected	7.3	10.9	16.6	22.3
	Std. residual	0.3	0.3	-0.1	-0.3
Yes	Count	6	9	16	22
	Expected	6.7	10.1	15.4	20.7
	Std. residual	-0.3	-0.4	0.1	0.3
Total		**14**	**21**	**32**	**43**

Disenchantment, as a result of the inability of the technology to meet the adopters anticipated expectation outcomes, is more common among late adopters than among early adopters. Early adopters have a more rational decision making process, a greater previous experience with technology and an enhanced behavioral control over the technology (Rogers, 2003). This leads to a more realistic view on the expectation outcomes and enables them to utilize the technology more extensively. Based on this, combined with field evidence, Parthasarthy and Bhattacherjee (1998) conclude that early adopters are less likely to discontinue technology use than late adopters. Therefore, the differences in personal innovativeness among the user groups was investigated with a one-way ANOVA. It is assumed here that more innovative people are more likely to be early adopters than less innovative people.

The results have indicated that there was no significant effect for personal innovativeness between the four user groups ($F(2,99) = 5.795$, $p = .066$). Personal innovativeness was equally distributed among the user groups. The mean score for personal innovativeness and standard deviations of the user groups are presented in table 7.14.

Table 7.14: User group vs. personal innovativeness

	User group		
Personal innovativeness	Rejecters	Discontinuers	Users
Mean	4.34	5.27	5.00
SD	1.16	1.33	1.65

A REFLECTION ON THE RESULTS ON NON-USE

Providing understanding of who are non-users along with their motivations for non-use could provide important insights for policy makers and suppliers of social robots. In the Karotz Home Study, there were no demographic or personality differences between the user groups as was expected from earlier findings. One very reasonable explanation for these results are the fact that the people who responded to the call for participation of this study were already interested in using a robot in their own homes.

However, the user groups each provided different reasons for non-use, and different acceptance variables explained their non-use. The most common reason for non-adoption was the unavailability of the Dutch language on the robot. This result is similar to the findings of Selwyn (2006) who has reported that non-adopters of computer technologies are more likely to experience some type of barrier (e.g., time, age, health) or a lack of knowledge, even though they at least had had some degree of access at some point. Although this language problem can easily be fixed, one can imagine that, when more sophisticated robotic systems will enter the user's home, the lack of other interaction skills may become a barrier of use. Similar findings emerge for digital media and the need for certain digital skills necessary to make optimal use of these digital media (van Deursen & van Dijk, 2011). For example, ever since the blooming of the internet, users have continuously expressed disappointment and worries concerning information retrieval, navigating the web, and keeping their personal information secure (Wyatt, Thomas, & Terranova, 2002). The question remains whether particular skills may exist or are even needed for an optimal use of robotic technologies in the future.

For rejecters, disenchantment was the main reason for non-use. They just did not like (the use of) the robot. This result was also supported by the binary logistic regression analyses which indicated that lower perceptions of enjoyment and a higher evaluation of the robot's intelligence were the main reasons why the participants rejected the use of the robot in the confrontation phase. Besides not liking (the use of) the robot, insights from the interviews highlight that some participants did not appreciate the autonomous actions of the robot and only wanted the robot to act when it was instructed to by a user. This perception on the robot was why some participants had deinstalled all the autonomous settings on the robot. Rejecters in the adoption phase stopped using the robot when they evaluated it as less useful. This result is reflected by the reason given by participants from the interviews, that they felt that the robot could not fulfill their needs or expectations (i.e., disenchantment).

Discontinuers indicated that the main reason for non-use was that they replaced (functionalities of) the robot by another device. These other technological devices not only fulfilled similar goals, but did this in a more satisfying way. Unfortunately, the acceptance variables could not explain why discontinuers stopped using the robot in the adaptation phase. However, the results indicated that discontinuers stopped using the robot in the integration phase when they evaluated it as less adaptable to their needs and less sociable. This result is reflected by the reason given by the participants from the interviews, who explained that they had replaced the robot by other devices because those other devices offered similar, yet better, functionalities.

8

ACCEPTANCE VARIABLES DURING LONG-TERM USE

"It is the framework which changes with each new technology and not just the picture within the frame."
– Marshall McLuhan –

The previous chapter provided the insights of the users' experiences of both users and non-users from the Karotz Home Study. This chapter will address the results on the acceptance variables of social robot acceptance of that study. Section 8.1 will provide descriptions of the acceptance variables based on the user stories gained from the interviews together with the quantitative evaluations of these acceptance variables and how they changed over time. Section 8.2 will present the influence of the acceptance variables on social robot acceptance and how the influences of these acceptance variables fluctuate from phase to phase. The quantitative results of this study have been published before in:

Graaf, M.M.A. de, Ben Allouch, S., & Dijk, J.A.G.M. van (2014). Long-term evaluation of a social robot in real homes. *Paper presented at the AISB Workshop on New Frontiers in Human-Robot Interaction, London, UK*.

8.1 DESCRIBING AND EVALUATING ACCEPTANCE VARIABLES

When people use technologies over time, it might be that their opinions of that technology changes as they get familiar with it (Kim et al., 2013). Participants evaluations of the robot and their user experiences with it were assessed using a recurring questionnaire based on the social robot acceptance variables as addressed in chapter 4. The interview data was used to enrich our understanding of the acceptance variables. Therefore, from the interviews (n= 97, Cohen's kappa= .73) 'striking' or 'typical' quotes (Hansen et al., 1998) were selected which illustrated what each of the acceptance variables means for the user. Table 8.1 on the next two pages provides an overview of all the acceptance variables as discussed during the interviews from phase to phase.

For the analysis of the quantitative data, factorial repeated measures analysis of variance was used with time (6 acceptance phases) as a within subjects factor and gender (male vs. female), household type (single vs. couple vs. young family vs. mature family), pet ownership (pets vs. no pets) and user group (rejecters vs. discontinuers vs. users) as the between subjects factor.

Factorial repeated measures analysis of variance with more than three time points carries some concerns about the sphericity assumption, which is the assumption of equal variances across groups in between subjects analysis of variance. For most analyses, Mauchly's chi-square test for violations of the sphericity assumption was significant, which indicates non-equal variances. To increase statistical power, the *F*-scores from the Greenhouse-Geisser test are reported for all factorial repeated measures analysis of variance tests. Moreover, some participants dropped out before the end of the study and therefore did not complete all the questionnaires. Missing values because of this drop-out were replaced with the mean score of that acceptance phase for this analysis.

Table 8.1:Acceptance variables (n= 2682) as coded in the interviews for all the acceptance phases

Acceptance variable	**Expectation phase** % of all reported variables (n= 288)	**Confrontation phase** % of all reported variables (n= 365)	**Adoption phase** % of all reported variables (n= 574)
Utilitarian attitudes	*12*	*36*	*26*
- Usefulness	6	19	9
- Ease of use	0	9	4
- Adaptability	3	3	4
- Diversity of use	2	2	3
- Intelligence	1	1	0
- Reliability	0	2	6
Hedonic attitudes	*22*	*40*	*45*
- Enjoyment	0	8	13
- Attractiveness	4	8	5
- Social presence	8	11	7
- Animacy	0	2	3
- Sociability	3	3	9
- Companionship	7	8	8
Social norms	*19*	*1*	*9*
- Social influence	0	0	9
- Media influence	19	0	0
- Status	0	1	0
Personal norms	*1*	*1*	*5*
- Privacy	1	1	2
- Trust	0	0	3
Control beliefs	*46*	*23*	*14*
- Self-efficacy	0	1	3
- Previous experience	27	2	0
- Prior expectations	11	7	3
- Personal innovativeness	3	2	1
- Cost	5	1	1
- Situational factors	0	10	6
Total	100	100	100

Adaptation phase % of all reported variables (*n*= 703)	**Integration phase** % of all reported variables (*n*= 512)	**Identification phase** % of all reported variables (*n*= 294)	**All phases combined** % of all reported variables (*n*= 2682)
34	*38*	*27*	*30*
11	15	14	12
4	4	2	4
8	7	3	5
4	5	5	4
1	1	1	1
6	6	2	4
42	*42*	*41*	*42*
10	12	13	10
2	3	5	4
11	9	8	10
2	0	3	2
9	11	4	8
8	7	8	8
7	*6*	*11*	*6*
5	5	7	5
0	0	0	0
2	1	4	1
2	*6*	*5*	*3*
1	5	5	2
1	1	0	1
15	*8*	*16*	*18*
2	1	0	2
0	0	0	3
2	2	2	4
1	1	2	1
1	0	2	1
9	4	9	7
100	100	100	100

Table 8.2: Evaluations of social robot acceptance variables in the different acceptance phases

	Acceptance phase														
	Expectation		Confrontation		Adoption		Adaptation		Integration		Identification				
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(5,96)$	p	part. η^2
Attitudinal beliefs															
Usefulness	4.35	1.19	3.64	1.09	3.06	1.35	2.64	1.24	2.89	1.39	3.55	1.00	36.007	.000	.265
Ease of use	5.08	1.03	4.73	0.83	4.58	1.03	4.59	1.07	4.77	1.07	4.61	1.08	4.522	.001	.043
Adaptability	4.33	1.17	3.72	0.76	3.19	1.01	2.85	1.08	3.00	1.24	4.03	1.32	35.572	.000	.262
Intelligence	4.24	1.15	3.93	0.82	3.53	1.01	3.59	0.88	3.82	0.99	3.63	1.19	9.555	.000	.087
Enjoyment	4.89	1.01	3.93	0.95	3.82	1.20	3.21	1.10	3.50	0.84	3.87	1.29	36.564	.000	.268
Attractiveness	5.05	0.88	4.84	0.83	4.41	1.08	4.22	0.84	4.73	0.80	3.74	1.11	33.731	.000	.252
Social presence	4.73	1.21	2.56	0.68	2.49	0.82	2.16	0.65	2.31	0.90	4.02	1.14	155.756	.000	.609
Animacy	3.32	1.06	3.14	0.78	2.72	0.83	2.59	0.78	2.78	0.95	3.56	1.20	21.111	.000	.174
Sociability	3.07	1.22	2.22	0.56	2.17	0.77	2.00	0.65	1.98	0.89	3.48	1.43	50.696	.000	.336
Companionship	3.13	1.06	2.39	0.67	1.93	0.67	1.93	0.66	2.04	0.89	3.25	1.09	56.709	.000	.362
Normative beliefs															
Social influence	4.97	1.14	5.00	0.71	4.41	1.09	4.32	1.11	4.11	1.15	4.36	1.40	13.115	.000	.116
Media influence	4.08	1.34	3.93	0.77	4.17	1.12	3.99	1.04	4.08	1.17	4.26	1.43	1.186	.316	.012
Status	2.44	1.13	2.26	0.72	1.65	0.56	1.62	0.55	1.90	0.95	3.07	1.19	46.089	.000	.315
Trust	5.67	1.18	4.59	0.73	4.22	0.95	4.26	0.73	4.46	0.86	3.73	1.13	64.266	.000	.391
Attitude towards robots	3.51	1.05	3.97	0.94	3.90	0.86	3.91	0.82	3.88	0.69	3.72	1.10	4.052	.002	.039
Control beliefs															
Self-efficacy	4.40	1.20	3.65	0.87	3.91	1.32	3.64	1.26	3.51	1.38	4.21	1.09	10.582	.000	.096
Anxiety towards robots	3.29	1.25	3.70	0.72	3.23	1.05	3.51	0.67	3.83	0.87	3.65	1.22	6.542	.000	.061
Cost	5.37	0.98	5.66	0.55	5.23	0.93	5.45	0.79	5.41	0.94	4.39	1.29	27.089	.000	.213
Dependent variables															
Use intention	4.31	1.04	3.60	0.94	2.97	1.21	2.64	1.16	2.96	1.30	4.05	1.20	45.386	.000	.312
Actual use					3.71	1.23	2.60	1.01	2.48	1.03	2.54	0.78	50.983	.000	.347
Habit					2.63	1.06	2.37	1.04	2.38	1.07	3.50	1.22	26.902	.000	.219

UTILITARIAN BELIEFS FROM PHASE TO PHASE

As defined in section 4.2, utilitarian beliefs are the users' beliefs that are connected to the practicality and usability of a technology.

USEFULNESS

In the category of utilitarian factors, it was the (lack of) usefulness of the robot that received most attention in the interviews. The purpose of the robot must be clear and should have obvious benefits for users in order for it to be fully put to use. Most people did not perceive the robot as an advantage as they compared the functionality of the robot to that of their smartphones. And their smartphone had more functionalities, was easier to use and always within reach.

> "I think with the abilities [the robot] has now, it would be more practical for that to be an app on your phone which can always take with you. Because I should actually be able to carry it with me." - female, 38, living with mature family
>
> "I don't see any advantages compared to my mobile phone… That I can put in my pocket and does similar things as the robot… If all those functionalities weren't available yet on my mobile phone… then I can imagine that the robot would have been an advantage." - male, 38, living with young family

However, some participants did acknowledge the robot's usefulness and they discussed saving time, creating family moments, and bringing joyful moments. But the robot was also appreciated as something that assists you with your everyday tasks.

> "It is not just for one person, it is fun for everybody. That is what makes it advantageous." - female, 32, living with young family
>
> "I see [the robot] as an advantage to our household so to speak. I like it that he helps us remembering things… And also because he says funny things and mentions the time every hour. That is nice and useful." - female, 24, living with mature family
>
> "[The robot] is a good assistant. Definitely. He can't take care of everything, but parts of it and that relieves someone of an obligation." - male, 55, living alone

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's usefulness ($F(5,96)= 36.007$, $p < .001$, partial $\eta^2= .265$). As table 8.2 on page 278 shows, the participants' evaluation of the robot's usefulness declined until the adaptation phase and seems to increase from that point in time. A Bonferroni post-hoc test indicated that the evaluation of usefulness in the expectation phase differed significantly from all the other evaluations of usefulness (between all pairs $p < .001$). Similar results were found between the score in the confrontation phase and all other phases with exception off the identification phase (between all pairs $p < .010$). The evaluation of usefulness between the adoption phase and the adaptation phase ($p = .010$) as well as between the adoption and the identification phase ($p = .036$) also differed significantly. Furthermore, the evaluations of the robot's usefulness in both the adaptation ($p < .001$) and the integration phase ($p < .001$) differed significantly from those in the identification phase. There was no significant main effect for either gender or pet ownership for usefulness, nor were there any significant interaction effects. However, a main effect was found for household type ($p = .024$). Overall, participants' being part of a mature family evaluated the robot as more useful than all other household types. Another main effect was found for user group ($p = .002$). Overall, users evaluated the robot as more useful that all other user groups.

EASE OF USE

Another topic frequently noted was ease of use and almost all participants thought it was easy to install all the applications and that the robot was very easy to control. Almost all participants agreed that it was very easy to learn how to control the robot, as well as installing different applications and adjusting their settings.

> "Very user friendly… It is just one button here and one button there, so it does not look all too difficult." – female, 32, living with young family
>
> "Easy to understand everything. I mean, if you want to give a command, it is just one button you must push, [the robot] is not difficult to control." – female, 24, living with mature family
>
> "I think I understand how [the robot] works, that is not very difficult." – male, 32, living alone

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's ease of use ($F(5,96) = 4.522$, $p = .001$, partial $\eta^2 = .043$). As table 8.2 on page 278 shows, the participants' evaluations of the robot's ease of use declined after the confrontation phase, seems to increase again in the integration phase but drops again in the identification phase. A Bonferroni post-hoc test indicated that the evaluation of ease of use was significantly different between the evaluation in the expectation phase and all other phases with exception of the integration phase (between all pairs $p < .001$). However, the evaluation of the robot's adaptability seems to be stabilizing over time as the measures did not differ significantly from one another after the confrontation phase. There was no significant main effect for either gender, household type, pet ownership or user group for ease of use, nor were there any significant interaction effects.

ADAPTABILITY

Another utilitarian factor the participants brought up was adaptability. Adaptability is largely connected to the concept of appropriation as discussed in the acceptance phase of adaptation. The participants appreciated the fact that all the applications for the robot could be adjusted to their personal preferences. And these preferences might changes as the use behavior changes as well.

> "When I am in a different situation and the robot needs something, then I can adapt that myself… to personalize it." - female, 22, living in student dorm
>
> "Basically, it come down to making it to my liking. Just like you personalize other objects, such as a cover for your phone.." - female, 24, living with mature family
>
> "In the beginning I had programmed [the robot] differently. But I also used it differently back then, had less apps installed. Now I use it somewhat differently." - male, 32, living alone

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's adaptability ($F(5,96) = 35.572$, $p < .001$, partial $\eta^2 = .262$). As table 8.2 on page 278 shows, the participants' evaluation of the robot's adaptability declined until the adaptation phase and seems to increase from that point in time. A Bonferroni post-hoc test indicated that the evaluation of adaptability was significantly different between the evaluation in the expectation phase and all other phases with exception of the identification phase (between all pairs $p < .001$). Similar results were found between the confrontation phase and all other phases, also with exception off the identification phase (between all pairs $p < .001$). Moreover, the adaptability scores in the adoption phase differed significantly from both the adaptation phase ($p = .031$) and the identification phase ($p <$

.001). Furthermore, the participants' evaluation of adaptability in both the adaptation ($p < .001$) and the integration phase ($p < .001$) differed significantly from those in the identification phase. There was no significant main effect for either gender, household type or pet ownership for adaptability, nor were there any significant interaction effects. However, there was a main effect for user group ($p = .009$). Overall, users evaluated the robot as more adaptive to their needs.

RELIABILITY

The participants also talked much about the fact that the robot did not always work properly. Some participants experienced malfunction much more often than other participants. Nevertheless, most participants agreed that one should be able to fully depend on a technology, to trust that technology in that it will always work without any hesitations.

> "That [the robot] did not work every other day. I thought that was that annoying… He didn't wake up this morning, which he should do at 9 o'clock. So I pulled the plug, stuck it back in and then it worked again." - female, 57, living alone
>
> "I won't say that [the robot] got stuck, but he wouldn't take any command anymore. But that was over the other day." - male, 32, living alone
>
> "Sometimes [the robot] doesn't work, or an app won't work… then I am done with it. Then I think never mind." - female, 26, living with young family

INTELLIGENCE

The intelligence of the robot was only rarely noted by the participants during the interviews and was often related to social competence or social intelligence. Most participants postulated that a robot should be more aware of its social environment and therefore needs to be more intelligent.

> "[The robot] should not only say something back, but what he says needs to be sensible… He needs to be incredibly more intelligent or, even better, needs to understand the algorithms of the human kind." - male, 31, living alone
>
> "That [the robot] can be creative on its own… can combine stuff to create some type of artificial intelligence." - female, 55, living with spouse
>
> "Similar to a program on the computer with just enough knowledge and command of a language to say something back." - female, 19, living in student dorm

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's intelligence (F(5,96)= 9.555, p < .001, partial η^2= .087). As table 8.2 on page 278 shows, the participants' evaluations of the robot's ease of use declined after the confrontation phase, seems to increase again in the adaptation phase but drops again in the identification phase. A Bonferroni post-hoc test indicated that the evaluation of intelligence in the expectation phase differed significantly from the evaluations in all other phases with the exception of the evaluation in the confrontation phase (between all pairs p < .005). The evaluation of intelligence in the confrontation phase differed significantly from the evaluations in the adoption (p= .002) and adaptation phase (p= .020). However, after the confrontation phase the evaluation of intelligence seems to stabilize as all acceptance phases after the confrontation phase did differ significantly from one another. There was no significant main effect for either gender, pet ownership or user group for intelligence, nor were there any significant interaction effects. However, a main effect was found for household type (p= .034). Overall, participants' being part of a mature family evaluated the interaction with the robot as more intelligent than all other household types. Nevertheless, in the expectation phase it were the young families who evaluated the robot as most intelligent.

DIVERSITY OF USE

The participants talked much about diversity of use during the interviews. In general, they expect robots to have a multitude of possibilities and purposes. Most participants agreed that this robot was not diverse enough in its use, however, this also seems to depend on the acceptance phase. In the beginning, most participants were still positive about the diversity of the robot. But after some time, when the participants had discovered all or most of the robots possibilities, they were less satisfied with its diversity.

> "I can't do anything else with [the robot]. It is actually boring. I had expected to be able to do more things with it." - female, 57, living alone
>
> "Versatility, I like that. That is an advantage. You can't do one or two things with it, but much more." - female, 32, living with young family
>
> "I was somewhat disappointed with the amount of apps you could install." - male, 30, living with spouse

HEDONIC BELIEFS FROM PHASE TO PHASE

In contrast to utilitarian beliefs, hedonic beliefs are the users' evaluation of the technologies characteristics that are related to the user experiences while using a product.

ENJOYMENT

In the category of hedonic factors, the most frequently noted topic was enjoyment. Most participants discussed enjoying the use of the robot or their wishes to enjoy its use more. Most people enjoyed the utterances coming from the robot. Sometimes, this created fun family moments in which the robot shortly become the topic of conversation. And most participants stated that especially children enjoyed the robot, either their own children or those from visitors.

> "I like to work with [the robot], to see the programs for example. And I like the manner in which he talks. I think that is funny." – female, 22, living in student dorm
>
> "Those bursary songs, [my son] likes those, because… [the robot] is standing on the table and the ears will go up and down. He really enjoys that and says 'mom the ears, the ears'. That is fun." – female, 32, living with young family
>
> "The grandchildren like [the robot[, especially when he plays music, the relaxation music. The ears will turn around then. Upon arrival, they go there and push the button." – male, 64, living with spouse

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's enjoyment ($F(5,96)= 36.564$, $p < .001$, partial $\eta^2= .268$). As table 8.2 on page 278 shows, the participants' evaluation of enjoyment declined until the adaptation phase and seems to increase from that point in time. A Bonferroni post-hoc test indicated the evaluations of enjoyment in both the pre-adoption and the confrontation phase differ significantly from all other evaluations (between all pairs $p < .001$). Additionally, the evaluations in the adoption phase differed significantly from those in the adaptation phase ($p < .001$) and the evaluations in the adaptation phase differed significantly from those in the identification phase ($p < .001$). There was no significant main effect for either gender or pet ownership for enjoyment, nor were there any significant interaction effects. However, a main effect was found for household type ($p= .024$). Overall, participants' being part of a mature family evaluated the interaction with the robot as more enjoyable than all other household types. Moreover, another main effect was found for user group (p= .012). Overall, user evaluated the robot as more enjoyable than other user groups.

ATTRACTIVENESS

All participants were very much attracted by the looks of the robot. They all thought the robot looked cute and that its appearance was fine just as it is.

> "Very friendly. Which I find very important, that [the robot] has an appealing charisma." - female, 38, living with mature family

Other participants explained that the appearance of a robot has a big impact on whether or not they would use the robot or have it in their home. A robot should not look scary and its appearance should match the style of the user's interior.

> "I like [the robot] as he is. Not too big, not too small… I am pleased with it looking cute and not all too robot-like. Like last week, with the robot convention. They showed all kinds of robots people were working on. There were really scary robots among those which made we thought like 'whhaa'. I wouldn't find that attractive enough to have even if it could perform all kinds of tasks." - female, 32, living with young family
>
> "[The robot] looks quite neat, a little bit neutral, nice ears, that is funny… He could look cute in your home… Maybe if I will ever move and I think that he wouldn't match with my interior / home decoration, I could imagine [to stop using the robot]." - male, 32, living alone

A few participants explained that the appearance of a robot also creates expectations about the robot's sociability, which, in this case, had led to little disappointment when the robot turned out not to offer any real conversations.

> "[The robot] has a friendly appearance… The design creates a feeling of appreciation. And it makes you hope for more… If it was just a box, you would think 'oh a box'. But that cute little face, and the moving ears, that makes you wish that something more will happen." - female, 55, living with spouse

However, not all participants attached that much value to the appearance of the robot. A few participants were more focused on the robot's usability and usefulness, but for others the robot's appearance was just as important as its capacities.

> "The robot] looks cute, yes. It is nicely made. I think everybody will like that… For me [its looks] are less important." – female, 22, living in student dorm
>
> "I think [the robot] looks touching… but it doesn't really matter for its functionality… He could have been round or square-shaped. He might as well be elongated. That is completely up to you." – male, 64, living with spouse

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's attractiveness ($F(5,96)= 7.972$, $p < .001$, partial $\eta^2= .097$). As table 8.2 on page 278 shows, the participants' evaluations of the robot's attractiveness declined since the confrontation phase, seemed to increase again in the integration phase but drops back in the identification phase. A Bonferroni post-hoc test indicated the evaluation of attractiveness in the expectation phase differed significantly from the evaluation in all other phases with the exception of the evaluation in the confrontation phase (for all pairs $p < .05$). The evaluation of attractiveness in the confrontation phase differed significantly from the evaluation in the adoption ($p= .004$), adaptation ($p < .001$) and identification phase ($p < .001$). Moreover, the evaluation of attractiveness in the adoption phase differed significantly from the evaluation in both the integration ($p= .04$) and identification phase ($p < .001$). Additionally, also the evaluations of attractiveness in either the adaptation, integration and identification phase differed significantly from one another (for all pairs $p < .01$). There was no significant main effect for either gender, pet ownership or user group for attractiveness, nor were there any significant interaction effects. However, a main effect was found for household type ($p= 0.24$). Overall, participants' being part of a mature family evaluated the interaction with the robot as more attractive than all other household types.

ANIMACY

The topic of animacy or liveliness had a lot of overlap with the participants' experiences of social presence. Therefore, all relevant quotes from the interviews will be discussed under social presence.

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's animacy ($F(5,96)= 21.111$, $p < .001$, partial $\eta^2= .174$). As table 8.2 on page 278 shows, the participants' evaluation of the robot's animacy declined until the adaptation phase and seems to increase from that point in time. A Bonferroni post-hoc test indicated that the evaluation of animacy in the expectation phase differed significantly from the evaluation in the adoption, adaptation and integration phase (between all pairs $p < .001$). The evaluation of animacy in the confrontation phase differed significantly with the evaluations in all other phases (between all pairs $p < .05$). However, the evaluation in either the adoption, adaptation and integration phase differed only with the evaluation in the identification phase (between all pairs $p < .001$). There was no significant main effect for either gender, pet ownership or user group for animacy, nor were there any significant interaction effects. However, a main effect was found for household type ($p= 0.3$). Overall, participants being part of a mature family evaluated the robot as more realistic than all other household types.

SOCIAL PRESENCE

The participants felt a type of social presence when interacting with the robot or discussed the robot as if it had lifelike features. The participants discussed the robot as having a personality and having intentions or thoughts. Basically the robot's autonomous behavior, and especially the robot's moving ears and its utterances, were noted along with feelings of social presence.

> "I noticed that [the robot] has become somewhat moody. He sometimes says something, he grumbles a little bit… But that's okay… I like his presence." - female, 24, living with mature family
>
> "[The robot has something social. You think it looks cute, you are human after all. You know it is nonsense, that it is just a radio, an object, a technical object, programmed and all. And still, it works. It has something appealing that makes you turn it on… If it were just an ugly machine, you are less likely to do that." - female, 55, living with spouse

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's social presence ($F(5,96)= 155.697$, $p < .001$, partial $\eta^2= .609$). As table 8.2 on page 278 shows, the participants' evaluation of the robot's social presence declined until the adaptation phase and seems to increase from that point in time. A Bonferroni post-hoc test indicated that the evaluation of social presence in the expectation phase differed significantly from all the other evaluations of social presence (between all pairs $p < .001$). The evaluation of social presence in the confrontation phase differed significantly from the evaluation in the adaptation ($p = .003$) and the identification phase ($p < .001$). The evaluation of social presence in both the adaptation ($p < .001$) and integration phase ($p < .001$) differed significantly from those in the identification phase. There was no significant main effect for either gender, household type, pet ownership or user group for social presence, nor were there any significant interaction effects.

SOCIABILITY

Another frequently noted hedonic topic was sociability. Most comments on the robots sociability were about its shortcomings of natural humanlike interaction. Especially the must first press a button before you could speak to the robot felt very unnatural and uneasy. Most participants would have like it when one could just call the robot by its name to get its attention followed by a command or short conversation. And a socially behaving robot should be able to show and interpret emotions. Other desired adjustments according to the participants were awareness of their presence so the robot would know when someone is in the room and could ask for your attention when needed.

> "I think you should be able to really communicate with [the robot]. That you can really talk to him." - female, 57, living alone
>
> "If he wants to be a full-fleshed interlocutor, he needs to be able to show emotions." - male, 32, living alone
>
> "You won't communicate with [the robot] because it is all one-way communication… It would have been nice to be able to say something back to him." - female, 24, living with mature family

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's sociability ($F(5,96) = 50.696$, $p < .001$, partial $\eta^2 = .336$). As table 8.2 on page 278 shows, the participants' evaluation of the robot's social presence declined until the integration phase and increased vigorously in the identification phase even past the initial evaluation of sociability in the expectation phase. A Bonferroni post-hoc test indicated that the evaluation of sociability in the expectation phase differed significantly from all the other evaluations with the exception of the identification phase (between all pairs p < .001). The evaluation of sociability in all other phases only differed significantly from the evaluation in the identification phase (between all pairs p < .001). There was no significant main effect for either gender, pet ownership or user group for sociability, nor were there any significant interaction effects. However, a main effect was found for household type (p= .024). Overall, participants being part of a mature family evaluated the robot as more sociable than all other household types. Nevertheless the in the identification phase, it were the singles and couples who evaluated the robot as most sociable.

COMPANIONSHIP

Most participants were somewhat skeptical about robots being our companions. However, most participants were open to this possibility when robots would develop into more intelligent and social beings. And under certain conditions (e.g., for people without an active social live) the current robot could even be a companion. Although most participants just called it ‘the robot’ or referred to the robot’s appearance by calling it ‘bunny’, some participants actually gave the robot a name.

> “Just Karotz, because he had that name already… It would be weird to give him another name… Like when you get a dog and you give him one name first and later another one. No, it is just Karotz.” - female, 59, living alone
>
> “My godchild called him Poeh. So that has settled down.” - male, 55, living alone
>
> “We call her Heidi… because she has a female voice.” - female, 57, living alone
>
> “We have given [the robot] a name, it’s Fluffy.” - female, 27, living with spouse

Nevertheless, some participants agreed that the relationship they felt with the robot resembled a human-pet relationship or that the robot brought some companionableness.

> “I can laugh about [the robot]. You could see that as companionship… but not human companionship. Maybe if I didn’t have friends, the robot could be a companion.” - female, 22, living in student dorm
>
> “It is a little bit companionship. Like having pets, that make some noises and you can do something with them.” - female, 57, living alone
>
> “[The robot] brings liveliness in the home, because he makes sounds once and a while when you don’t expect it.” - male, 32, living alone

A few participants even programmed the robot to say good morning and other extra phrases. In that way, they actually increased its social interactions. For three out of the seven remaining participants at the end of the study, the companionableness experiences by the presence of the robot was the main reason why they still had the robot standing in their homes.

> “That is something I miss a little bit, especially my mom, that [the robot] says something but you can’t say anything back… I would like to be able to react on him… I also programmed him to say ‘good night, see you tomorrow’ in the evening.” - female, 24, living with mature family
>
> “[The robot] gives the feeling of an animal. He is always standing there. That could be an advantage. It is just like having fish. They don’t say much but you know they are there.” - female, 27, living with spouse

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of companionship with the robot ($F(5,96) = 56.709$, $p < .001$, partial $\eta^2 = .362$). As table 8.2 on page 278 shows, the participants’ evaluation of the robot’s potential as companion declined until the integration phase and increased vigorously in the identification phase even past the initial evaluation of sociability in the expectation phase. A Bonferroni post-hoc test indicated that the evaluation of companionship in both the pre-adoption and confrontation phase differed significantly from all the other evaluations (between all pairs $p < .001$). The evaluation of companionship in all other phases only differed significantly from the evaluation in the identification phase (between all pairs $p < .001$). There was no significant main effect for either gender, household type or pet ownership for companionship, nor were there any significant interaction effects. However, there was a main effect for user group ($p = .019$). Overall, users saw more potential for the robot as a companion compared to the user groups.

SOCIAL NORMATIVE BELIEFS FROM PHASE TO PHASE

A user’s social normative beliefs encompass their beliefs about the likelihood and importance of the social consequences of performing a particular behavior.

SOCIAL INFLUENCE

Far less of the topics in the interviews included normative beliefs of which more than half were about social influences. The participants talked to other people about the robot or showed the robot to visitors coming to their homes. And in all cases, according to the participants, those other people were more than willing to give their personal opinions on the robot. However, most participants were not susceptible for dissimilar opinions.

> "[My roommates] don't really use it. They don't like [the robot] that much. But they do different studies, less technical. That might be it, I don't know." - female, 22, living in student dorm
>
> "We had some visitors and they saw what the robot could do and wondered what we were doing with that. A little bit skeptical… They did not see the purpose of it, so to speak. They said that out loud. That is fine, that is allowed." - male, 64, living with spouse

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of social influence ($F(5,96)= 13.115$, $p < .001$, partial $\eta^2= .116$). As table 8.2 on page 278 shows, participants' evaluation of social influence increased from the pre-adoption to the confrontation phase, declined towards the integration phase and increased again in the identification phase. A Bonferroni post-hoc test indicated that the participants' evaluation of social influence in both the pre-adoption and confrontation phase differed significantly from all the other evaluations of social influence (between all pairs $p < .005$). However, the participants' evaluations of social influence seemed to stabilize after the confrontation phase as all other pairs did not differ significantly. There was no significant main effect for either gender, household type or pet ownership for social influence, nor were there any significant interaction effects. However, there was a main effect for user group ($p= .019$). Overall, users experienced a higher degree of social influence compared to other user groups.

MEDIA INFLUENCE

The topic of media influence was only noted in the expectation phase. During the interviews, the participants were asked what first comes to mind when thinking of robots. Almost all participants referred to the influence of media in their status of robots. Most participants explained that they first thought about some movies with robots they have seen before.

> "That is influenced mostly by television and movies… On television, you see [robots] do all kind of things, and people are almost friends with them… In the movies [robots] are portrayed as creatures with feelings." - female, 57, living alone
>
> "When you say robot to me, then the status that first appears is often related to one of the last movies I have seen with robots." - male, 32, living alone

However, some participants stated that their status of robots was also influenced by documentaries about robots on television.

> "I am mainly thinking about programs I have watched on Discovery Chanel and National Geographic." - female, 32, living with young family
>
> "The first robots one comes across are those portrayed in the media, and for me that were those robots that you see in factories building cars." - male, 38, living with young family

A factorial repeated measures analysis of variance (see table 8.2 on page 278) showed that the acceptance phase did not significantly affect the evaluation of media influence (F(5,96)= 1.186, p= .316, partial η^2= .012). Thus, over time, the participants equally evaluated the influence of media on their perceptions of and opinions about robots. Moreover, there was also no significant main effect for either gender, household type, pet ownership or user group for media influence, nor were there any significant interaction effects.

STATUS

In addition to social influence, a few of the participants said that having a social robot enhanced their status. They perceive a robot as something unique that most people do not own. They liked showing the robot to visitors and impose their friend with it on social media.

> "I had visitors over a few times. Yes, that is the attention, if people get to see [the robot]… When I put on FaceBook that I have got a social robot, I hope to get a lot of reactions." - male, 31, living alone
>
> "[The robot] is something you don't see that often by other people. For example my brothers and sisters, it would not make sense there. It's really something from us." - female, 32, living with young family
>
> "I have placed a picture [of the robot] on FaceBook, but nobody gave me any likes. That was kind of a disappointment." - female, 27, living with spouse

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of status ($F(5,96)= 14.237$, $p < .001$, partial $\eta^2= .161$). As table 8.2 on page 278 shows, the participants' evaluation of status declined until the integration phase but increased vigorously in the identification phase. A Bonferroni post-hoc test indicated that the evaluation of status in the expectation phase differed significantly from all the other evaluations of status with exception of the confrontation phase (between all pairs $p < .005$). The evaluation of status in confrontation phase differed significantly from all the other evaluations of status (between all pairs $p < .005$). However, the evaluation of status in either the adoption ($p < .001$), adaptation ($p < .001$) and integration phase ($p < .001$) differed only significantly with the evaluation in the identification phase. There was no significant main effect for either gender, household type, pet ownership or user group for status, nor were there any significant interaction effects.

PERSONAL NORMATIVE BELIEFS FROM PHASE TO PHASE

Personal normative beliefs contain the user's beliefs that engaging in a particular behavior leads to salient personal beliefs and are connected to what is perceived as the norm within one's social environment.

TRUST

Some participants discussed the trustworthiness of the information the robot provided. However, all participants were aware that the robot received its information from the internet and none of them doubted the quality of the information provided by the robot. Some of the participants never even thought of questioning this information.

> "I believe that what [the robot] tells me is coming from the same spot online as I would have searched it. So in that sense that information should be trustworthy." - male, 31, living alone
>
> "I haven't doubted that actually [the information]. I just assume that what comes out of it is trustable." - female, 26, living with young family

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's trustworthiness ($F(5,96)= 64.266$, $p < .001$, partial $\eta^2= .391$). As table 8.2 on page 278 shows, the participants' evaluations of the robot's ease of use declined in the confrontation phase, seems to increase again in the adaptation phase but drops again in the identification phase. A Bonferroni post-hoc test indicated that the evaluation trust in the expectation phase differed significantly from all the other evaluations (between all pairs $p < .001$). Similar results were found between the evaluation of trust in the confrontation phase and all other phases with the exception of the evaluation in the integration phase (between all pairs $p < .01$). However, the evaluation of trust in either the adoption, adaptation and integration phase differed only significantly with the evaluation in the identification phase (between all pairs $p < .001$). There was no significant main effect for either gender, pet ownership or user group for trust, nor were there any significant interaction effects. However, a main effect was found for household type ($p = .001$). Overall, participants' being part of a mature family trusted the robot more than those participants from all other household types.

PRIVACY CONCERN

The topic of privacy concerns was only noted by a few of the participants. However, those participants that raised this topic during the interviews continued doing this in all later interviews and their concern somewhat increased over time. Especially the fact that the robot had a camera and who could make use of that was for some participants quite concerning. A few participants felt as if the robot itself was looking at them.

> "I haven't felt unsafe… You know that there are hackers out there who do these kind of things, but you can think about that for 5 minutes. But my husband is working in ICT and he has everything properly secured, almost no one can get through that." - female, 32, living with young family
>
> "When I walked past [the robot], I was wondering if he could see what I am doing." - female, 57, living alone

Some participants even placed an object in front of the robot's camera or turn the robot in such a manner that the camera was not overlooking the sitting area.

> "I wouldn't want a robot of which I think it is spying on me… It is kind of a disadvantage that the robot has a webcam. Sometime you have the feeling of being watched, even though you know it can't see you. But I have got it on my app, so it can be hacked. And you are kind of afraid that those people could peep at you. We actually have sealed the webcam from the beginning." – female, 27, living with spouse
>
> "The webcam was a little bit irritating at a certain point. I have put the box from the ears in front of it. Because every time I thought [my son] can turn on the webcam on every moment at school and peep at me with his whole class. because that is what they do at that age." – female, 38, living with mature family

Other participants were worried whether other people could get hold of their personal information or the messages from the robot.

> "My first question is what can [the robot] record? Can it send things, etcetera? Because that is what makes you suspicious… I find it extremely important that he can't tap into our conversations and share that with particular companies. That is what makes me shiver. That is what we in our society must be aware of." – male, 64, living with spouse
>
> "At the moment [the robot] had taken some picture, it felt kind strange. They were send to a website and it said in the app that you could forward it to your mail. But I didn't understand completely how it worked… That made me feel uncomfortable." – female, 19, living with spouse

Moreover, some participants perceived the utterances of the robot as intrusive, especially when in the company of visitors.

> "When I have people over who don't know the robot and we are in a conversation, then the conversation is interrupted when [the robot] begins [to talk]." – female, 59, living alone
>
> "When I am watching television… and you hear [the robot] babble something, you think like whatever. You will give him some angry looks and continue watching." – male, 31, living alone
>
> "Those utterances, they come appropriately and inappropriately. At what times, that doesn't bother [the robot]." – male, 64, living with spouse

SOCIETAL IMPACT

The participants did not talk about the societal impact social robot could have in the future, thus, there was no code for it in the coding scheme. A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the participants general attitude towards robots ($F(5,96)= 4.052$, $p= .002$, partial $\eta^2= .039$). As table 8.2 on page 278 shows, the participants' evaluation of societal impact became more negative after the confrontation phase. However, this negativity decreased over time. A Bonferroni post-hoc test indicated that the participants' evaluation of societal impact in the expectation phase differed significantly from the evaluations in the confrontation phase ($p= .011$), the adaptation phase ($p= .028$), and the integration phase ($p= .024$). After the participants had been introduced to the robot their evaluation of societal impact did not change much as the differences were not significant after the confrontation phase. There was no significant main effect for either gender, household type, pet ownership or user group for attitude towards robots, nor were there any significant interaction effects.

CONTROL BELIEFS FROM PHASE TO PHASE

Control beliefs consists of the user's beliefs about salient control factors, that is their beliefs about the presence or absence of resources, opportunities and obstacles which may facilitate or impede performance of the behavior. These variables were the most important topics as discussed by the participants during the expectation phase. However, in the remaining acceptance phases, control beliefs were only minimally discussed by the participants during the interviews.

SITUATIONAL FACTORS

From the control beliefs, participants mostly indicated that the context of the interaction had an impact on their experiences with the robot. For example around big events, such as vacation holidays, moving house and weddings, people explained that they had less time to spend on the robot.

> "I am going away for two weeks, so I was busy doing other things." - female, 57, living alone
>
> "We have bought a house… There were a lot of things to arrange, and that has influenced why we had used [the robot] a little less." - female, 27, living with spouse

But also at specific moments during the day or week in which the circumstances would encourage the use of the robot.

> "Especially in the evenings [using the robot], because I am not at home during the day." - female, 24, living with mature family
>
> "I usually only have time in the mornings or evenings. And in the weekends I have more time. So I use [the robot] more often then. The moment itself can also play a role." - male, 32, living alone

Other types of situations that had an influence of the user experiences with the robot were when visitors came to the house. As visitors are unfamiliar with the robot, such moments offered the participants the opportunity to show what the robot can do and talk about it together.

> "When visitors come over it is nice to talk about [the robot]. It is funny. My sisters were here this weekend and we have played with it, with the apps, making it say stuff." - female, 27, living with spouse
>
> "I have had visitors a couple of times. That is the attention, when people see [the robot]." - male, 31, living alone
>
> "Almost every visitor basically [has noticed the robot]. So they thought it was funny and asked where they could buy it. So I provided them with the website." - male, 55, living alone

SELF-EFFICACY

The participants did not talk much about self-efficacy during the interviews. Most participants explained that they were familiar with technological devices and felt comfortable using this knowledge when operating the robot.

> "It's what I do with other appliances as well. Just pull the plug and reconnect it to the electricity grid.... The wireless network is working well, so it couldn't be that." - female, 59, living alone

However, some other participants were less familiar with technological devices and sometimes felt as if properly using the robot was out of their control.

> "Every time I want to work on [the robot], I am not succeeding.. things go wrong." - female, 57, living alone
>
> "And then my ignorance begins to play a role... I am not familiar with computers. I can use it for what I do most with it, but this is different." - female, 55, living with spouse

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the participants' perceptions on their behavioral control over the robot (F(5,96)= 10.582, p < .001, partial η^2= .096). As table 8.2 on page 278 shows, the participants' self-efficacy fluctuated over time. However, a Bonferroni post-hoc test indicated that the participants' evaluations of their self-efficacy only significantly differed between the adaptation phase and the identification phase (p= .045) and between the corporation and identification phase (p= .009). There was no significant main effect for either pet ownership or user group for self-efficacy, nor were there any significant interaction effects. However, a main effect was found for both gender (p= .024) and household type (p= .008). Overall, female participants as well as participants being part of mature families had higher evaluations of self-efficacy compared to either male participants and other household types.

ANXIETY TOWARDS ROBOTS

None of the participants had discussed being afraid of robots, thus there was no code for it in the coding scheme. A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the participants' anxiety towards robots (F(5,96)= 6.542, p < .001, partial η^2= .061). As table 8.2 on page 278 shows, anxiety towards robots fluctuated over time. A Bonferroni post-hoc test indicated that the participants' anxiety towards robots in the expectation phase differed significantly from the evaluations in the confrontation phase (p= .024) and the integration phase (p= .002). The anxiety levels between the adoption and adaptation phase differed significantly (p= .001). Both the adoption scores (p < .001) and the adaptation scores (p= .025) differed significantly from those in the integration phase. All other pairs did not differ significantly from one another. There was no significant main effect for either gender, household type, pet ownership or user group for anxiety towards robots, nor were there any significant interaction effects.

COST

The participants only discussed the cost associated with (the use of) the robot during the first interviews. However, this was a result of one of the questions in the interview about what they would be willing to pay for a domestic social robot in the future when the technology matures. The results of this question are already presented in chapter 2.4.

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the participants' evaluations of cost ($F(5,96)= 27.089$, $p < .001$, partial $\eta^2= .213$). As table 8.2 on page 278 shows, the participants' perception of cost of the robot fluctuated over time. A Bonferroni post-hoc test indicated that only the evaluation of cost in the expectation phase differed significantly from their evaluation in the identification phase ($p < .001$). The participants' perception of cost in the confrontation phase differed significantly from their evaluations in both the adaptation ($p < .001$) and identification phase ($p < .001$). Additionally, the participants' perception of cost in both the adaptation ($p < .001$) and integration phase ($p < .001$) differed significantly from their evaluation in the identification phase. There was no significant main effect for either gender, household type, pet ownership or user group for cost, nor were there any significant interaction effects.

PREVIOUS EXPERIENCES

The participants talked a lot about their previous experiences with robots or other technologies in relation to their current uses of the robot. This is much related to the subject of association as described in the user experiences within the acceptance phases. To get familiar with the robot, the participants discussed the resemblances and differences between the robot and other (technical) objects they were familiar with.

> "I have seen such a vacuum cleaning robot on the internet once, and also one that mows the lawn." - female, 24, living with mature family
>
> "On the internet you have such agents as well, which you can talk to." - male, 55, living alone
>
> "I have an mp3 player, upstairs I have always the radio on… I have also the radio on via my digital television… Now I can use the robot for that." - female, 27, living with spouse

PRIOR EXPECTATIONS

Additionally, the participants discussed their prior expectations of the robot. Most participants had higher prior expectations of the robot's sociability. That the robot would be able to express some emotions or that it would be able to interact more socially with its users. For some participants, these high prior expectations were not fulfilled by the actual performance of the robot. Even though most participants had realized that their prior expectations were too high for the type of robot that was installed at their homes, still the occurrence of the expectation gap had caused some participants to stop use the robot after initial adoption.

> "On the one hand you couldn't expect that [the robot] would say something back. But that is what's in your head, that he should be able to do that." - female, 57, living alone
>
> "I had expected that [the robot] had moods. A bad mood, and if you would play a game with him that his mood would change to positive. Just like the Tamagotchi you had in former times." - female, 24, living with mature family
>
> "[The robot] was brought to me with the expectation of a robot, and I don't see him as such… I had hoped to have a real robot with which you can have more interactions." - male, 31, living alone

DEPENDENT VARIABLES FROM PHASE TO PHASE

Technology acceptance is a process that begins with an individual becoming aware of a technology and, ideally, ends with that individual incorporating the use of that technology in their everyday life. This is where the technology exceeds its functional purpose and becomes a personal object because the individual gets attached to it. Adoption is when people start using a technology, which follows from people's use intention and/or their habits.

USE INTENTION

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the participants' use intention of the robot ($F(5,96)= 45.386$, $p < .001$, partial $\eta^2 = .312$). As table 8.2 on page 278 shows, the participants' use intention declined until the adaptation phase and seemed to increase from that point in time. A Bonferroni post-hoc test indicated that the participants' use attitude in the expectation phase differed significantly from all the other evaluations of use attitude with the exception of the identification phase (between all pairs $p < .001$). Similar results were found between the participants' use attitude in the confrontation phase and all the other evaluations of use attitude (between all pairs $p < .05$). Additionally, the participants' use attitudes in all the other acceptance phases differed significantly from their use attitudes in the identification phase (between all pairs $p < .001$). There was no significant main effect for either gender, household type or pet ownership for use attitude, nor were there any significant interaction effects. However, there was a main effect for user group ($p > .001$). Overall, users had higher use intentions than any other user groups.

ACTUAL USE

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the participants' actual use of the robot ($F(3,98) = 50.983$, $p < .001$, partial $\eta^2 = .347$). As table 8.2 on page 278 shows, the participants' actual use of the robot declined until the integration phase, but slightly increased again in the identification phase. A Bonferroni post-hoc test indicated that the participants' actual use in the adoption phase differed significantly from all the other evaluations of actual use (between all pairs $p < .001$). However, the participants' actual use of the robot seems to be stabilizing over time as the measures did not differ significantly from one another after the adoption phase. There was no significant main effect for either gender, household type or pet ownership for use attitude, nor were there any significant interaction effects. However, there was a main effect for user group ($p > .001$). Overall, users used the robot more frequently and the duration of each interaction pasted longer as well compared to other user groups.

HABIT

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the participants' habitual use of the robot ($F(3,98) = 26.902$, $p < .001$, partial $\eta^2 = .219$). As table 8.2 on page 278 shows, the participants' habitual use of the robot declined from the adoption into the adaptation phase, but increased again in both the integration and identification phase. However, a Bonferroni post-hoc test indicated that only the participants' habitual use in the identification phase differed significantly from their habitual use in all other acceptance phases (p < .001). There was no significant main effect for either gender, household type or pet ownership for use attitude, nor were there any significant interaction effects. However, there was a main effect for user group (p > .001). Overall, users had a more prominent habitual use compared to other user groups.

8.2 INFLUENTIAL VARIABLES OF SOCIAL ROBOT ACCEPTANCE

Using stepwise multiple regression analysis, I investigated which variables explain the outcome variables of social robot acceptance for each acceptance phase separately.

EXPECTATION PHASE

In the expectation phase, people want to know more about the technology and its purpose and therefore seek information about the concerning technology. Based on the gathered information, people will form an initial opinion about the technology and establish initial expectations. The expectation phase concerns the anticipation and preparation of obtaining a technology. With these expectations about the social robot that was coming to live with the participants, their intentions to use the robot were investigated once it would arrived.

INFLUENTIAL FACTORS FOR USE INTENTION IN THE EXPECTATION PHASE

A stepwise multiple regression indicated that together usefulness (β= .510), enjoyment (β= .388), animacy (β= .170), social presence (β= -.225) and anxiety towards robots (β= -.116) explained 68% of the variance of use intention (F(5,95)= 42.763, p < .001). Table 8.3 displays the results of this regression analysis.

Table 8.3: Regression analysis for use intention in the expectation phase

Acceptance variables	Use intention *t*	*β*	*p*
Attitudinal beliefs			
Usefulness	**5.966**	**.510**	**.000**
Ease of use	0.920	.055	.360
Adaptability	-0.135	-.009	.893
Intelligence	0.702	.061	.485
Enjoyment	**4.443**	**.388**	**.000**
Attractiveness	-0.214	-.015	.831
Animacy	**2.318**	**.157**	**.023**
Social presence	**-3.027**	**-.225**	**.003**
Sociability	0.612	.050	.542
Companionship	1.348	.118	.181
Normative beliefs			
Social Influence	0.685	.042	.685
Media Influence	0.650	.039	.517
Status	0.720	.043	.473
Trust	-0.297	-.020	.767
Attitude towards robots	-0.807	-.055	.422
Control beliefs			
Self-efficacy	-1.511	-.090	.134
Anxiety towards robots	**-1.989**	**-.116**	**.050**
Personal innovativeness	-0.494	-.029	.622
Robot related experiences	-0.046	-.003	.963
Cost	0.110	.007	.913
R^2		.68	
f		42.763	
df		5,95	
p		.000	

THE CONFRONTATION PHASE

In the confrontation phase, people encounter the technology for the first time. At this point, people may try out the technology if possible or just observe others using the technology. Based on this first encounter with the technology, people reevaluate and adjust their earlier formed expectations. With the first short trial of the social robot that just arrived in the participants' homes, their intentions to use the robot in the near future were investigated.

INFLUENTIAL FACTORS FOR USE INTENTION IN THE CONFRONTATION PHASE

A stepwise multiple regression indicated that usefulness (β= .589), adaptability (β= .144), companionship (β= .156), social influence (β= .238), media influence (β= .130), trust (β= -.175) and cost (β= -.122) explained 77% of the variance of use intention (F(7,93)= 48.563, p < .001). Table 8.4 displays the results of this regression analysis.

Table 8.4: Regression analysis for use intention in the confrontation phase

	Use intention		
Acceptance variables	*t*	β	*p*
Attitudinal beliefs			
Usefulness	**7.894**	**.589**	**.000**
Ease of use	-0.190	.011	.849
Adaptability	**2.412**	**.144**	**.018**
Intelligence	-0.093	-.008	.926
Enjoyment	0.597	.058	.552
Attractiveness	-0.341	-.030	.734
Animacy	0.003	.000	.998
Social presence	0.631	.048	.530
Sociability	-0.368	-.025	.714
Companionship	**2.071**	**.156**	**.041**
Normative beliefs			
Social Influence	**3.725**	**.238**	**.000**
Media Influence	**2.523**	**.130**	**.013**
Status	0.519	.030	.605
Trust	**-3.072**	**-.175**	**.003**
Attitude towards robots	1.103	.056	.273
Control beliefs			
Self-efficacy	1.309	.068	.194
Anxiety towards robots	-0.091	-.005	.928
Personal innovativeness	0.001	.023	.982
Robot related experiences	0.033	.002	.974
Cost	**-2.207**	**-.122**	**.030**
R^2	.77		
f	48.563		
df	7,93		
p	.000		

THE ADOPTION PHASE

The adoption phase is where people actually start using the technology in their privacy environment and gain their first serious user experiences with the technology. Based on their first user experiences with the robot, the participants' intention to continue the use of the robot in the next phase and their current actual use was explored.

INFLUENTIAL FACTORS FOR USE INTENTION IN THE ADOPTION PHASE

A stepwise multiple regression indicated that together usefulness (β= .623), companionship (β= .225), social influence (β= .167) and anxiety towards robots (β= -.109) explained 84% of the variance of use intention ($F(4,94)$= 125.866, p < .001). Table 8.5 displays the results of this regression analysis.

Table 8.5: Regression analysis for use intention in the adoption phase

	Use intention		
Acceptance variables	*t*	β	*p*
Attitudinal beliefs			
Usefulness	**9.805**	**.623**	**.000**
Ease of use	-0.890	.042	.376
Adaptability	0.041	.002	.967
Intelligence	-0.102	-.005	.919
Enjoyment	0.718	.047	.475
Attractiveness	-0.505	-.027	.615
Animacy	-1.110	-.056	.270
Social presence	-0.588	-.028	.558
Sociability	0.135	.007	.893
Companionship	**3.789**	**.225**	**.000**
Normative beliefs			
Social Influence	**3.001**	**.167**	**.003**
Media Influence	-0.354	-.017	.724
Status	0.705	.031	.483
Trust	-1.512	-.075	.134
Attitude towards robots	1.055	.048	.294
Control beliefs			
Self-efficacy	-0.170	.007	.865
Anxiety towards robots	**-2.631**	**-.109**	**.010**
Personal innovativeness	1.161	.048	.249
Robot related experiences	0.516	.022	.607
Cost	1.070	.050	.287
R^2	.84		
f	125.866		
df	4,94		
p	.000		

INFLUENTIAL FACTORS FOR ACTUAL USE IN THE ADOPTION PHASE

A second stepwise multiple regression indicated that together ease of use (β= .145), media influence (β= .130), trust (β= .115), self-efficacy (β= .165) and habit (β= .705) explained 73% of the variance of actual use (F(5,93)= 54.157, p < .001). The results are presented in table 8.6.

Table 8.6: Regression analysis for actual use in the adoption phase

Acceptance variables	Actual use *t*	β	*p*
Attitudinal beliefs			
Usefulness	1.738	.134	.086
Ease of use	**2.219**	**.145**	**.017**
Adaptability	1.491	.093	.139
Intelligence	-0.082	-.006	.935
Enjoyment	0.683	.056	.496
Attractiveness	-0.601	-.052	.550
Animacy	-1.173	-.075	.244
Social presence	-0.784	-.048	.435
Sociability	-1.018	-.062	.311
Companionship	-0.042	-.003	.966
Normative beliefs			
Social Influence	0.055	.004	.956
Media Influence	**2.207**	**.130**	**.030**
Status	-0.497	-.030	.621
Trust	**1.825**	**.115**	**.071**
Attitude towards robots	-0.329	-.018	.743
Control beliefs			
Self-efficacy	**2.829**	**.165**	**.000**
Anxiety towards robots	1.462	.091	.174
Personal innovativeness	-0.822	-.046	.413
Robot related experiences	0.803	.043	.424
Cost	-0.673	-.038	.503
Outcome variables			
Use intention	1.382	.108	.170
Habit	**11.897**	**.705**	**.000**
R^2		.73	
f		54.157	
df		4,93	
p		.000	

THE ADAPTATION PHASE

In the adaptation phase, users have a broad idea of what the technology is about. However, they still encounter novel features and this might come along with some learnability flaws. Yet, while exploring the functionalities of the technology and making attempts to adapt these to their personal needs, the users are increasingly getting familiarized with the technology. Based on their first user experiences with the robot, the participants' intention to continue the use of the robot in the next phase and their current actual use was explored.

INFLUENTIAL FACTORS FOR USE INTENTION IN THE ADAPTATION PHASE

A stepwise multiple regression indicated that together usefulness (β= .390), adaptability (β= .261), enjoyment (β= .294), animacy (β= -.138) and companionship (β= .207) explained 83% of the variance of use intention (F(5,91)= 96.126, p < .001). The results are presented in table 8.7.

Table 8.7: Regression analysis for use intention in the adaptation phase

	Use intention		
Acceptance variables	t	β	p
Attitudinal beliefs			
Usefulness	**5.942**	**.390**	**.000**
Ease of use	1.453	.066	.150
Adaptability	**4.460**	**.261**	**.000**
Intelligence	0.994	.061	.323
Enjoyment	**4.035**	**.294**	**.000**
Attractiveness	0.404	.024	.687
Animacy	**-2.804**	**-.138**	**.006**
Social presence	1.116	.059	.268
Sociability	-0.756	-.048	.452
Companionship	**3.161**	**.207**	**.002**
Normative beliefs			
Social Influence	-0.067	-.004	.947
Media Influence	1.371	.063	.174
Status	0.740	.034	.461
Trust	-0.207	-.010	.836
Attitude towards robots	0.106	.005	.916
Control beliefs			
Self-efficacy	0.093	.004	.926
Anxiety towards robots	-0.653	-.028	.515
Personal innovativeness	0.161	.007	.873
Robot related experiences	1.644	.072	.104
Cost	0.321	.016	.749
R^2	.83		
f	96.126		
df	5,91		
p	.000		

INFLUENTIAL FACTORS FOR ACTUAL USE IN THE ADAPTATION PHASE

A second stepwise multiple regression indicated that together usefulness (β= .502), social influence (β= -.158), robot related experiences (β= .156) and habit (β= .413) explained 64% of the variance of actual use ($F(4,92)$= 44.421, p < .001). The results are presented in table 8.8.

Table 8.8: Regression analysis for actual use in the adaptation phase

	Actual use		
Acceptance variables	*t*	β	*p*
Attitudinal beliefs			
Usefulness	**5.350**	**.502**	**.000**
Ease of use	1.576	.098	.119
Adaptability	0.075	.006	.941
Intelligence	-0.414	-.031	.680
Enjoyment	1.140	.116	.257
Attractiveness	1.021	.077	.310
Animacy	-0.169	-.012	.867
Social presence	-1.489	-.098	.140
Sociability	-0.220	-.016	.826
Companionship	-0.727	-.062	.469
Normative beliefs			
Social Influence	**-2.231**	**-.158**	**.028**
Media Influence	0.173	.012	.863
Status	0.192	.012	.848
Trust	0.812	.059	.419
Attitude towards robots	-0.766	-.048	.445
Control beliefs			
Self-efficacy	0.504	.034	.616
Anxiety towards robots	0.749	.049	.456
Personal innovativeness	0.317	.020	.752
Robot related experiences	**2.545**	**.156**	**.013**
Cost	1.471	.100	.145
Outcome variables			
Use intention	1.820	.206	.072
Habit	**4.881**	**.413**	**.000**
R^2	.64		
f	44.421		
df	4,92		
p	.000		

THE INTEGRATION PHASE

In the integration phase, a used technology has become meaningful in a user's life. The technology is modified or personalized by the user to adapt to their preferences. The users do no longer notice the presence of the technology and have fully integrated its use into their everyday lives. Based on their first user experiences with the robot, the participants' intention to continue the use of the robot in the next phase and their current actual use was explored.

INFLUENTIAL FACTORS FOR USE INTENTION IN THE INTEGRATION PHASE

Another stepwise multiple regression indicated that together usefulness (β= .749), enjoyment (β= .123), status (β= .141), personal innovativeness (β= .096), and anxiety towards robots (β= -.127) explained 88% of the variance of use intention (F(5,69)= 105.456, p < .001). The results are presented in table 8.9.

Table 8.9: Regression analysis for use intention in the integration phase

	Use intention		
Acceptance variables	*t*	β	*p*
Attitudinal beliefs			
Usefulness	**12.549**	**.749**	**.000**
Ease of use	-0.492	-.023	.624
Adaptability	0.433	.030	.666
Intelligence	-0.190	-.011	.850
Enjoyment	**1.893**	**.123**	**.063**
Attractiveness	-0.695	-.037	.489
Animacy	-1.011	-.055	.316
Social presence	1.552	-.098	.125
Sociability	-0.646	-.052	.521
Companionship	1.133	-.083	.261
Normative beliefs			
Social Influence	-0.211	.010	.834
Media Influence	-1.247	-.056	.217
Status	**2.691**	**.141**	**.009**
Trust	-0.978	-.045	.331
Attitude towards robots	0.993	.049	.324
Control beliefs			
Self-efficacy	1.183	-.050	.241
Anxiety towards robots	**-2.953**	**-.127**	**.004**
Personal innovativeness	**2.302**	**.096**	**.024**
Robot related experiences	1.397	.061	.167
Cost	0.802	.037	.426
R^2		.88	
f		105.456	
df		5,69	
p		.000	

INFLUENTIAL FACTORS FOR ACTUAL USE IN THE INTEGRATION PHASE

A second stepwise multiple regression indicated that together usefulness (β= .593), companionship (β= -.229), self-efficacy (β= -.183), personal innovativeness (β= .200), use intention (β= .263) and habit (β= .226) explained 81% of the variance of actual use ($F(6,68)$= 54.631, p < .001). The results are presented in table 8.10.

Table 8.10: Regression analysis for actual use in the integration phase

	Actual use		
Acceptance variables	*t*	β	*p*
Attitudinal beliefs			
Usefulness	**4.528**	**.593**	**.000**
Ease of use	0.246	.015	.807
Adaptability	-0.615	-.050	.540
Intelligence	-0.526	-.037	.600
Enjoyment	-0.900	-.084	.371
Attractiveness	-0.374	-.024	.710
Animacy	1.217	.072	.228
Social presence	-0.039	-.003	.969
Sociability	0.129	.014	.897
Companionship	**-3.273**	**-.229**	**.002**
Normative beliefs			
Social Influence	-0.384	-.025	.702
Media Influence	-0.243	-.015	.809
Status	0.427	.033	.671
Trust	0.476	.028	.636
Attitude towards robots	-0.830	-.045	.410
Control beliefs			
Self-efficacy	**-3.352**	**-.183**	**.001**
Anxiety towards robots	0.108	.006	.915
Personal innovativeness	**3.683**	**.200**	**.000**
Robot related experiences	1.291	.069	.201
Cost	-0.001	-.001	.989
Outcome variables			
Use intention	**2.022**	**.263**	**.047**
Habit	**3.440**	**.226**	**.001**
R^2	.81		
f	54.631		
df	6,68		
p	.000		

THE IDENTIFICATION PHASE

In the identification phase, a technology exceeds its functional purpose and becomes a personal object. People may use a technology to express a certain lifestyle, to differentiate or connect to other groups. Moreover, in this phase, users seek supportive information that approves continuance of use and therefore confirms their initial decision to adopt the technology. Based on their first user experiences with the robot, I explored the participants' intention to continue the use of the robot after the study if possible.

INFLUENTIAL FACTORS FOR USE INTENTION IN THE IDENTIFICATION PHASE

A stepwise multiple regression indicated that together usefulness (β= .351), adaptability (β= .367) and media influence (β= .223) explained 40% of the variance of use intention ($F(3,50)$= 12.644, p < .001). The results are presented in table 8.11.

Table 8.11: Regression analysis for use intention in the identification phase

	Use intention		
Acceptance variables	*t*	β	*p*
Attitudinal beliefs			
Usefulness	**2.999**	**.351**	**.004**
Ease of use	0.069	.008	.945
Adaptability	**3.119**	**.367**	**.003**
Intelligence	-0.789	-.097	.343
Enjoyment	-0.167	-.021	.868
Attractiveness	0.824	.097	.414
Animacy	-0.812	-.100	.421
Social presence	-0.750	-.099	.457
Sociability	-0.376	-.044	.708
Companionship	-0.587	-.070	.560
Normative beliefs			
Social Influence	0.297	.033	.768
Media Influence	**2.082**	**.223**	**.042**
Status	-0.222	-.025	.825
Trust	0.192	.022	.849
Attitude towards robots	0.640	.072	.525
Control beliefs			
Self-efficacy	-0.254	-.029	.800
Anxiety towards robots	0.362	.039	.719
Personal innovativeness	-0.174	-.019	.863
Robot related experiences	1.396	.150	.169
Cost	-0.824	-.090	.414
R^2	.40		
f	12.644		
df	3,50		
p	.000		

INFLUENTIAL FACTORS FOR ACTUAL USE IN THE IDENTIFICATION PHASE

A second stepwise multiple regression indicated that together usefulness (β= .509), trust (β= .259), and use intention (β= .264) explained 63% of the variance of actual use ($F(3,50)$= 31.546, p < .001). The results are presented in table 8.12.

Table 8.12: Regression analysis for actual use in the identification phase

	Actual use		
Acceptance variables	*t*	β	*p*
Attitudinal beliefs			
Usefulness	**5.092**	**.509**	**.000**
Ease of use	1.213	.106	.231
Adaptability	0.802	.081	.426
Intelligence	0.107	.011	.915
Enjoyment	1.291	.125	.203
Attractiveness	-0.659	-.061	.513
Animacy	0.474	.050	.637
Social presence	0.944	.097	.350
Sociability	-0.527	-.046	.601
Companionship	-0.252	-.022	.802
Normative beliefs			
Social Influence	-0.996	-.088	.324
Media Influence	-0.169	-.015	.866
Status	-0.471	-.040	.639
Trust	**2.922**	**.259**	**.005**
Attitude towards robots	0.862	.073	.393
Control beliefs			
Self-efficacy	1.955	.163	.056
Anxiety towards robots	1.938	.157	.058
Personal innovativeness	-0.056	-.005	.955
Robot related experiences	0.956	.083	.344
Cost	0.706	.062	.483
Outcome variables			
Use intention	**2.728**	**.264**	**.009**
Habit	0.293	.032	.770
R^2		.63	
f		31.546	
df		3,50	
p		.000	

DEMOGRAPHIC DIFFERENCES FOR ACCEPTANCE

To investigate potential demographic differences for the influence of the acceptance variables on use intention and actual use behavior, it was chosen to collect the overall average from all phases together of these measure to perform the regression analyses.

GENDER DIFFERENCES

A multiple stepwise regression for use intention was performed for both males and females. For males, together usefulness (β= .520), ease of use (β= .124), adaptability (β= .398), social presence (β= -.262), companionship (β= .210) and robot related experiences (β= .241) explained 83% of the variance of use intention (F(6,41)= 39.054, p < .001). For females, the explained variance of use intention (F(2,50)= 116.794, p < .001) was 82% with usefulness (β= .800) and media influence (β= .178) as the explanatory variables.

A second multiple stepwise multiple regression was performed for actual use for both males and females. For males, together social influence (β= -.284), use intention (β= .615) and habit (β= .506) explained 70% of the variance of actual use (F(3,44)= 38.236, p < .001). For females, the explained variance of actual use (F(3,49)= 55.829, p < .001) was 76% with usefulness (β= .588), animacy (β= -.187) and habit (β= .468) as the explanatory variables.

DIFFERENCES FOR HOUSEHOLD TYPE

A multiple stepwise regression for use intention was performed for all household types. For singles, together usefulness (β= .959), intelligence (β= -.330) and companionship (β= .208) explained 83% of the variance of use intention (F(3,24)= 46.355, p < .001). For couples, the explained variance of use intention (F(2,23)= 26.423, p < .001) was 67% with usefulness (β= .718) and sociability (β= .289) as the explanatory variables. For young families, together usefulness (β= .637), media influence (β= .348) and robot related experiences (β= .328) explained 75% of the variance of use intention (F(3,18)= 21.728, p < .001). For mature families, the explained variance of use intention (F(2,12)= 70.568, p < .001) was 91% with usefulness (β= .506) and enjoyment (β= .477) as the explanatory variables.

A second multiple stepwise multiple regression was performed for actual use for all household types. For singles, together ease of use (β= .171), use intention (β= .664) and habit (β= .321) explained 84% of the variance of actual use (F(3,24)= 49.626, p < .001). For couples, the explained variance of actual use (F(2,23)= 10.084, p= .001) was 42% with enjoyment (β= .779) and social influence (β= -.384) as the explanatory variables. For young families, together usefulness (β= .987), ease of use (β= .226), attractiveness (β= -.306), companionship (β= -.359) and trust (β= .238) explained 94% of the variance of actual use (F(5,16)= 61.525, p < .001). For mature families, the explained variance of actual use (F(1,13)= 71.213, p < .001) was 83% with habit (β= .920) as the only explanatory variable.

DIFFERENCES FOR PET OWNERSHIP

A multiple stepwise regression for use intention was performed for participants with and without a pet. For pet owners, together usefulness (β= .685), social influence (β= .260) and robot related experiences (β= .187) explained 79% of the variance of use intention (F(3,42)= 56.290, p < .001). For participants without a pet, the explained variance of use intention (F(6,42)= 66.953, p < .001) was 89% with usefulness (β= .574), adaptability (β= .204), social presence (β= -.291), companionship (β= .341), social influence (β= .144) and self-efficacy (β= -.162) as the explanatory variables.

A second multiple stepwise multiple regression was performed for actual use for participants with and without a pet. For pet owners, together usefulness (β= .534), ease of use (β= .195) and habit (β= .310) explained 66% of the variance of actual use (F(3,42)= 29.777, p < .001). For participants without a pet, the explained variance of actual use (F(3,45)= 47.633, p < .001) was 75% with personal innovativeness (β= .171), use intention (β= .435) and habit (β= .446) as the explanatory variables.

DIFFERENCES FOR USER GROUP

A multiple stepwise regression for use intention was performed for all user groups. For rejecters, together usefulness (β= .392) and enjoyment (β= .599) explained 81% of the variance of use intention (F(2,20)= 48.260, p < .001). For discontinuers, the explained variance of use intention (F(1,30)= 116.387, p < .001) was 79% with usefulness (β= .892) as the only explanatory variable. For users, the explained variance of use intention (F(4,41)= 49.362, p < .001) was 81% with usefulness (β= .678), adaptability (β= .383), social presence (β= -.209) and robot related experiences (β= .148) as the explanatory variables.

A second multiple stepwise multiple regression was performed for actual use for all user groups. For rejecters, together intelligence (β= -.259), cost (β= .180) and habit (β= .883) explained 87% of the variance of actual use (F(3,19)= 48.415, p < .001). For discontinuers, the explained variance of actual use (F(3,28)= 14.488, p < .001) was 57% with social influence (β= -.395), use intention (β= .594) and habit (β= .467) as the explanatory variables. For users, together enjoyment (β= .450), self-efficacy (β= -.222) and use intention (β= .545) explained 71% of the variance of actual use (F(3,42)= 38.500, p < .001).

8.3 A REFLECTION ON THE RESULTS ON THE ACCEPTANCE VARIABLES

This chapter has presented the results of the Karotz Home Study on the users' evaluation of the acceptance variables. The goal was to better understand the users' evaluations of the robot over time, which can help to better shape the design and implementation of social robots in domestic environments.

QUALITATIVE DESCRIPTIONS OF THE ACCEPTANCE VARIABLES

Examining the acceptance phases separately (see table 8.1 on page 232 and figure 8.1 on the next page), it can be observed that in the expectation phase the central theme was control beliefs of which the most discussed topic was the participant's previous experiences with robots or other technologies. Previous experiences with either the robot or other technological devices, such as mobile phone, tablets and computers, is all the participants had to create some type of mental status of what having and using a robot in the home could entail.

In the confrontation phase, the participants talked most about the utilitarian and hedonic factors. Usefulness was the most noted utilitarian topic, and hedonic factors noted were social presence, enjoyment and attractiveness.

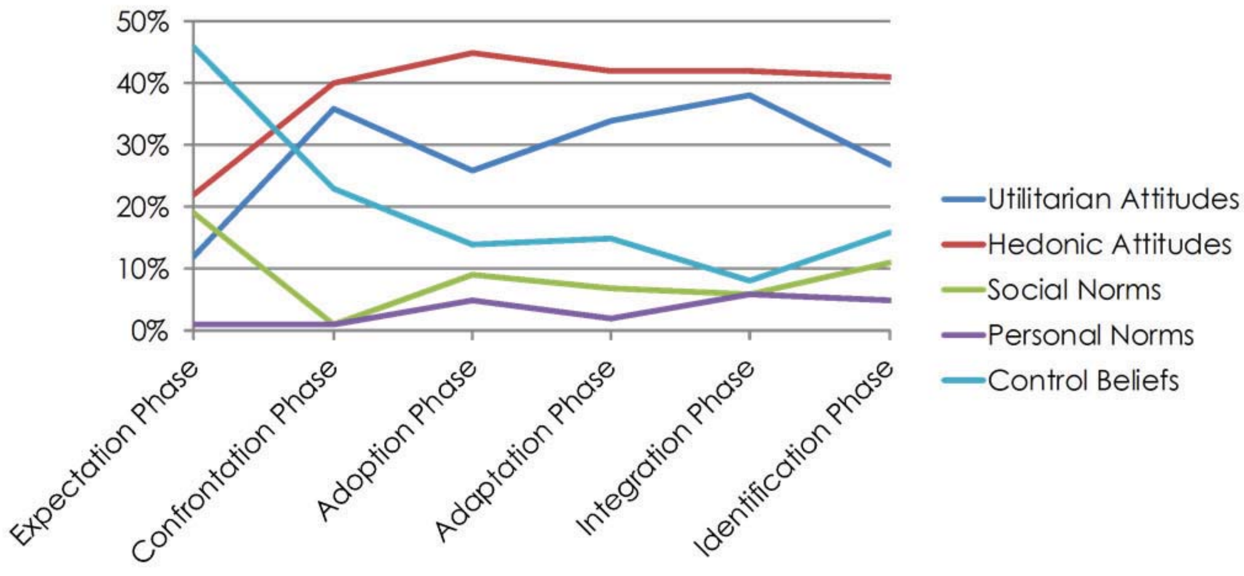

Figure 8.1: Visualization of the Acceptance Variables (n= 2682) as Coded in the Interviews

In the adoption phase, the participants talked the most about their hedonic attitudes about the robot with a special attention for the anticipated fun the robot could offer.

In the adaptation phase, both the utilitarian and hedonic attitudes were important topics during the interviews, with a slight focus on hedonic attitudes. By far, the utilitarian attitude of usefulness was noted most for which the participants explained that they had expected more or better functionalities on the robot. For the hedonic attitudes, both enjoyment en social presence were important topics. The utterances of the robot offered some funny moments and the participants realized that the autonomous behavior of the robot elicited an urge to treat the robot as something alive.

In the integration phase, both utilitarian and hedonic attitudes were almost equally important for the participants and again also usefulness and enjoyment were noted most. However, with respect to usefulness, the participants talked now more about the robot’s shortcomings and how other devices could offer similar and even better functionalities. Yet, most of the descriptions for enjoyment have indicated that the participant still acknowledged the robot’s potential for fun interactions.

In the identification phase, both utilitarian and hedonic attitudes were the most important topics during the interviews, with again a slight focus on hedonic attitudes. Again, the participants mainly focused on usefulness and enjoyment, however, now the participants also discussed the sociability of the robot or actually its shortcomings in that. Most participants explained that they would have liked it if the robot was a better conversational partner, at least for the commands but for some participants also for small talk. In none of the acceptance phases personal or social norms occurred among the most frequent acceptance variables in the interviews.

STATISTICAL EVALUATION OF THE ACCEPTANCE VARIABLES

Before the participants were introduced to the robot, the evaluations of the participants about the robot and their experiences were the most positive ones. This means that the participants had higher expectations of the robot which were not met after the participants made their first impressions of the robot. This was especially the case for rejecters. They had even higher expectations than any other user groups. Additionally, compared to rejecters and discontinuers, users evaluated the robot and their interaction experiences with it more positively on some variables than other user groups.

A mere-exposure effect was observed within our data, which is the tendency for novel stimuli to be liked more or rated more positively after someone has been repeatedly exposed to them. Moreover, our findings suggest that people living in mature families evaluated the robot more positively compared to people living alone, with a spouse or with young children.

INFLUENCING VARIABLES OF SOCIAL ROBOT ACCEPTANCE

Overall, the acceptance variables used in this study could very well explain the participants' use intention as well as their actual use of the robot in this study. The explained variances ranged from 40% to 88% for use intention, and from 63% to 81% for actual use for the complete sample. When controlled for gender, household type, pet ownership or user group, the explained variance for use intention even increased to 91% and for actual use to 94%, both concerning mature families.

Examining all regression analyses, it seems that usefulness is an important acceptance variable for social robot, as it was part of almost all of the regressions and often was the strongest predictor for use intention and actual use. The importance of usefulness was also stressed in an earlier long-term study with the Roomba vacuum cleaner robot (Fink et al., 2013) in which the majority of the households did not perceive the robot as useful.

Moreover, the exploration of demographic differences for the influence of acceptance variables on use intention and actual use indicate that males and females focus on different acceptance variables for social robot acceptance, especially with regard to actual use. For the household types, the results show that couples may partially focus on different aspects for social robot acceptance as the explained variances was much lower for this group compared to singles, young families and mature families. Pet ownership provided some different results as well. Participants without a pet did focus on the social aspects of the robot (i.e., social presence and companionship) in their evaluation of social robot acceptance whereas pet owners did not. Finally, the user groups seem to focus on different acceptance variables for social robot acceptance, and users give the impression to evaluate more acceptance variables which was especially the case for use intention.

PART IV

EFFECTS

9

THEORIES OF HUMAN RELATIONSHIPS

"The bird a nest, the spider a web, man friendship."
– William Blake –

Close relationships are tremendously important for human beings. Psychologists have demonstrated the crucial role that relationships play in various aspects of life from the development of self-identity to self-esteem, and its capability of reducing stress (Perlman & Fehr, 1987). Since computer technologies increasingly interact with us complex and humanlike ways through robots, wearable devices, PDAs, and various other ubiquitous interfaces, the psychological aspects of our relationships with them take on an increasingly important role (Bickmore & Picard, 2005). In the future, robots are expected to serve humans in various social roles such as nursing, child and elder care, and teaching environments. Robots in these social roles, in addition to their functional requirements, also include socially interactive components (Feil-Seifer & Mataric, 2011). Besides performing their monitoring and assistive tasks, these robot also must engage in social interaction and create (trust) relationships with their users in order to gain their goals (e.g., increasing an elderly persons health). Establishing a form of relationship between the user and the robot seems to increase the long-term acceptance of robots (de Graaf, Ben Allouch, & Klamer, 2015; Kanda et al., 2007). Investigating the factors that could explain why some people are willing to build human-robot relationships could help the long-term acceptance of robots with abilities for social interaction.

Today, several digital and embodied pets have been introduced into the marketplace, such as the Tamagotchi, Furby, AIBO, Paro, Karotz, and Pleo. These robotic artifacts provide increasingly sophisticated simulations of companions which require some level of care taking and are designed explicitly to provoke emotional responses from their users. All these are examples of zoomorphic social robots designed to interact with us as human companions would do. These robotic companions will listen to you empathetically and provide encouraging or even flattery feedback when necessary. Regardless of the moral or ethical implications, these robotic companions will be entering our everyday lives as soon as their abilities are technically feasible for the application in domestic environments.

This chapter will discuss different types of human relationships. It begins with human-human relationships to explore the foundations of the human need to socially connect with others. Next, some insights on relationships with non-humans will be presented using research on people's attachments to objects and parasocial relationships. Thereafter, current knowledge on human-robot relationships will be presented. This chapter ends with some implications for further research on human-robot relationships. Parts of this chapter have been submitted as an article currently being reviewed as:

> Graaf, M.M.A. de, & Ben Allouch, S. (under review). The influence of expectation setting on companionship with a zoomorphic robot. *International Journal of Social Robotics*.

9.1 HUMAN-HUMAN RELATIONSHIPS

Relationships with others lie at the very core of human existence, as humans are conceived within relationships, born into relationships, and live their lives within relationships with others (Berschied & Peplau, 1983). This section describes theories of human-human relationships to provide insight into the aspects of human relationships with others and how they develop over time.

THEORIES OF HUMAN RELATIONSHIPS

We are, in our roots, social creatures, destined to bond with others. Researchers have compared the nature of attachment in various close relationships (Davis, 1985; Maxwell, 1985; Sternberg and Grajek, 1984) and found that some elements are common to all attachments: mutual understanding, giving and receiving support, valuing and enjoying being with the designated other. There are several theoretical frameworks in psychology that deal with different aspects of human relationships. Two prominent theories in this respect will be described below.

ATTACHMENT THEORY

Exploring how people form attachments provide insights regarding how they experience close relationships and interact with significant others. Especially the application of Bowbly's (1958) infant-parental attachment theory to subsequent adult relationships (Hazan & Shaver, 1987) has generated a wealth of information regarding the development and maintenance of social relationships. The attachment theory was originally used to explain the bond that develops between a human infant and its caregiver (Bowlby, 1958), but later successfully applied to adult relationships as well (Feeney & Noller, 1996). According to the attachment theory, individuals are characterized according to their experiences with intimacy during childhood and form either a secure, an avoidant or a pre-occupied attachment style (Hazan & Shaver, 1994). The distribution among the three attachment styles, e.g., 55% for secure, 25% for avoidant, and 20% for pre-occupied attachments, has been replicated in many studies across nations (Feeny & Noller, 1996).

People's attachment styles play a fundamental role in how they experience close relationships in adult life. Secure individuals have parents that were available, responsive and warm, and are sociable and engaging in high levels of exploration (Hazan & Shaver, 1994). Secure individuals hold a variety of positive expectations that manifest themselves in relational interactions and outcomes. Avoidant individuals have parents who were rejecting, rigid, hostile and averse to contact. These individuals respond with defensiveness and avoidance of close social contact, especially when in stressful or distressing situations (Hazan & Shaver, 1994). They fear intimacy and have a tendency to maintain distance in 'close' relationships, have a pessimistic view on relationships and a relatively high rate of relationship dissolution (Hazan & Shaver, 1987). Avoidant individuals, who have a difficult time trusting others, often engage in behaviors designed to keep others at a comfortable distance. Finally, pre-occupied individuals have parents who were insensitive, intrusive and inconsistent. Those individuals respond with anxious behaviors such as crying and clinging. They have a lack of confidence in the reliability of partner responsiveness, are mentally and behaviorally dedicated to keeping others close by and engaged, and view others as hesitant to commit and as inadequate caregivers (Hazan & Shaver, 1994). Pre-occupied individuals are more likely to engage in extreme range of behaviors, which are probably linked to their fear of being alone and disappointment that their partners do not live up to their idealized expectations.

People's attachment styles thus seem to lay a foundation for future relationships and provide a framework for understanding how people experience close relationships in adult life. These attachment categories may also be useful in identifying the types of individuals who may be especially receptive to using robotic companions.

THE NEED TO BELONG

Another framework that provides insight into how and why people bond with others is given by the human need to belong. Adler (1930) was the first to formulate that humans have a fundamental need to belong or socially bond with others. However, the major impact of this meaningful statement has arisen when Baumeister and Leary (1995) presented a prolonged account of evidence that supported the argument that the need to belong is a fundamental human need. Based on their literature review, the authors claim that the need to belong provides a framework for understanding and integrating most existing literature on human interpersonal behaviors such as relationships. The need for belongingness has been described in the middle of Maslow's (1968) motivational hierarchy as the first human need after satisfying our basic physiological needs (e.g., breathing, food and water, shelter) and our need for safety and security. The need to belong is presumed to be a result of an evolutionary basis to use social bonds for survival and reproductive benefits (Ainsworth, 1989; Bowlby, 1969; Hogan, Jones, & Cheeck, 1985). Humans living in a group can share food, provide mates and can help in taking care of offspring. These behaviors are presumed to be the result of a set of internal mechanisms that guide individuals to seek belongingness with social groups (Baumeister & Leary, 1995).

Thus, to satisfy the need to belong, humans seek the company of other people: we build groups (e.g. families, cliques), we are interested in other people lives, and we help each other and join clubs merely because it satisfies us to affiliate with other people (Baumeister & Leary, 1995). Moreover, people need relationships characterized by frequent interpersonal contact and a feeling of mutual social bond (Perlman & Fehr, 1987; Weiss, 1973). Additionally, a lack of belongingness constitutes severe deprivation and cause a variety of ill effects (Baumeister & Leary, 1995). Indeed, research among individuals who experience unmet belonging needs, either through randomly assigned experimental conditions or self-assessment measures, has reported that treats to belongingness and chronic unmet belonging needs are related to greater attention to and processing of social relevant information (Gere & McDonald, 2010). Moreover, individuals whose need to belong is threatened are more likely to experience social presence from nonhumans such as television persona and pets (Epley, Akalis, & Cacioppo, 2008). Perhaps, those individual experience this social presence from television persona and pets to provide a social outlet (Gere & MacDonald, 2010). Thus, the human need to belong may also explain why some individuals seek social relationships with robotic others.

ATTACHMENT THEORY VERSUS THE NEED TO BELONG

The need to belong contradicts the attachment theory of Bowlby (1958) in that it does not regard the need as derived from a particular relationship or focuses on a particular individual (Hazan & Shaver, 1994). In contrast, the need to belong can, in principle, be directed toward any other human being, and the loss of relation with one person can to some extend be replaced by any other (Baumeister & Leary, 1995). Also, the need to belong focusses on the commonality in this need, whereas attachment theory emphasizes individual differences in attachment style (Hazan & Shaver, 1994). Finally, the need to belong regards this needs as plausible to be satisfied in other ways, whereas attachment theory stresses the implicitly of emotional needs and satisfaction within certain kind of relationships (Baumeister & Leary, 1995).

PRECONDITIONS FOR HUMAN-HUMAN RELATIONSHIPS

Although the attachment theory and the theory of need to belong describe the human necessity to connect with others, they both lack the specific knowledge to predict with whom we engage in human-human relationships and with whom not. Therefore, this section continues to provide insights into the known preconditions which influence with whom we affiliate and under which circumstances human-human relationships are likely to be established (Myers, 1999).

PROXIMITY

Human-human relationships start as an acquaintance between two people. Acquaintances cannot start before one person meets another, thus proximity is one of the most powerful predictors of human-human relationships. Randomly assigned college roommates, which forces frequent interactions, are far more likely to become good friends than enemies (Newcomb, 1956). Proximity, or more precisely functional distance, powerfully predicts the formation of human-human relationships. Functional distance is how often people's paths cross. When two people are in a ‘closed field’ situation in which people are forced to be together, such travelling on the same bus each morning, the environment itself makes these people notice each other (Levinger, 1983). But why does proximity affect the formation of human-human relationships? One factor is availability (Myers, 1999). Obviously there are fewer opportunities to get to know someone who's path you are unlikely to cross. Proximity enables people to discover commonalities and exchange rewards. Proximity leads to the formation of human-human relationships for another reason. Mere exposure to all sorts of novel stimuli boosts people's ratings of them. The mere-exposure effect is the tendency for novel stimuli to be evaluated more positively after the rater has been repeatedly exposed to them. Proximity is rewarding. It costs less time and effort to receive benefits of the relation with another human who lives or works close by. Proximity serves an opportunity for the formation of human-human relationships.

ATTRACTIVENESS

But proximity is not enough for the establishment of human-human relationships. When two people are not in an closed environment but in an ‘open field’ situation, such as the bus station, there are other aspects that makes one notice the other (Berscheid & Graziano, 1979). One such aspect is physical attraction, which is the positive evaluation of the physical appearance of the other (Berscheid & Reis, 1998). There is a lot of research studies showing the importance of physical appearance, which is regarded as a crucial factor for first impressions of other people (Byrne, London & Reeves, 1968). This is explained by the ‘what is beautiful is good’ paradigm (Dion, Berscheid, & Walster, 1972), which constitutes the presumption that physically attractive people (or things) possess other socially desirable traits as well. To say that attractiveness is important, other things being equal, is not to say that physical appearance always outranks other qualities. But first impressions are important and becoming more so as societies become increasingly mobile and urbanized and as contacts with people become more fleeting (Manago, Taylor, & Greenfield, 2012). We like attractive people because we associate them with other desirable traits (Andreoni, & Petrie, 2008; Kniffin & Wilson, 2004).

SIMILARITY

As people get to know one another, other factors influence whether acquaintance develops into a relationship between humans. Factors determining initial attraction are different from those determining prolonged relationships (Duck & Spencer, 1972). Cues related to the formation of human-human relationships are considered to shift from the physical characteristics to those immediately concerned with more cognitive attributes (Duck, 1973). This is where people start to select those individuals with whom a relationship is assumed to be a positive appeal. This is where people concern themselves with ways of describing the other’s personality and personal characteristics. They are also evaluating the other’s personality in terms of overlap with their own personality, i.e. similarity.

The formulation of the similarity-attraction hypothesis is drawn from Newcomb's (1956) well-known paper on the prediction of interpersonal attraction. In this hypothesis, similarity (real or perceived) of personality is considered to be a major determinant of likeability and relationship choice (McCroskey, Richmond, & Daly, 1975). Since Newcomb's (1956) discovery, research found over and over again that the more similar someone's attitudes are to our own, the more likeable you will find the person. Likeness produces liking. Research on liking and attraction has shown that we tend to like others who are similar to us (Aronson, Wilson, & Akart, 1994), because they provide us a source of validation for ourselves. This provides the basis for the next precondition of the formation of human-human relationships, reciprocal liking.

RECIPROCAL LIKING

Proximity and attractiveness influence our initial attraction to someone, and discovering similarities helps people to progress through the various stages of relationship development (Altman & Taylor, 1973; Miller & Steinberg, 1975). Particularly similarity between attitudes is related to reciprocal liking (Aronson, 1980; Byrne, 1961; Newcomb, 1956). If others have similar opinions, we feel rewarded because we presume that they like us in return (Altman & Taylor, 1973; Berscheid, 1985; Kelley & Thibaut, 1978). The phenomenon of reciprocal liking is grounded in Heider's (1958) balance theory: we like those who like us, or who likes the same things we like (one of which is ourselves). Thus, liking is usually mutual, i.e., reciprocal liking. However, reciprocal liking depends on one believing oneself to be likable (Jones & Schrauger, 1970), but also on the sequence in which liking and disliking may have been expressed (Aronson & Linder, 1965). Furthermore, it is not only the liking itself but also the reasons for it which can be interpreted (Jones et al., 1968). The explanatory power of reciprocal liking seems, therefore, to have its limitations.

Reciprocal liking also occurs when people interact with technologies. People who were flattered by their computers reported more positive affect, better performance, more positive evaluations of the interaction, and more positive regard for the computer (Reeves & Nass, 1996). Flattery can thus be a good strategy for social robots to get their users to like it. For example, in the studies of Leite and colleagues (2010, 2014), children preferred receiving esteem support (i.e., reinforcing the other's sense of competence) from the robot they interacted with and evaluated those robots that provide positive feedback more positively.

INTIMACY

There is agreement amongst researchers that intimacy is essential for many human friendships (Laurenceau & Barret, 1998), such as human-human relationships. Intimacy results from a dynamic, interpersonal process which combines self-disclosure and partner responsiveness as key components (Reis & Shaver, 1988). Self-disclosure is the verbal communication of personally relevant information, thoughts, and feelings to another and research on self-disclosure often relies on the degree or depth of self-disclosure as an index of intimacy (Altman & Taylor, 1973). In self-disclosure, scientists have distinguished between factual and emotional disclosure (Reis & Shaver, 1988). Factual self-disclosures reveal personal facts and information and emotional self-disclosures reveal one's private feelings, opinions and judgments. Emotional self-disclosure is believed to create greater intimacy because they provide the listener the opportunity to support and confirm core aspects of the disclosure's view of self (Reis & Shaver, 1988). Trusting the listener will enhance self-disclosure (Hazan & Shaver, 1994). However, the causal relation between self-disclosure and growing intimacy has been criticized (Petronio, 2002). It could be that a person reveals private information merely to express oneself, to release tension, or to gain relational control, which does not necessarily entails that this individual seeks nor achieves a more intimate bond with a partner.

Other researchers advocate the necessity to evaluate self-disclosure together with the level of partner responsiveness for measuring the level of intimacy (e.g., Berg, 1987; Davis, 1982). Perceived partner responsiveness is conceptualized as the "belief that a relationship partner understands, values, and supports important aspects of the self" (Birnbaum & Reis, 2012, p. 946). In human-human relationships, responsiveness plays a major role in any interaction that involves effective communication, caregiving and social support (Clark & Lemay, 2010; Reis, 2007). Positively evaluating partner responsiveness leads to security and enjoyment, whereas negative evaluation leads to anxiety and distress (Hazan & Shaver, 1994). Therefore, an integrated model of intimacy has been developed by Reis and Shaver (1988) who describe intimacy as the product of a transactional, interpersonal process whereby an individual discloses personal information, thoughts, and feelings to a partner; receives a response from the partner; and interprets that response as understanding, validating, and caring.

The integrated model of intimacy is supported by principle of depth of penetration from the social penetration theory (Taylor & Altman, 1987). The depth of penetration refers to the degree of intimacy which increases when human-human relationships develop into a more personal level. According to the social penetration theory (Taylor & Altman, 1987) is self-disclosure reciprocal. Shown vulnerability by an individual elicits trust, which in turn evokes a need for emotional equity that could be fulfilled by self-disclosure from the partner. Consequently, intimacy grows through interaction in which an individual discloses personal information, thoughts and feelings to a partner. In return, these partners respond in such a way that is perceived by the individual as understanding, validating and caring.

9.2 RELATIONSHIPS WITH NONHUMANS

People are not only capable of forming relationships with other humans, but also have the ability to engage in social relationships with nonhumans. This section addresses people’s relationships with their pets, further explore attachments to objects and relationships people can build with persons on television, i.e. parasocial relationships, and reflect on how this knowledge can be used to study the relationships people might establish with robots.

HUMAN-PET RELATIONSHIPS

We share our planet with an astounding variety of different animals but we have selected only a minority to hold the privilege position of pets. And among these pets, merely a few have been considered for companionship

(Serpell, 1996). Pets are either a substitute for caring with people treating it as a child, a substitute for security with people treating it as a parent, or a substitute for companionship with people treating it as a partner (Archer, 1997). Indeed, surveys addressing human-pet relationships (Harris Poll, 2007; Petsode.com, 2008; Pew, 2006) report that people indicate feelings and actions that portray their pets as legitimate participants in social interaction. Those surveys show that people indicate that they can understand their pets language and that their pets understand human language as well, and those people define intimate bonds with their pets sometimes stronger than those developed with friends and family members.

ESTABLISHING RELATIONSHIPS WITH A PET

People have owned pets since the beginning of humanity. Nowadays, people spend a lot of affection and money on their pets, which, from a Darwinian perspective, is a questionable form of behavior (Archer, 1997). As described above, the evolutionary significance of attachments formed to other humans is clear. However, in the case of human-pet relationships, the question is raised of why people should form similar attachment to members of a different species. It involves taking care of a member from another species and in turn there are no apparent benefits connected it. According to Serpell (1996) there are two main reasons why people treat some pets as companions. First, because they have been part of our natural environment for thousands of years and our ancestors were domesticating these animals, and thus have had plenty of time to adapt to the role of companion. Second, because they possess certain qualities that made them especially suitable and desirable as animal companions. These qualities are their everyday rhythm, their height, their considerable pleasure for physical attention and their apparent signals of human-human relationships (Serpell, 1996).

In addition to these qualities, Archer (1996) argues that pets achieve their evolutionary position in human life is caused by their ability to adapt to the human way of life (Serpell, 1986), the similarity of emotions and moods although expressed differently (Lorenz, 1970), their capability to show affection to their owner (Smith, 1983), and their historical availability as a pet (Messent

& Serpell, 1981). There is a great body of evidence pointing to several health related benefits of owning a pet (Friedmann, 2003). Combining these qualities, pets persuade us that they love and understand us, despite all our manifest deficiencies and failures. And although compared to a relationship with another person, the human-pet relationship might seem shallow –at least a pets affection for us is reliable and unconditional (Serpell, 1983). And because of our ability to assign humanlike attributes to non-human objects (Eply, Waytz, & Cacioppo, 2007), we are able to fill in the huge gap between humans and animals in terms of language and thoughts.

SIMILARITIES BETWEEN HUMAN-PET AND HUMAN-ROBOT RELATIONSHIPS

As people show similar behaviors of assigned humanlike attributes to robots, human-robot relationships might develop as well. Indeed, there are some similarities between how we relate to animals and robots. These similarities suggest that it is the appearance of the robot or the animal among other things, and not their ontological status, that matters how we treat them. These similarities are related to how we perceive both entities in different contexts such as their functionalities in society and between societies or cultures (Coeckelbergh, 2011).

Regarding functionalities, both animals and robots appear in different roles. For example, we have different relations with animals: as companions or pets; as living meat, livestock, and production units or farm animals; as game when we hunt them; as wild animals; as experimental material in scientific experiments; and as entertainment in the zoo (Harbers, 2002; Waiblinger, 2009).

Similarly, we treat robots differently depending on their appearance in different use contexts. For example, we will treat robots as slaves in an industrial context but will more easily perceive them as companions when they interact socially with us in our home environments.

In addition to the use context, Coeckelbergh (2011) points to the similarity of different views on animals and robots with regard to cultural differences. For example, in some cultures, dogs are seen as dinner, whereas in our Western society dogs are treated as companions. Similarly, there seems to be a cultural difference in how cultures perceive robots (MacDorman et al., 2009) in which Western countries is dominated by slave models of robots and Eastern countries are more familiar with treating robots as companions. Thus, the way we related to both animals and robots depends on their appearance. This means that how we regard both entities depends on our human perception, which depends on personal, contextual and cultural categories (Coeckelbergh, 2011). Understanding human-robot relationships should not be related to what the robot actually can or cannot do, but should be approach by how they appear to us and how we perceived them in these relationships.

ATTACHMENT TO OBJECTS

Before forming a complete understanding of the reason why people would bond with technology, we must also gain some understanding of the meanings people attach to possessions. Linked to the attachment theory from Bowlby (1958), attachment to objects is a feeling of affection, usually for a person but sometimes for an object or even an institution such as a school of corporation (Cassidy, & Shaver, 2008). The object of focus is changing over the years when someone grows up.

EMOTIONAL RELATIONSHIPS WITH OBJECTS

Most people are unaware of the relationships they have with the objects in our lives. Our favorite objects in our houses are the ones that have attachment to certain people or particular times in our lives (Quinn, 2003). Looking back to our childhood, most people can remember something with symbolic meaning. Every object has its own individual story and utilitarian aspects are no longer the primary reasons to buy an object. If users associate the product with real human emotions, they go beyond the satisfaction of emotional-hit and are engaging in an emotional rapport turning the object in a living being (Quinn, 2003). People that have become emotionally attached to a technology perceive its usability more positively and have higher intentions to continue to use that technology in the future (Sung, et al., 2007; Zhang & Li, 2005). Thus emotional attachment can lead to greater acceptance of technologies, such as social robots.

OBJECTS AS EXTENDED SELVES

Belk (1988a) argues that we regard our possession as parts of ourselves, whether this occurs consciously or subconsciously, intentionally or intentionally. Possessions literary can extend our selves, as when a tool allows us to do things we otherwise could not. Possessions can also symbolically extend our selves, as when wearing a uniform transforms us into someone we are convinced would not be without it. Having possessions thus contribute to our capabilities for doing and being, pointing to an interrelationship of having, doing and being (Belk, 1988a). Sartre (1943) outlines three means to make objects part of our extended selves: control or mastery, we have control over the objects we use; creation, we mark our self-created objects with copyrights, patents, and scientific citation; and knowledge, we extent ourselves by knowing the existence of objects. Clear examples of such self-extension are acknowledged in collecting certain objects, owning pets and relating to other people. Also, people seem to take care of durable possessions. The more homeowners embrace their accommodations, the more frequently or recently they reported maintained activities in and around the house (Belk, 1988b). A similar behavior pattern has been signalized in a study on male car owners (Bloch, 1982). Material possessions as parts of our extended selves seem to form an anchor for our identities by leaving behind a track of existence. The importance of certain materials to our extended selves are changing with key life stages, changes of view on our ideal self-images, or changes in the view on our entire personal history (Belk, 1988a).

TYPES OF RELATIONSHIPS WITH OBJECTS

According to Norman (2004), emotional attachment can be seen as the sum of cumulated emotional episodes of users' experiences with an object in various context areas. When people use objects or see it for the first time, the visceral level takes place. At the visceral level, people gain a first impression of an object through its appearance spontaneously judge that object (Norman, 2004).

After adoption of an object, the behavioral level begins, which concerns the usage and experience of an object with people appraising its functions (Norman, 2004). From a design point of view, people could attach to objects as a ‘meaningful tool’, which comprises attachment to an object because it serves as a symbol for a highly valued capability (Battarbee & Mattelmäki, 2002). Here, the object is a facilitator as it is needed for an activity which is meaningful to the person. However, the object can be replace at any time for another similar or better one.

Moreover, during the use of an object, the reflective level could be elicited. This is where consciousness takes part in the process, with people understanding and interpreting things (Norman, 2004). From a design point of view, people attach to objects as a ‘meaningful association’, which encloses attachment to an object because it is associated with a prized cultural or personal meaning or value (Battarbee & Mattelmäki, 2002). Here, the object is an symbolic product as it represents or refers to something outside the product itself. Both these categories can provide those feelings of security and place so important to adult human attachment.

Some indications of relationships with objects go beyond the visceral level of Norman (2004). According to Battarbee and Mattelmäki (2002), people could also attach to objects as ‘living objects’. This entails attachment to an object because it is seen as “a companion that has been with a person for so long that it is perceived as having personality, soul, character, is loved and cared for” (Battarbee & Mattelmaki, 2002, p. 4). Here, the object has become alive as it has a personal history of how it was made, acquired, and how it survived. Because of people’s natural social reactions towards autonomous objects (Reeves & Nass, 1996), this third category might be triggered more easily within human-robot interactions. Moreover, as concluded from chapter 2, social robots should be regarded as a new technological genre, for which the attachment to objects may be elicited more easily or at least differently so far compared to other objects and technological devices.

PARASOCIAL RELATIONSHIPS

The concept of parasocial interaction and parasocial relationship has been developed in communication science and media psychology to explain people's social and communicative reactions towards media protagonists. The concept was originally developed by Horten and Wohl (1956) who targeted at the phenomenon that people react to a persona on television by actually interacting with, for example, a smile, because they feel personally addressed by this persona. This imaginary relationship is based on the belief that the television persona is like other people in the viewer's social network (Rubin, Perse, & Powell, 1985). People thus tend to respond to television persona as if it occupies their own physical space. Since the origin of the concept parasocial interactions, several mass communication researchers have addressed the phenomenon, mainly adopting the uses and gratifications approach (Turner, 1993). If people behave as if television persona share their physical space, we might expect similar psychological processes between parasocial relationships and those in human-human relationships.

COMPARING PARASOCIAL RELATIONSHIPS AND HUMAN-HUMAN RELATIONSHIPS

Actually, research exploring the similarities between the development of parasocial relationships and human-human relationships have revealed that many aspects of parasocial relationships are similar to those of human-human relationships (Giles, 2002; Rubin & McHugh, 1987). First, human-human relationships are based on voluntary interaction and involves personal focus (Wright, 1978). Parasocial relationships are also voluntary, but the personal focus is what moves a viewer from detachment to parasocial interaction (Rosengren & Windahl, 1972). Second, human-human relationships serve companionships, utility, self-disclosure, and affection functions (Hays, 1984). Companioship has been a salient viewing motive for many types of viewers (Rubin, 1983). Third, social attraction appears to be a significant predictor of parasocial relationships development (Rubin & McHugh, 1987). This is also the case with human-human relationships. Consistent with human-human relationships, the similarity theory also applies to parasocial relationships. Those who perceive more similarity between themselves and a television persona strengthens the parasocial relationship (Turner, 1993). Fourth, there are also similar patterns in the development of social relationships and parasocial relationships (Rubin & McHugh, 1987). Like natural face-to-face relationship, parasocial relationships develop over a period of time and are enhanced when a television persona resemble interpersonal interaction (Horton & Wohl, 1956). When parasocial relationships show similarities to real-life aspects as in human-human relationships, maybe they also share similar preconditions for the establishment of such types of relationships with social robots.

APPLYING ATTACHMENT THEORY TO PARASOCIAL RELATIONSHIPS

Evidence has been found for the application of attachment theory to parasocial relationships as these relationships demonstrate at some level the three fundamental attributes of adult attachment (Weiss, 1982; Weiss, 1991). First, people will attempt to reduce the distance between themselves and their attachment figure and seek for proximity. Indeed, television viewers want to stay informed on their media characters by collecting trivia about them (Ferguson, 1992), reschedule their appointments or recording television broadcasts (Rubin & Bantz, 1989), and sometimes even attempt to contact their media character (Leets, deBecker, & Giles, 1995). Second, people should feel a sense of security when in presence of their attachment figure who provide their secure base. Although there is little direct research on the integration of parasocial relationships in people's lives (Cole & Leets, 1999), studies have revealed that companionship is a notable motive for many types of loyal viewers (Rubin, 1983). Third and last, it is expected that people show some form of protest when they are confronted with separation from their attachment figure. Indeed, a study on the dissolution of parasocial breakups indicates that viewers who have developed a meaningful relationship with their television persona where likely to be unhappy when these personas are taken off air (Cohen, 2003).

In conclusion, there are several important ways in which attachment to parasocial figures mirror the attachment process to actual people. Indeed, results show that people's willingness to bond with a television character relates to their attachment beliefs, whereby pre-occupied individuals are most likely and avoidant individuals are the least likely to form parasocial relationships (Cole &

Leets, 1999). These findings support Horton & Wohl's (1956) deficiency paradigm that people turn to parasocial relationships as a result of unfulfilled relational needs with 'real' humans. Moreover, just like parasocial interactions, social robots do not offer sincere social interactions. Indeed, with parasocial relationships, the interaction with a television persona provides less pertinent information than interpersonal communication because of the lack of immediate feedback (Perse & Rubin, 1989). Therefore, human-robot relationships may be regarded as a type of parasocial relationship.

9.3 HUMAN-ROBOT RELATIONSHIPS

The big question remains, would people really be able to establish relationships with robots? And what kind of relationships could these be? Based on people's reactions to existing socially interactive technologies, the answer seem to be that people are capable of establishing some kind of relationships with robots. Just look at the high selling rates of virtual pets such as the Tamagotchis, the user acceptance of ELIZA (Turkle, 2007), and people's ability to ascribe human attributes to computers (Reeves & Nass, 1996). All these examples indicate that the general public is willing to welcome artificial technology as companions in their lives.

To create artificial companions, either virtual agents or robots, that are capable of building long-term social relationships, the complex social dynamics of human behavior must be incorporated into the robotic design. Chapter 2 has described the necessary characteristics for robots to be believable as social actors. In designing social robots the challenge lies within the aspects of individualism and subjectivity, because of the differences in nature of robot bodies, experiences, and internal processes (Dautenhahn, 1995). Nevertheless, the relationships people can form with their pets (Archer, 1997) shows us that satisfying interspecies communication is possible. However, the interface between robots and humans has to be more carefully designed since humans and animals share the mammal morphology and physiology.

FORMS OF HUMAN-ROBOT RELATIONSHIPS

Some people even show a form of relationship with non-social functional robots. Sung et al. (2010) have described five types of relationships that occurred during the long-term acceptance of a functional robot, the Roomba vacuum cleaner: a tool, an agent, a mediating factor, and a mediator. When people treated the Rooma as a tool to perform tasks, the robot served as a utilitarian instrument to replace the manual labor, and to improve the quality of life. When the robot as regarded as an agent, it directly had an impact on the surrounding environments. The Roomba induced physical impacts, such as removing pet hair on the floor and moving smaller objects during navigation. When people considered the Roomba to be a mediating factor, it was observed that it had motivated people to make changes in the environment. The robot could sometimes also elicit negative impacts, such as breaking a mirror and dragging wires. The limited compatibility with the existing environment mediates people to make necessary changes to incorporate robots better. When people reflected on the robot as a mediator, the Roomba had enhanced social relationships among household members. Sung et al. (2009) found that children and men took more responsibility in cleaning after robot adoption. Furthermore, robots often became a new means for social activities. For instance, some people had demonstrated the robot to the visitors, or even brought it along on their vacation to show around. Finally, when people treat the robot as an agent, the Roomba had engaged with people in social events, such as name giving, genders, and personalities, and ascribe lifelike qualities to the robot.

Another study (Capenter et al., 2006) investigated how potential robot users differentiate between companion and service robot preferences and expectations. They found that humanoid products powerfully engage people's natural tendencies towards product attachment with people often relating to robots as social entities ranging from pets to human assistants. People may be more comfortable, at least initially, with robots that moderately capture human likeness, as high levels of human likeness might evoke negative reactions (e.g., the uncanny valley). The degree of a robot's human likeness should be directly proportional to the robot's functionality, as high levels of human likeness can lead to unrealistic expectations. People could spontaneously experience companionship in human-robot interactions, but people expect robots for domestic use, besides being socially interactive, to have more physically orientated capabilities as well.

WE ATTACH TO WHAT WE NURTURE

Social robots evoke a sense of mutual relating (Turkle, 2011). When people meet social robots, they feel a desire to nurture them. Dautenhahn (2007) refers to this as the caretaker paradigm, which considers humans as caretakers of robots and is clearly demonstrated in work of Breazeal (2002) on the robotic head Kismet with facial features. And with nurturance comes the fantasy of reciprocation, a need to be cared for in return. Experiences of these relationships with social robots have changed to “as though”, instead of “as if” experiences (Turkle, 2011), bringing the story of computational creatures and their evocation to a new place. The focus of interacting with social robots moved from the psychology of projection, as children do when playing their dolls, to the psychology of engagement.

Nowadays, children spend the majority of their leisure time in the house, with some form of advanced technology device (Beran & Ramirez-Serrano, 2011). In the last years, robots have started being developed to mimic human behavior. Given the importance of play as a source of socialization for children, combined with the human need to feel connected to others through relationships, it is plausible that when interacting with a robot, children would develop an affiliation with it (Kerepesi et al., 2006). A recent study by Melson et al. (2009), examining children’s understanding of robotic (i.e., AIBO) versus living animals (i.e., a real living dog), suggests that children may treat technical devices as if they were social beings. This provides a bases for a child-robot companionship. A majority of the children from the study of Beran and Ramirez-Serrano (2011) perceived robots as social beings and are willing to befriend them.

9.4 IMPLICATIONS FOR RESEARCH ON HUMAN-ROBOT RELATIONSHIPS

Multiple human-robot interaction studies show that people respond socially to robots, some of whom establish a kind of relationship with those robots. Based on these results, it is assumed that, especially those robots with additional features for self-disclosure and simulating empathic personalities in robots would provide a solid basis for companionship with robotic others (Levy, 2008). Moreover, the literature described above suggests that nonhumans play a more prominent and more active role in human interactions with their social environment than previously acknowledged by sociologists (Cerulo, 2009). People interact with robots in a similar manner as they do in face-to-face interactions (Kerepesi et al., 2006) and seemingly build relationships along the same rules as in human-human interactions (Banks, Willoughby, & Banks, 2008; Bickmore & Pickard, 2005). Therefore, it seems unnecessary to depart from the rules of human interpersonal communication when evaluating human-robot interactions (Krämer, von der Pütten, & Eimler, 2012). Hence, there will probably be more similarities between human-human and human-robot interactions than differences. Moreover, these similarities are needed to create meaningful interactions and relationships between humans and robots (Dautenhahn, 2002). Thus, if these premises hold true in future human-robot interaction research, the fundamentals for human-human interpersonal communication should form the point of departure for the development and implementation of social behaviors for robots.

The theory of need to belong predicts that people are in principle capable of bonding with robots, on the precondition that these robots are socially enough to satisfy the relation with respect to regular and meaningful interactions. (Krämer, von der Pütten, & Eimler, 2012). The media equation (Reeves & Nass, 1996), outlined in chapter 2.3, denoted that people ascribe human characteristics to nonhuman objects, which challenges the restriction of meaningful social interaction to minded human beings. Some interactionists (e.g., Sanders, 1993; Weindberg, 1997) have argued that humans can project mind onto nonhumans —including animals, objects and images— seemingly endowing them with human capacities. Similarly, the process of the media equation allows humans to perceive nonhumans as viable others in social interactions. This makes it irrelevant whether nonhumans actually possess the human capacities traditionally defined as critical for social interaction (Cerulo, 2009). Together, these arguments appeal for the inclusion of nonhumans in the conceptualization of meaningful social interaction. Thus robots endowed with capacities perceived by humans as social behavior could easily pass as legitimate partners in social interactions with humans.

It is difficult to predict whether people are capable of establishing long-term relationships with robots in the future. However, first research insights indicate that people are not only capable of building relationships with robots, they can also benefit from those relationships, such as the increase of our health (Wada & Shibata, 2007). It might thus be that social robots are just as capable as other humans of satisfying the human need to belong. In line with the theory on the need to belong (Baumeister & Leary, 1995), people easily intend to form relationships with robots (Krämer, von der Pütten, & Eimler, 2012). However, this bonding depends on various aspects of the robot, which indicates that people do not bond with just any object. Then again, already very simple interactions with robots seduce people to engage with them. Human-robot relationships seem to relate to the relationships people have with objects and the social reactions people have to these objects. However, triggered by the media equation, the interactions with social robots elicit social responses from human users. As a result, human-robot relationships are also related to human-human interpersonal communication, at least in the mind of the users.

Some researchers argue for a further exploration of robots as companion in our society and the value placed on relationships with them (Bartneck, Reichenbach, & Carpenter, 2008). Other researcher state that the ability to develop and maintain individual relationships may be a useful benchmark for human-robot interaction and that robots should be able to maintain relationships with people that are unique, individual, and personal (MacDorman, & Cowley, 2006). Since robots are predicted to increasingly serve in social roles for which some kind of relationship is beneficial, the next chapter will focus on our results investigating people’s willingness to treat robots as companions.

10

BONDING WITH SOCIAL ROBOTS

"I do think, in time, people will have, sort of, relationships with certain kinds of robots where they might feel that it is a sort of friendship, but it's going to be of a robot-human kind."
– Cynthia Breazeal –

With the upcoming rise of social robots, it becomes increasingly important to study the psychology of human-robot relationships (Levy, 2008). Yet, exploring human-robot relationships is a fairly new field of research. Human-computer interaction research already indicates that people treat computers as social actors, a phenomenon known as the media equation (Reeves & Nass, 1996). Being autonomous systems and possessing high levels of anthropomorphism, robots could easily be treated in a similar manner (Bartneck & Hue, 2008). Moreover, it has been argued that the fundamental human motivation of the need to belong (Baumeister & Leary, 1995; Cacioppo & Patrick, 2008) not only induces the desire for meaningful and enduring relationships with others, but also increases the probability that people will form emotional attachments to artificial beings as well (Krämer, Eimler, von der Putten, & Payr, 2012).

This chapter will present some primary results on influential factors that explain human-robot relationships. As there is no common knowledge yet on why some people are willing to treat social robots social robots as companions, some first explorations have been done using known preconditions why people become friends with each other as described in chapter 9. Parts of this chapter have been submitted as an article currently being reviewed as:

> Graaf, M.M.A. de, & Ben Allouch, S. (under review). The influence of expectation setting on companionship with a zoomorphic robot. *International Journal of Social Robotics*.

10.1 INTENTION TO BOND WITH A ZOOMORPHIC ROBOT

As a first step, the influence of the preconditions defined for human-human relationships on people's willingness to treat robots as companions has been tested in an experiment. As prior expectations (Lohse, 2011; Paepcke & Takayama, 2010) as well as gender (Schermerhorn, Scheutz, & Crowell, 2008) has been found to influence the results of human-robot interaction studies, it was decided to include these parameters in the experiment.

PRIOR EXPECTATIONS OF THE ROBOT"S LIFELIKENESS

People's prior expectations of a robot could influence their evaluations of that robot. Prior human-robot interaction research shows that people with high expectations of a robot's lifelikeness are more likely to be disappointed in their interactions with that robot compared to people with low expectations (Paepcke & Takayama, 2010). Lifelikeness is related to Bartneck et al.'s (2009) concept of animacy, which resembles the degree to which users believe the robot behaves and responds realistically. Several studies have indicated that a more animate robot improves the interaction between humans and robots (Bartneck et al., 2009; Groom et al., 2009) and users are more willing to perceive such a robot as a friendly companion (Libin & Libin, 2004). These results indicate that the user's expectation of the robot's lifelikeness might play a role for human-robot companionships. The concept of companionship is defined as the user's willingness to perceive or treat the robot as a companion.

As robots today still have quite limited interaction capabilities, this might cause a gap between the users' initial expectations of a robot and the actual experiences they have had after some first interactions with that robot (Lohse, 2011). In the Karotz Home Study, presented in chapter 8, the participants also encountered an expectation gap, which has caused some participants who had high expectations of the robot's capabilities and sociability to stop using the robot before the end of the study. Similar results were found by Fernaeaus et al. (2010), who's participants also stopped using the robot because of their high expectations about the robot's social and learning behavior which were not fulfilled.

Prior expectations have been determined to play an important role in human-human interactions as well (Blanck, 1993). As people react similarly to robots as they do to human beings (Kerepesi et al., 2006), it could be that this reaction increases people's expectations of the robot's abilities to behave as an lifelike social agent (Young et al., 2007). The Pleo Study will therefore focus on people's expectations about the robot's lifelikeness.

Two theories that could help explain the influence of people's prior expectations on behavioral outcomes are the self-fulfilling prophecy and the confirmation bias. The self-fulfilling prophecy describes how (social) expectations influence how people interact with one another (Merton, 1948). High expectations of another person makes us evaluate that other person as more capable in advance than when expectations are set low. The confirmation bias refers to the tendency for humans to seek for or interpret evidence in such a way that it will support someone's beliefs or prior expectations (Nickerson, 1998). Based on these theories, it was assumed that people with high expectations of a robot tend to find evidence from their interaction with that robot that supports their expectation, which, in turn, makes them evaluate that robot more positively than when having low prior expectations. Either way, prior expectations could possibly influence people's willingness to treat robots as companions, which makes it a vital determinant for further investigation. Based on this knowledge, the following hypotheses were formulated:

H_{1a}: *People with high prior expectations of the robot's lifelikeness evaluate the robot more positively on companionship.*

H_{1b}: *People with high prior expectations of the robot's lifelikeness evaluate the robot more positively on the preconditions of human-human relationships.*

H_{1c}: *The preconditions of human-human relationships better explain people's willingness to treat robots as companions in the high prior expectations condition.*

GENDER EFFECTS IN HUMAN-ROBOT INTERACTION

Besides the effects of prior expectations, also differences between men and women have been found within human-robot interaction research. When evaluating robot technologies in general, compared to males, females are more skeptical and afraid of becoming dependent to robots (Scopelliti, Giuliani, & Fornara, 2005), and are less likely to accept robotic technologies in their everyday lives (Arras & Cerqui, 2005). In the evaluation of humanoid robots, females tend to be more negative than males as well. Females rated a humanoid robot more negatively and anthropomorphized it less than males

(Schermerhorn, Scheutz, & Crowell, 2008). However, when the robot in question has a zoomorphic appearance, females tend to be more positive than males. In the evaluation of zoomorphic robots, females perceived a rabbit-shaped robot as having higher self-presentational potential and more useful (Eimler, Krämer, & von der Pütten, 2011), are more likely to follow the advice of a catlike robot (Vossen et al., 2009), and are more willing to build human-robot relationships with a robotic seal (Fujita, 2004; Turkle, 2011). The existence of gender differences in human-robot interaction studies motivates further investigation in the Pleo Study. Based on this knowledge, the following hypotheses were formulated:

H_{2a}: *Females evaluate a zoomorphic robot more positively on companionship.*
H_{2b}: *Females evaluate a zoomorphic robot more positively on the preconditions of human-human relationships.*
H_{2c}: *The preconditions of human-human relationships better explain people's willingness to treat a zoomorphic robot as a companions for females.*

METHOD

The influence of the preconditions defined for human-human relationships on people's willingness to treat robots as companions has been tested with an experiment.

EXPERIMENTAL DESIGN

In a between-subject experiment (high vs. low expectations), the influence of expectation setting on the preconditions of initiating human-robot relationships was explored. The two conditions were initiated by a manipulation of the description of the lifelikeness of the robot on the instruction and information sheet provided to the participants before the interaction with the robot. The text of the instruction sheet is presented in textbox 10.1, and the differences in wording of the robot lifelikeness for both conditions are provided in table 10.1 on the next page.

Textbox 10.1: Text on the instruction sheet

The robot you are going to meet …(A)… . Its name is Pleo and it resembles a …(B)…. Pleo …(C)… and it …(D)… . This means that it can perform …(E)… tasks and …(F)… from the interactions with you. Pleo can …(G)…, be …(H)… and it has …(I)… ways to move. Pleo has …(J)… possibilities for communication, for example …(K)… sounds and body movements.

The way Pleo moves is …(L)… , because its internal motors …(M)… . It has …(N)… speakers with which it can …(O)… , just like a …(P)… . In addition, Pleo has sensors …(Q)… through which it can sense …(R)… of your touch.

In short, Pleo is …(S)… social robot with …(T)… technologies, which offers …(U)… interaction possibilities.

Table 10.1: Manipulated wordings on the instruction sheet for the two conditions

Position	High expectation	Low expectation
A	…is recently introduced on the consumer market…	…has been on the market for some years…
B	…lifelike pet…	…moving stiffed animal…
C	…acts autonomously…	…cannot act autonomously…
D	…reacts limitless to your actions…	…responds to your actions in a limited way…
E	…many…	…a few…
F	…learns…	…cannot learn…
G	…communicate with you…	…produce some sounds…
H	…raised…	…nurtured…
I	…infinite..	…limited…
J	…many…	…a few…
K	…pet…	…stiffed animal…
L	…limitless and lifelike…	…limited and rigid…
M	…offer a lot of capacity…	…don’t offer enough capacity…
N	…multiple…	…two…
O	…produce some pre-installed sounds…	…freely communicate with you…
P	…real life pet…	…stiffed animal…
Q	…on its whole body…	…at a few positions on its body…
R	…all…	…some…
S	…a modern…	…an outmoded…
T	…the newest…	…old…
U	…very lifelike…	…some nice…

ZOOMORPHIC ROBOT

The robot used in the Pleo Study is the zoomorphic robot Pleo (see figure 10.1), which looks like a baby dinosaur and has approximately the size of a cat. Pleo can act autonomously, explores and reacts to the environment, interacts with its users and express emotions. Its rubber skin covers a mechanical frame. Pleo runs on fourteen different motors which are placed in different segments of his body. This motors enable it to shake its tail, bend its neck in different directions, control its mouth and eye-lids, and walk slowly. Pleo is capable of making different noises, which support its expression of feelings. It also has many different sensors all over its body, including eight capacitive touch sensors, two infrared (IR) sensors and a small CMOS camera, most of which are mounted on the back and head area. The robot operated fully autonomous using its standard build-in personality and behavior software.

Figure 10.1: Pleo, the robotic dinosaur

Using a robot with a zoomorphic embodiment has the advantage that the 'uncanny valley effect' can be better avoided (Fong, Nourbakhsh, & Dautenhahn, 2003). The 'uncanny valley effect' is a hypothesis which predicts that robots with human-like characteristics look and act almost, but not perfectly, like actual human beings, which causes a response of revulsion among human observers (Mori, MacDorman, & Kageki, 2012). Moreover, robots with a zoomorphic embodiment exhibit characteristics that are associated with domesticated animals and are designed to imitate living creatures that can establish a human-robot relationship similar to that of an owner-pet relationship (Kerepesi et al., 2006).

Although humans and animals differ in many aspects, such as language, learning and culture, still the human-human relationships analogy has helped to explain a large number of human-pet attachment studies (Sable, 1995), such as the attachment theory (Archer, 1997; Zilcha-Mano, Mikulincer, & Shaver, 2011). Thus, even though the robot used in this study is not humanoid but zoomorphic, we presumed that we could still build on theories of human-human relationships to explain why people are willing to bond with a zoomorphic robot. According to the classification of social robots by Breazeal (2003), Pleo would be a social interface robot that provides a natural interface by employing humanlike social cues and communicate modalities, whereas the social behavior only occurs at the interface level resulting in shallow models of social cognition.

PROCEDURE

Because previous experiences may be of influence (Bartneck et al., 2006), only those participants could take part in the Pleo Study who had never interacted with a robot before. First, the participants completed a questionnaire to measure their personality. Afterwards, participants were briefed about the study in which they could interact freely with the robot for approximately ten minutes. The choice for free interaction over task based interaction was to give the participants enough freedom for interacting with the robot in their own way and to avoid disappointment. It was assumed that a task-based interaction could lead to more disappointment when participants fail to perform a specific task, therefore free interaction seemed to be a better method. Before the interaction, participants first had to read the information and instruction sheet, containing the expectation setting. After interacting with the robot, the participants completed a second questionnaire in which they assigned a personality to the robot along with the constructs of physical attraction, reciprocal liking, intimacy and companionship.

MEASUREMENTS

Existing validated questionnaire items from human relationships research were used for the evaluation of the participant's intention to bond with a zoomorphic robot. Table 10.2 displays the mean scores of the variables in the two experimental conditions. All items (presented in appendix B) were presented on 7-point scales. To check the appropriateness of the experimental condition of the participant's prior expectations of the robot's lifelikeness, Bartneck et al.'s (2008) measurement for animacy was administered, which produced a reliable scale (α= .70).

Table 10.2: Variable means and standard deviations in the two conditions

	High expectation		**Low expectations**	
Preconditions	*M*	*SD*	*M*	*SD*
Companionship	3.78	1.40	3.35	0.88
Attractiveness	5.75	0.92	5.23	0.80
Similarity	0.38	0.74	0.65	0.59
Intimacy	4.45	1.18	3.87	0.95
Animacy	4.43	0.99	3.60	0.67

Note: Similarity is higher when the value is closer to zero.

Companionship was measured with a modified version of McCroskey et al.'s (1974) measurement for social attraction, which offered a reliable scale (α= .86). Attractiveness was measured with McCroskey et al.'s (1974) measurement for physical attraction, which offered a reliable scale (α= .85). The items were modified to be suitable for human-robot interactions.

Similarity was measured here with a focus on the similarity between the personality of participant and their evaluation of the robot's personality. For this purpose, a latent variable was composed obtained from the subtraction of the perceived personality of the robot from the participant's own personality. A value closer to zero represents higher similarity between the participant's personality and the robot's personality. As earlier studies have emphasized the greater impact of subjective similarity rather than that of objective similarity on interpersonal attraction (Condon & Crano, 1988; Hoyle, 1993), letting the participants indicate the robot's personality traits seemed to be an appropriate way to measure similarity.

Personality for both the participant and the robot was measured using the Dutch version of the big-five personality inventory, developed by Denissen et al. (2008), containing five personality traits: extraversion, agreeableness, conscientiousness, emotional stability, and openness. All scales of the personality factors were reliable (e.g., extraversion participant α= .83, robot α= .68; agreeableness participant α= .71, robot α= .74; conscientiousness participant α= .72, robot α= .72; emotional stability participant α= .78, robot α= .79; and openness participant α= .69, robot α= .88).

Intimacy was measured with a modified version of Laurenceau and Barret's (1998) scale which covers three items for the participant's self-disclosure (e.g., how much did you disclosure thoughts to the robot?), three items for the participant's evaluation of the self-disclosure of the robot (e.g., how much did the robot disclose thoughts and feelings?), and three items for the participant's evaluation of the responsiveness of the robot (e.g., To what degree did you feel understood by the robot?). The items were modified for human-robot interactions and produced a reliable scale (α= .70).

The measurement for reciprocal liking measurement was also obtained from Laurenceau and Barret (1998), which contains two questions: (1) Do you like the robot?; and (2) Do you think the robot likes you? Reciprocal liking was confirmed when the participant indicated that they both liked each other.

PARTICIPANTS

A total of 86 respondents (41 males and 45 females, age M= 25,76 and SD= 7,42) participated in the Pleo Study. To generate a more or less homogeneous group, participants were recruited within the faculty of behavior sciences at a university in The Netherlands. Table 10.3 on the next page shows that gender was equally distributed over the two experimental conditions (χ= 0.047, p= .829).

Table 10.3: Distribution of gender among the conditions

Gender		Condition: High expectation	Low expectation
Male	Count	20	21
	Expected	20.5	20.5
	Std. residual	0.1	-0.1
Female	Count	23	22
	Expected	22.5	22.5
	Std. residual	-0.1	0.1
Total		43	43

RESULTS

The formulated hypotheses were tested using multiple two-way ANOVA's, some Chi-squares and multiple stepwise regressions. However, as a first step, the manipulation of the two conditions were checked for appropriateness.

MANIPULATION CHECK

To check whether the participants in the high expectation condition actually had a higher expectation about the robot's human-likeness, an independent samples T-test was performed on animacy. The results show that the participant's prior expectations about the robots lifelikeness differed significantly ($t = -4.564$, $p < .001$). The participants in the high expectations condition perceived the robot as more lifelike ($M = 4.43$, $SD = 0.99$) than the participants in the low expectations condition ($M = 3.60$, $SD = 0.67$). This means that the manipulation of the participant's prior expectations of the robot's lifelikeness by means of the information and instruction sheet was appropriate.

EFFECTS OF PRIOR EXPECTATIONS VERSUS GENDER

A two way ANONA was performed to investigate the effect of the participants' prior expectations versus gender on people's willingness to treat robots as companions. The results indicate that there is no statistical difference between gender ($F(3,82) = 1.244$, $p = .268$) or prior expectation ($F(3,82) = 3.068$, $p = .084$), nor is there a significant interaction effect ($F(3,82) = 0.599$, $p = .441$) for these measures.

Another two way ANONA was performed to investigate the effect of the participants' prior expectations versus gender on attractiveness. The results indicate that there is no statistical difference between gender (F(3,82)= 0.424, p= .517) nor is there a significant interaction effect (F(3,82)= 2.285, p= .134) for attractiveness. However, the participants' prior expectations did have a significant effect for attractiveness (F(3,82)= 8.314, p= .005, partial η^2= .09). Participants with high prior expectations of the robot's lifelikeness evaluated the robot as more attractive (M= 5.77, SE= 0.13) than participants with low prior expectations (M= 5.23, SE= 0.13). Figure 10.2 displays the marginal means of males and females in both conditions.

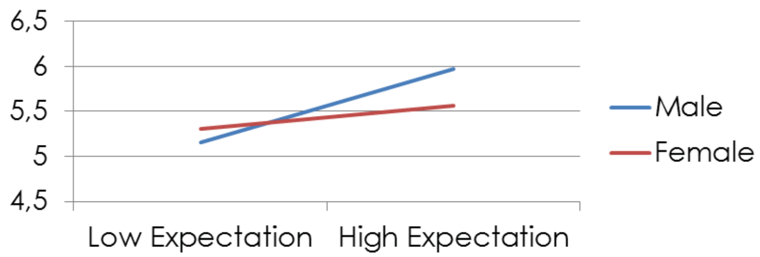

Figure 10.2: Marginal means of attractiveness in the two conditions

Next, a two way ANONA was performed to investigate the effect of the participants' prior expectations versus gender on similarity. The results indicate that the participants' prior expectations did not have a significant effect on similarity (F(3,82)= 3.765, p= .056) nor is there a significant interaction effect (F(3,82)= 2.008, p= .160) for similarity. However, there is a significant gender effect (F(3,82)= 4.750, p= .0329, partial η^2= .06) for similarity. Females evaluated the robot as more similar to themselves in both conditions (e.g., high expectation M= 0.33, SE= 0.14; low expectation M= 0.40, SE= 0.14) than males (e.g., high expectation M= 0.44, SE= 0.15; low expectation M= 0.91, SE= 0.14). Figure 10.3 on the next page displays the marginal means of males and females in both conditions.

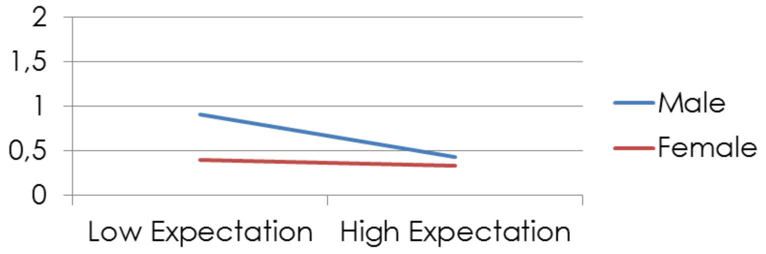

Figure 10.3: Marginal means of similarity in the two conditions

Another two way ANONA was performed to investigate the effect of the participants' prior expectations versus gender on intimacy. The results indicate that there is no statistical difference between gender (F(3,82)= 0.125, p= .724) nor is there a significant interaction effect (F(3,82)= 0.123, p= .727) for intimacy. However, the participants' prior expectations did have a significant effect for intimacy (F(3,82)= 6.169, p= .015, partial η^2= .07). Participants with high prior expectations of the robot's lifelikeness evaluated the robot as providing more intimacy (M= 4.45, SE= 0.17) than participants with low prior expectations (M= 3.87, SE= 0.17). Figure 10.4 displays the marginal means of males and females in both conditions.

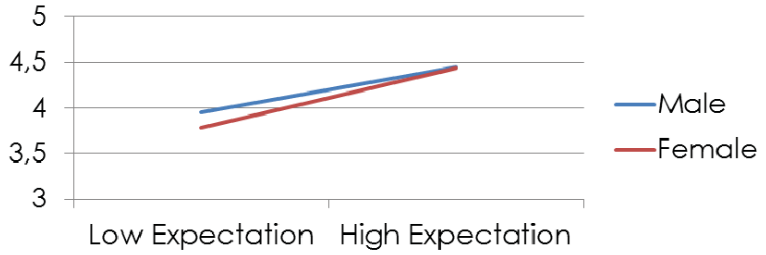

Figure 10.4: Marginal means of intimacy in the two conditions

Two separate Chi-square test were performed to investigate the effect of people's prior expectations of the robot's lifelikeness and the effect of gender on reciprocal liking (see table 10.4). The results show that there was no significant difference for reciprocal liking in the distribution in the two experimental conditions (χ= 2.324, p= .127), nor for gender (χ= 0.025, p= .875).

Table 10.4: Distribution of reciprocal liking in the conditions

Reciprocal liking		Condition: High expectation	Condition: Low expectation	Gender: Male	Gender: Female
Yes	Count	28	21	23	26
	Expected	24.5	24.5	23.4	25.6
	Std. residual	0.7	-0.7	-0.4	0.4
No	Count	15	22	18	19
	Expected	18.5	18.5	17.6	19.4
	Std. residual	-0.8	0.8	0.4	-0.4
Total		43	43	41	45

PRECONDITIONS OF COMPANIONSHIP WITH A ZOOMORPHIC ROBOT

To explore the influential factors of the participants' willingness to treat robots as companions, a stepwise multiple regression was performed. Together, intimacy (β= .391, t= 4.083, p < .001), similarity (β= -.245, t= -3.307, p= .001), and reciprocal liking (β= .327, t= 3.379, p= .001) explained 58% of the variance of companionship (see table 10.5).

Table 10.5: Significant regression paths for companionship on full sample

Preconditions	Companionship: β	Companionship: t	Companionship: p
Attractiveness	.122	1.459	.149
Similarity	**-.429**	**-3.307**	**.001**
Intimacy	**.391**	**4.083**	**.000**
Reciprocal liking	**.327**	**3.379**	**.001**
R^2	.58		
f	40.311		
df	3,82		
p	.000		

However, when controlled for the experimental condition, different regression models were found (see table 10.6). For participants with low prior expectations of the robot's lifelikeness, 33% of the variance of companionship was explained by intimacy (β= .325, t= 2.114, p= .041) and reciprocal liking (β= .353, t= 2.294, p= .027). For participants with high expectations of the robot's lifelikeness, 72% of the variance of companionship was explained by similarity (β= -.391, t= -4.487, p < .001) and reciprocal liking (β=.641, t= 7.359, p < .001).

Table 10.6: Significant regression paths for companionship controlled for experimental condition

	Companionship					
	Low expectation			High expectation		
Preconditions	*β*	*t*	*p*	*β*	*t*	*p*
Attractiveness	.113	0.818	.418	.165	1.649	.107
Similarity	-.044	-0.324	.748	**-.391**	**-4.487**	**.000**
Intimacy	**.325**	**2.114**	**.041**	.244	1.932	.061
Reciprocal liking	**.353**	**2.294**	**.021**	**.641**	**7.359**	**.000**
R^2	.33			.72		
F	11.279			53.903		
Df	2,40			2,40		
P	.000			.000		

Moreover, when controlled for gender, different regression models for males and females were found (see table 10.7). For males, 78% of the variance of companionship could be explained by similarity (β= -.305, t= -3.666, p= .001), intimacy (β= .395, t= 3.896, p < .001), and reciprocal liking (β= .387, t= 3.788, p= .001). For females, only 45% of the companionship could be explained by physical attraction (β= .333, t= 2.588, p= .013) and intimacy (β= .464, t= 3.604, p= .001).

Table 10.7: Significant regression paths for companionship controlled for gender

	Companionship					
	Male			Female		
Preconditions	*β*	*t*	*p*	*β*	*t*	*p*
Attractiveness	-.096	-1.058	.297	**.333**	**2.288**	**.013**
Similarity	**-.305**	**-3.666**	**.001**	-.213	-1.894	.065
Intimacy	**.395**	**3.896**	**.000**	**.464**	**3.604**	**.001**
Reciprocal liking	**.387**	**3.788**	**.001**	.193	1.216	.231
R^2	.78			.45		
F	47.499			19.438		
df	3,37			2,40		
p	.000			.000		

REFLECTION ON RESULTS ON INTENTION TO BOND WITH A ROBOT

It was hypothesized that companionship would be more positively evaluated by people with high prior expectations of the robot's lifelikeness (H1[a]) as compared to people with low prior expectations of the robot's lifelikeness. Moreover, it was hypothesized that companionship would be more positively evaluated by females (H2[a]) as compared to males. However, there were no statistically significant differences for gender or prior expectation for people's willingness to treat the zoomorphic robot Pleo as a companion. Therefore, hypothesis 1^a and 2^a are rejected.

Based on earlier findings, it was hypothesized that the preconditions of human-human relationships would be more positively evaluated by people with high prior expectations of the robot's lifelikeness ($H1^b$) and by females ($H2^b$). Having high prior expectations resulted in higher evaluations of the robot's attractiveness and the perceived intimacy. Therefore, hypothesis $H1^b$ was partially accepted. The results for gender differences show that females only evaluated more similarity in both experimental conditions compared to males. The other preconditions were not evaluated differently between males and females. Therefore, hypothesis $H2^b$ was only partly supported.

Finally, it was hypothesized that the preconditions of human-human relationships could better explain the variance of the willingness to treat the robot as a companion for participants with high expectations of the robot's lifelikeness ($H1^c$) and for females ($H2^c$). The results show that the preconditions of human-human relationships were better predictors of companionship for people with high expectations of the robot's lifelikeness. Therefore, $H1^c$ is fully supported. However, the results for gender differences show that the preconditions of human-human relationships were better predictors of companionship for males instead of females. Therefore, $H2^c$ was rejected.

10.2 BONDING WITH A ZOOMORPHIC ROBOT OVER TIME

The results from the experiment described in section 10.1 shows that the same preconditions that explain why people become friends could also partially help explain people's willingness to treat zoomorphic robots as companions. As a next step, it was investigated how the explanatory power of these preconditions for human-robot relationships evolve over time.

METHOD

A second goal of the Karotz Home Study was to investigate long-term human-robot relationships. Details on the robot, procedure, data analysis and participants of the Karotz Home Study have been presented in chapter 8. The similar scales as presented in section 10.2 were used here to measure the preconditions of human-human relationships for explaining the participants' willingness to treat a zoomorphic robot as a companion. These measurements were obtained during each of the six acceptance phases among the remaining participants (i.e., expectation n= 102, confrontation n= 102, adoption n= 100, adaptation n= 98, integration n= 75, and identification phase n= 55). Details on the internal consistency of each construct is provided in table 10.8 and 10.9, which were all above the threshold of $\alpha > .70$ (Nunnally, 1978). Unfortunately, low internal consistencies of the Big Five measurements were observed for the robot's personality. However, for each of the Big Five personality traits for the robot there was one reliable measurement and all of the Big Five personality traits for the participants were found to be reliable.

Table 10.8: Internal consistency of the companionship variables in all acceptance phases

	Internal consistency (α)					
Preconditions	Expectation	Confrontation	Adoption	Adaptation	Integration	Identification
Companionship	.85	.86	.87	.88	.92	.88
Attractiveness	.90	.93	.95	.95	.94	.91
Intimacy	.91	.87	.83	.79	.93	.89

Table 10.9: Internal consistency of the personality variables

Personality variables	**Internal consistency (α)**
User's extraversion	.84
User's agreeableness	.82
User's conscientiousness	.79
User's emotional Stability	.81
User's openness	.84
Robot's extraversion	.76
Robot's agreeableness	.82
Robot's conscientiousness	-
Robot's emotional Stability	.61
Robot's openness	.82

EVALUATION OF COMPANIONSHIP VARIABLES OVER TIME

Participants evaluations of the preconditions of companionship were assessed using a recurring questionnaire based on the preconditions of human friendship formation as addressed in the theoretical background. Factorial repeated measures ANOVA with time (6 acceptance phases) as a within subjects factor and gender (male vs. female), household type (single vs. couple vs. young family vs. mature family) and pet ownership (pets vs. no pets) as the between subjects factor was used to investigate the changes in the evaluation of these precondition over time. Factorial repeated measures ANOVA with more than three time points carries some concerns about the sphericity assumption, which is the assumption of equal variances across groups in between subjects ANOVA. For most analyses, Mauchly's chi-square test for violations of the sphericity assumption was significant, which indicates non-equal variances. Therefore, to increase statistical power, the F-scores from the Greenhouse-Geisser test are reported for all factorial repeated measures ANOVA tests. Moreover, some participants dropped out before the end of the Karotz Home Study and therefore did not complete all the questionnaires. Missing values because of this drop-out were replaced with the mean score of that time point in this analysis. Table 10.10 on the next page presents the results of the ANOVA tests.

Table 10.10: Evaluations of the precondition of human friendship formation in the different acceptance phases

	Pre-adoption		**introduction**		**adoption**		**adaptation**		**incorporation**		**identification**				
Preconditions	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(5,96)$	p	*part.* η^2
Attractiveness	5.05	0.88	4.84	0.83	4.41	1.08	4.22	0.84	4.73	0.80	3.74	1.11	33.731	.000	.252
Intimacy	2.98	1.15	2.09	0.59	2.03	0.65	1.83	0.60	2.08	0.89	2.29	0.79	39.661	.000	.284
Companionship	3.13	1.06	2.39	0.67	1.93	0.67	1.93	0.66	2.04	0.89	3.25	1.09	56.709	.000	.362

COMPANIONSHIP

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the participants' willingness to treat robots as companions ($F(5,96) = 56.709$, $p < .001$, partial $\eta^2 = .362$). As table 10.10 on the previous page shows, the participants' evaluation of their willingness to treat the robot as a companions declined up until the incorporation phase and increased vigorously in the identification phase even past the initial evaluation of sociability in the expectation phase. A Bonferroni post-hoc test indicated that the evaluation of the participants' willingness to treat robots as companions in both the pre-adoption and introduction phase differed significantly from all the other evaluations (between all pairs $p < .001$). The evaluation of the participants' willingness to treat robots as companions in all other phases only differed significantly from the evaluation in the identification phase (between all pairs $p < .001$). There was no significant main effect for either gender or household type or pet ownership for the participants' willingness to treat robots as companions, nor were there any significant interaction effects.

ATTRACTIVENESS

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of the robot's attractiveness ($F(5,96) = 7.972$, $p < .001$, partial $\eta^2 = .097$). As table 10.10 shows on the previous page shows, the participants' evaluations of the robot's attractiveness declined since the introduction, seemed to increase again in the incorporation phase but drops back in the identification phase. A Bonferroni post-hoc test indicated the evaluation of attractiveness in the expectation phase differed significantly from the evaluation in all other phases with the exception of the evaluation at the introduction (for all pairs $p < .05$). The evaluation of attractiveness at the introduction differed significantly from the evaluation in the adoption ($p = .004$), adaptation ($p < .001$) and identification phase ($p < .001$).

Moreover, the evaluation of attractiveness in the adoption phase differed significantly from the evaluation in both the incorporation (p= .04) and identification phase (p < .001). In addition, also the evaluations of attractiveness in either the adaptation, incorporation and identification phase differed significantly from one another (for all pairs p < .01). There was no significant main effect for either gender, pet ownership or user group for attractiveness, nor were there any significant interaction effects. However, a main effect was found for household type (F(4,95)= 5.634, p < .001, partial η^2= .192). Overall, participants from mature families evaluated the robot as more attractive than all other household types (see figure 10.5).

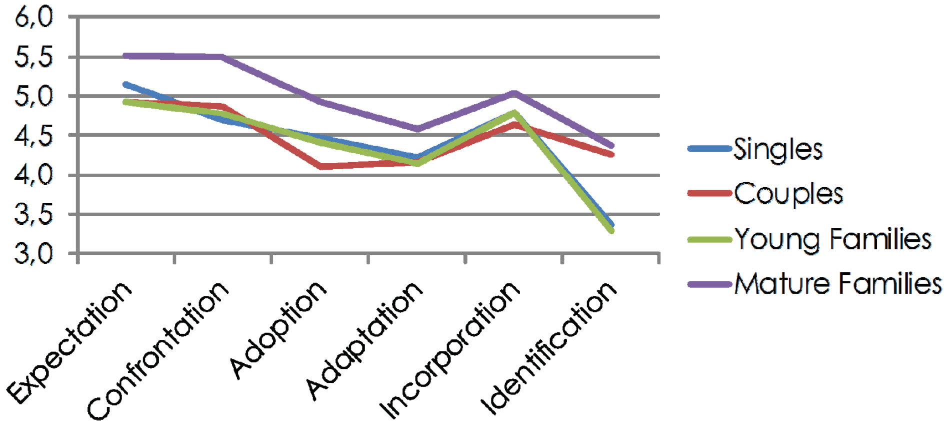

Figure 10.5: Attractiveness evaluated by the different household types over time

SIMILARITY

Two independent T-tests were used to investigate differences in similarity for both gender and pet ownership. For similarity, there was no gender effect (t= -0.052, p= .959) nor an effect for pet ownership (t= -0.186, p= .853). And a one-way ANOVA was performed to investigate an effect of household type on similarity. However, the result was non-significant (F(4,95)= 0.982, p= .421).

INTIMACY

A factorial repeated measures analysis of variance showed that the acceptance phase significantly affected the evaluation of intimacy (F(5,96)= 39.661, p < .001, partial η^2= .284). The participants' evaluation of intimacy declined up until the adaptation phase and seems to increase from that point in time (see table

10.10 on page 389). A Bonferroni post-hoc test indicated that the evaluation of intimacy in the expectation phase differed significantly from all the other evaluations of intimacy (between all pairs $p < .001$). Furthermore, also the evaluation of intimacy differed significantly between the confrontation and adaptation phase ($p = .009$), between the adaptation and incorporation phase ($p < .001$), and between the incorporation and identification phase ($p < .001$). This means that the participants evaluated the level of intimacy between themselves and the robot significantly higher towards the end.

Moreover, there was a significant effect for user group ($F(2,99) = 3.486$, $p = .034$, partial $\eta^2 = .066$) and household type ($F(4,95) = 3.360$, $p = .013$, partial $\eta^2 = .124$) on intimacy. Overall, users and mature families reported perceiving higher levels of intimacy compared to other user groups and household types (see figure 10.6 and figure 10.7, respectively). Additionally, there was also a significant interaction effect between acceptance phase and household type ($F(20,78) = 1.782$, $p = .026$, partial $\eta^2 = .070$). There were no significant main effect for gender or pet ownership for intimacy, nor were there any significant interaction effects for these variables.

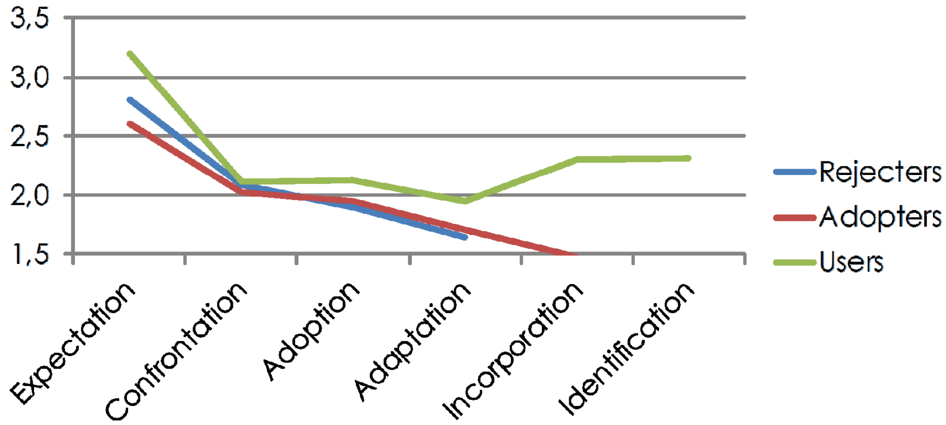

Figure 10.6: Intimacy evaluated by the user groups over time

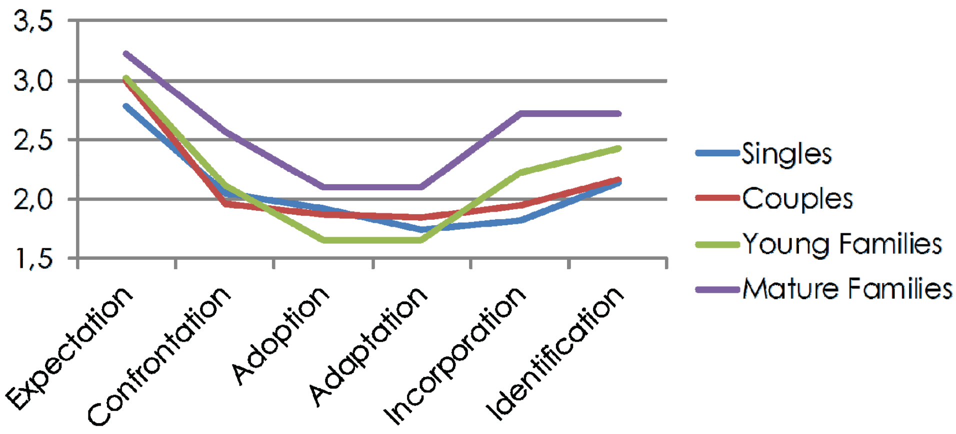

Figure 10.7: Intimacy evaluated by the different household types over time

RECIPROCAL LIKING

A Chi-square test was performed to see if the participants' evaluations of reciprocal liking differed across the acceptance phases (see table 10.11). The results show that there is a significant association between the acceptance phase and the participants' evaluations of reciprocal liking ($\chi^2(6)= 62.689$, $p < .001$). The values of the standardized residuals are used to further interpret the results of the Chi-square test. The standardized residuals represent the error between the observed frequency (i.e., what the data actually observes) and expected frequency (i.e., what the model predicts). A positive value indicates an overrepresentation and a negative value points to an underrepresentation. A value higher than 1.96 or lower than -1.96 for either the over- or underrepresentation is considered to be significant at $p < .05$ (Fields, 2013). The results in table 10.11 on the next page show that, in the identification phase, there is a significant underrepresentation for liking each other ($z= -3.6$) and a significant overrepresentation for not liking each other ($z= 5.3$).

Table 10.11: Evaluation of reciprocal liking in the different acceptance phases

		Acceptance phase					
Reciprocal liking		Pre-adoption	introduction	adoption	adaptation	incorporation	identification
No	Count	25	25	29	26	27	40
	Expected	32.9	32.9	32.3	31.6	24.5	17.7
	Std. residuals	-1.4	-1.4	-0.6	-1.0	0.5	5.3
Yes	Count	77	77	71	72	49	15
	Expected	69.1	69.1	67.7	66.4	51.5	37.3
	Std. residuals	1.0	1.0	0.4	0.7	-0.3	-3.6

In addition, differences in reciprocal liking for gender, household type, user group and pet ownership were also investigated with a Pearson's Chi-square test. The results show that there is no significant effect for gender ($\chi^2(1)= 0.039$, $p= .844$), household type ($\chi^2(3)= 0.606$, $p= .895$), pet ownership ($\chi^2(1)= 1.049$, $p= .306$). However, there was a significant association between user group and the participants' evaluations of reciprocal liking ($\chi^2(2)= 7.968$, $p= .019$). Nonetheless, further investigation of the standardized residuals reveals that there are also no significant under- or overrepresentations of reciprocal liking in the user groups. The results are presented in table 10.12.

Table 10.12: Evaluation of reciprocal liking among user groups

		User group		
Reciprocal liking		Rejecter	Adopters	Users
No	Count	8	9	16
	Expected	8.4	6.8	17.7
	Std. residuals	-0.5	2.1	-0.9
Yes	Count	18	12	39
	Expected	17.6	14.2	37.3
	Std. residuals	0.3	-1.4	0.6

INFLUENTIAL VARIABLES OF BONDING WITH A ROBOT OVER TIME

The variables that explain the participants' willingness to treat robots as companions for each acceptance phase separately were investigated using stepwise multiple regression analysis.

EXPECTATION PHASE

A stepwise multiple regression indicated that attractiveness ($\beta= .242$) and intimacy ($\beta= .675$) explained 59% of the variance of the participants' willingness to treat the robot as a companion ($F(2,99)= 74.730$, $p < .001$). Table 10.13 displays the results of the regression analyses on the complete sample.

Table 10.13: Regression analysis for companionship in the expectation phase

	Companionship		
Preconditions	*t*	*β*	*p*
Attractiveness	**4.986**	**.391**	**.000**
Similarity	0.878	.080	.459
Intimacy	**4.842**	**.380**	**.000**
Reciprocal liking	**3.473**	**.227**	**.001**
R^2	.59		
f	74.730		
df	2,99		
p	.000		

THE CONFRONTATION

A stepwise multiple regression indicated that attractiveness (β= .292) and intimacy (β= .457) explained 43% of the variance of the participants' willingness to treat the robots as a companion (F(2,99)= 38.556, p < .001). Table 10.14 displays the results of the regression analyses on the complete sample.

Table 10.14: Regression analysis for companionship in the confrontation phase

	Companionship		
Preconditions	*t*	*β*	*p*
Attractiveness	**3.265**	**.292**	**.002**
Similarity	-0.293	-.023	.770
Intimacy	**5.104**	**.457**	**.000**
Reciprocal liking	-0.010	-.117	.907
R^2	.43		
f	38.556		
df	2,99		
p	.000		

THE ADOPTION PHASE

A stepwise multiple regression indicated that attractiveness (β= .292) and intimacy (β= .457) explained 55% of the variance of the participants' willingness to treat the robots as a companion (F(3,96)= 40.870, p < .001). Table 10.15 displays the results of the regression analyses on the complete sample.

Table 10.15: Regression analysis for companionship in the adoption phase

	Companionship		
Preconditions	*t*	*β*	*p*
Attractiveness	**2.883**	**.245**	**.005**
Similarity	-0.380	-.026	.705
Intimacy	**6.231**	**.512**	**.000**
Reciprocal liking	**2.381**	**.172**	**.019**
R^2	.55		
f	40.870		
df	3,96		
p	.000		

THE ADAPTATION PHASE

A stepwise multiple regression indicated that intimacy (β= .610) explained 37% of the variance of the participants' willingness to treat the robots as a companion ($F(1,96)$= 56.931, p < .001). Table 10.16 displays the results of the regression analyses on the complete sample.

Table 10.16: Regression analysis for companionship in the adaptation phase

	Companionship		
Preconditions	*t*	*β*	*p*
Attractiveness	0.679	.062	.499
Similarity	0.864	.070	.390
Intimacy	**7.545**	**.610**	**.000**
Reciprocal liking	1.887	.165	.062
R^2	.37		
f	56.931		
df	1,96		
p	.000		

THE INTEGRATION PHASE

A stepwise multiple regression indicated that intimacy (β= .831) explained 69% of the variance of the participants' willingness to treat the robots as a companion ($F(1,74)$= 165.167, p < .001). Table 10.17 displays the results of the regression analyses on the complete sample.

Table 10.17: Regression analysis for companionship in the integration Phase

	Companionship		
Preconditions	*t*	*β*	*p*
Attractiveness	**12.852**	**.831**	**.000**
Similarity	-0.695	-.045	.489
Intimacy	**12.852**	**.831**	**.000**
Reciprocal liking	0.813	.057	.419
R^2	.67		
f	165.167		
df	1,74		
p	.000		

THE IDENTIFICATION PHASE

None of the variables could explain the participants' willingness to treat robots as companions in the identification phase.

DEMOGRAPHIC DIFFERENCES FOR COMPANIONSHIP

Additionally, potential demographic differences for the influence of the preconditions of human-human relationships on people's willingness to treat the robot as a companion were investigated. For this purpose, it was chosen to collect the overall average from all phases together of these measure to perform the regression analyses.

Gender differences. A multiple stepwise regression for the preconditions of companionship was performed for both males and females. For males, together intimacy (β= .626) and reciprocal liking (β= .316) explained 55% of the variance of companionship (F(2,45)= 29.828, p < .001). For females, the explained variance of companionship (F(1,52)= 74.972, p < .001) was 58% with intimacy (β= .768) as the only explanatory variables.

Differences for household type. A multiple stepwise regression for the preconditions of companionship was performed for all household types. For singles, it was intimacy (β= .726) that explained 51% of the variance of companionship (F(1,26)= 28.916, p < .001). For couples, the explained variance of companionship (F(1,24)= 19.264, p < .001) was only 42% with intimacy (β= .667) as the explanatory variable. For young families, together intimacy (β=

.589) and reciprocal liking (β= .355) explained 48% of the variance of companionship (F(2,20)= 11.053, p= .001). For mature families, the explained variance of companionship (F(1,13)= 15.586, p= .002) was 51% with intimacy (β= .738) as the only explanatory variable.

Differences for pet ownership. A multiple stepwise regression for the preconditions of companionship was performed for participants with and without a pet. For pet owners, together intimacy (β= .664) and reciprocal liking (β= .285) explained 52% of the variance of companionship (F(2,44)= 25.399, p < .001). For participants without a pet, the explained variance of companionship (F(2,46)= 49.369, p < .001) was 67% with attractiveness (β= .228) and intimacy (β= .663) as the explanatory variables.

Differences for user group. A multiple stepwise regression for the preconditions of companionship was performed for all user groups. For rejecters, it was reciprocal liking (β= .695) alone that explained 46% of the variance of companionship (F(1,21)= 19.648, p < .001). For discontinuers, the explained variance of companionship (F(1,30)= 24.749, p < .001) was 43% with intimacy (β= .672) as the only explanatory variable. For users, the explained variance of companionship (F(1,45)= 65.186, p < .001) was 58% with intimacy (β= .769) as the only explanatory variable.

REFLECTION ON RESULTS ON LONG-TERM HUMAN-ROBOT RELATIONSHIPS

Examining the results from the long-term Karotz Study, it was observed that the evaluation of the preconditions that explained people's willingness to treat a zoomorphic robot as a companion evolved over time. Similar to the acceptance variables in the Karotz Study (see chapter 8), a mere-exposure effect was also observed for the preconditions within the data. A mere-exposure effect is the tendency for novel stimuli to be liked more or rated more positively after someone has been repeatedly exposed to them.

Intimacy seems to represent one of the most important preconditions that explained the willingness to treat a zoomorphic robot as a companion in long-term interactions. Intimacy was always among the predictors that explained companionship in each phase and the influence of intimacy for explaining companionship increased over time. Moreover, in the adaptation (i.e., one month after the introduction) and the integration (i.e., two months after the introduction) phase, intimacy was the only predictor of companionship for the complete sample in the Karotz Study. Thus, the possibility for people to share personal information with robots, and having those robots respond in an empathic way seems important for the establishment of human-robot relationships in long-term interactions. There were no striking demographic differences for the explanatory power of the preconditions of companionship. For all groups, the most important predictor for companionship with the robot was intimacy, sometimes additionally supported by reciprocal liking.

PART V

GENERAL DISCUSSION

11

MAIN CONCLUSIONS

"The only thing I know is that I know nothing."

– Socrates –

This dissertation's starting point was building further on the findings from the EU-funded Social Engagement with Robots and Agents (SERA) project, which resulted in two main research questions for the current research:

RQ_a: Which acceptance variables in which phase of acceptance are the most important determinants of social robot acceptance in domestic environments?

RQ_b: How do users assess their willingness to treat robots as companions before and after the adoption of a social robot?

Together, these two research questions formed the core of the research presented in this dissertation and resulted in the following goal of this dissertation, which is threefold: (1) providing insight into which variables most influence the acceptance of social robots in domestic environments; (2) investigating how people's user experiences with a social robot develop over time; and (3) presenting some first insights into the variables that explain why some people are willing to treat robots as companions. To achieve these goals and guide the research presented in this dissertation, eight additional research questions were formulated.

The studies on social robot acceptance presented in this dissertation focused on the domestic context and were conducted among participants in The Netherlands. Thus, the conclusions drawn from these studies are applicable to the evaluation of social robots for domestic purposes. However, the findings on the acceptance experiences and evaluations of social robots are believed to be transferable to other robots whose main purpose is interacting socially with their users. Furthermore, this dissertation adopted a user-centered perspective because users may provide vital opinions and perceptions that will help researchers, designers, and engineers to create social robots that fit the special needs and demands of potential future users.

When studying social robot acceptance, it is important to make a clear distinction between the concepts of technology adoption and technology acceptance. Here, technology adoption is regarded as the initial decision to buy and start using a technology. By contrast, technology acceptance is a process that starts with an individual becoming aware of a technology and, ideally, ends with that individual incorporating the use of that technology in his or her everyday life to the extent that it exceeds its functional purpose and becomes a personal object as the individual becomes attached to it. This dissertation has provided a framework for the process of technology acceptance that defines six phases for this long-term process.

This chapter begins by answering the eight underlying research questions that guided the research process to achieve the three primary goals of this dissertation (chapter 11.1). Subsequently, the two main research questions of this dissertation are answered in chapter 11.2.

11.1 SUMMARY OF THE MAIN FINDINGS

In addition to the two main research questions of this dissertation, eight underlying research questions were formulated to guide the research process, dividing this dissertation into five parts. These research questions relate to the definition of social robots, the model of social robot acceptance, the long-term process of user acceptance, and the relationships between social robots and their human users. This paragraph provides the answers to these questions.

DEFINING SOCIAL ROBOTS

The first underlying research question was the following: *How can social robots be defined conceptually?* This dissertation combined the descriptions of social robots from other scholars (e.g., Bartneck & Forlizzi, 2004; Breazeal, 2002; Lee, Park, & Song, 2005) and defined social robots as robots that elicit social responses from their human users because they follow the rules of behavior expected by their human users. However, given that the technology will inevitably change in the future, the definition of social robots may similarly change. Yet, the core of all the definitions in the literature, which is interacting socially in a human-like way, will most likely remain.

To behave socially, robots must possess a set of essential social behaviors. The two most important social abilities indicated by the participants in the Karotz Home Study were two-way interaction and possessing thoughts, feelings and emotions. These social abilities are related to the social characteristics of dialog, learning and developing social competences, exhibiting a distinctive personality, and social learning that were presented by Fong et al. (2003) and Mutlu (2012). Dialog entails that robots should be capable of verbally communicating with us. Learning and developing social competences entail that robots should possess a considerable amount of social skills for interacting with their human counterparts. Exhibiting a distinctive personality entails that robots should have a compelling personality (Breazeal, 2005) that can be expressed through emotions, embodiment, motion, manner of communication, and the tasks that they perform (Fong et al., 2003; Severson-Eklund, Green, & Hüttenrauch, 2003; Yoon et al., 2000). Social learning and imitation partly entail the robot's ability to understand human mental models (Multu, 2011). However, roboticists need to acknowledge that social robots in themselves are essentially not social. Social robots are machines programmed in such a way that their behavior is perceived by users as social, which, in turn, evokes social responses from users. In other words, the robot's sociability lives in the interpretation of the user.

A MODEL FOR SOCIAL ROBOT ACCEPTANCE

Part II of this dissertation aimed to provide and test a conceptual model for social robot acceptance. A first step was presenting an overview of existing theories on human behavior and technology acceptance to gain insights into the concepts related to social robot acceptance. This part was guided by the second underlying research question: *What theoretical insights can be derived from a review of the existing variables, from a user's perspective, that influence the process of social robot acceptance in domestic environments?* Based on a thorough evaluation of existing theories of human behavior and technology adoption, the framework of the theory of planned behavior (Ajzen, 1991) was used to propose a new model for social robot acceptance for the following reasons: (1) it is especially suitable for explaining and predicting volitional behaviors, including technology adoption (Mathiesson, 1991; Taylor &

Todd, 1995; Venkatesh & Brown, 2001); (2) it has been successfully applied to explain a wide range of behaviors (Ajzen, 1991); and (3) its origin invites researchers to extend the model by adapting it to a specific behavior (Ajzen, 1991). Following other scholars (Taylor & Todd, 1995; Venkatesh & Brown, 2001), the three constructs of attitudinal beliefs, social normative beliefs and control beliefs from the theory of planned behavior were decomposed to reflect the specific underlying factors based on a detailed review of the literature on social robot acceptance.

Based on the theoretical framework of the theory of planned behavior (Ajzen, 1991), a conceptual model guided by the third underlying research question was presented: *Which variables, from a user's perspective, influence the initial adoption and sustained use of social robots in domestic environments, and how can these be modeled in a conceptual model of social robot acceptance?* Because intentions are found to be good predictors of specific behavior, they have become a critical part of many contemporary theories of human behavior (Ajzen & Fishbein, 2005). Although these theories differ in their details, they all show convergence on a small number of variables that account for much of the variance in behavioral intentions. These variables can be viewed as the three major types of considerations that influence the decision to engage in a given behavior.

First, attitudinal beliefs are the (expected) positive or negative consequences of the behavior, which, in the case of social robot acceptance, can be viewed as the user's evaluation of his or her beliefs when using a robot (in the future). Together, the utilitarian and hedonic attitudes form the attitudinal beliefs structure in the model of social robot acceptance. Utilitarian attitudes are tied to usability and emphasize the extrinsic motivations for accepting a technology, including the variables of ease of use and adaptability. Hedonic attitudes are related to the users' experience while performing the task and emphasize the intrinsic motivations for technology acceptance, including the variables of enjoyment, attractiveness, animacy, social presence, sociability, and companionship.

Second, normative beliefs are the (expected) approval or disapproval of the behavior by prevailing norms in the social environment of the individual, which, in the scope of this dissertation, can be perceived as the user's evaluation of the prevailing norms involved in using a robot. Both the personal norms and the social norms reflect the normative belief structure in the model of social robot acceptance. Personal norms contain an individual's beliefs that engaging in a particular behavior leads to salient personal beliefs, including the variables of privacy, trust and societal impact. Social norms encompass an individual's beliefs about the likelihood and importance of the social consequences of performing a particular behavior, including the variables of social influence and image.

Third, the control beliefs are the factors that may facilitate or impede the performance of the behavior, which can be observed here as the contextual factors that play a role while using a robot. The variables of self-efficacy, personal innovativeness, anxiety towards robots, safety and cost were included in this dissertation as control beliefs.

In addition to those three beliefs, for actual use scenarios, use behavior and habit were included along with use intention in the model of social robot acceptance. The ultimate goal of my conceptual model of social robot acceptance is to explain and predict people's use behavior or full acceptance of a social robot in their own homes. Full acceptance is "the actual use of the system over a longer period in time" (Heerink et al., 2010, p. 364). The concept of use intention in the context of social robot acceptance is defined as "the intention to use the system over a longer period in time" (Heerink et al., 2010, p. 364). The concept of habit is defined as the extent to which people tend to perform a learned sequence of behaviors as an automatic response to specific cues; they are functional in obtaining certain goals or needs (Limayem, Hirt, & Cheung, 2007; Verplanken & Orbell, 2003). Figure 11.1 on the next page visualizes this model and the interrelationships between the different components.

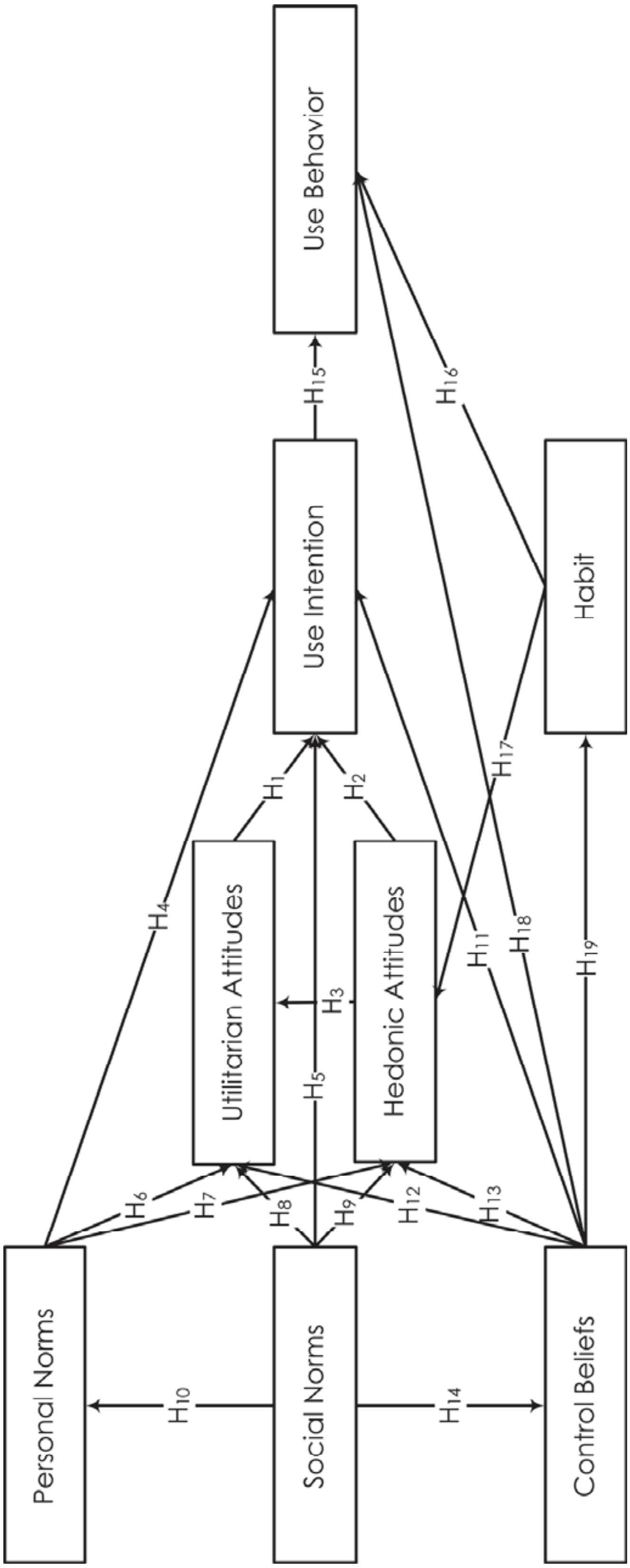

Figure 11.1: Conceptual model of social robot acceptance

A final step in Part II was to empirically test the conceptual model of social robot acceptance. Given that the diffusion of social robots within society has yet to begin, an online survey was administered to investigate the anticipated acceptance of social robots in domestic environments based on three possible future use scenarios of social robots in home environments. This study was guided by the fourth underlying research question: *Which variables from the conceptual model of social robot acceptance are most important in the anticipated acceptance of social robots in domestic environments, and how do these variables relate to each other?* The results of the Acceptance Survey (see figure 11.2 on the next page) indicate that the utilitarian attitudes of potential users of social robots seem to be influenced by both the hedonic attitudes and the control beliefs but are not directly affected by personal or social norms. The direct effect of hedonic attitudes on utilitarian attitudes supports earlier findings in both the information systems literature (e.g., Agarwal & Karahanna, 2000; Lee, Kozar, & Larsen, 2003) and the human-robot interaction literature (e.g., Heerink et al., 2010; Lee, Jung, Kim, & Kim, 2006; Shin & Choo, 2011). The direct effect of control beliefs has been reported before in studies on information systems (e.g., Hackbarth et al., 2003; Karahanna & Limayem, 2000) and human-robot interaction (e.g., Bartneck, Suzuki, Kanda et al., 2007b).

The hedonic attitudes of potential future users of social robots seem to be influenced by the control beliefs and both personal and social norms. The direct effects of normative beliefs on attitudinal beliefs have been reported in both the information systems literature (e.g., Ben Allouch, Van Dijk, & Peters, 2009; Lee, Kozar, & Larsen, 2003; Yu et al., 2005) and the human-robot interaction literature (e.g., Heerink et al., 2010; Shin & Choo, 2011).

To the best of my knowledge, this is the first time that the distinction between personal norms and social norms has been made in social robotics research. Given that personal norms arise from beliefs that are considered to be the norm in one's social environment, it was assumed that social norms would affect one's personal norms. The results suggest that personal norms indeed seem to be influenced by social norms.

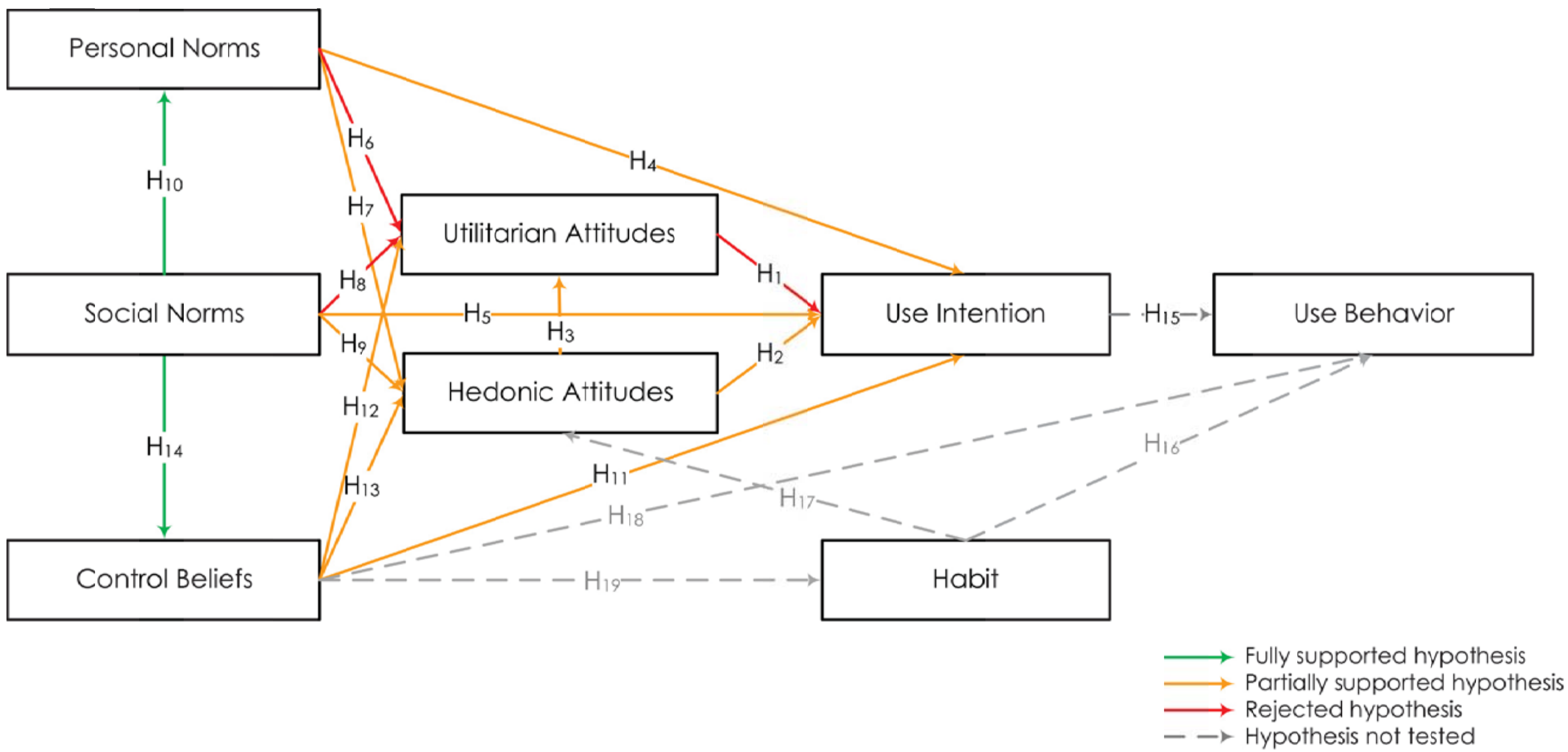

Figure 11.2: Overview of the tested hypotheses of the social robot acceptance model

The conceptual model of social robot acceptance did not hypothesize any predictors for social norms. Social norms function as the core of the conceptual model because they not only theoretically influence use intention and all other factors in the model directly but also theoretically indirectly influence use intention through all these other factors. The results show that the direct effects of social norms on personal norms and control beliefs were fully supported and that only the direct effect of social norms on utilitarian attitudes was not supported by these data. However, social norms affect utilitarian norms indirectly via both hedonic attitudes and control beliefs. The direct effects of social norms on all other factors in the model were partially supported. This means that social norms still have a core function in our empirical model of social robot acceptance.

The control beliefs of potential future users of social robots seem to be influenced by social norms. Both the theory of planned behavior (Ajzen, 1991) and social cognitive theory (Bandura, 1977) indicate that control beliefs are affected by opinions from one's social network.

THE PROCESS OF LONG-TERM ACCEPTANCE

Part III of this dissertation focused on the process of long-term acceptance by conducting the long-term Karotz Home Study. A first step was to provide insight into the existence of a long-term acceptance process guided by the fifth underlying research question: *How do people's user experiences with a social robot in their own homes evolve in a process of long-term acceptance?* Mainly based on innovations theory (Rogers, 2003) and domestication theory (Silverstone & Haddon, 1996), together with findings from earlier long-term studies on technology use in the home (e.g., Demiris et al., 2008; Karapanos et al., 2009; Sung et al., 2009; Sung et al., 2010), six acceptance phases were formulated: expectation, confrontation, adoption, adaptation, integration and identification. The results from the Karotz Home Study indicated that the acceptance experiences, to a large extent, corresponded with the time-line suggested for these phases. Most acceptance experiences, which were theoretically related to a certain acceptance phase, occurred according to the corresponding time line used for the interviews.

However, in general, the participants of the Karotz Home Study did not fully reach the identification phase, given that the acceptance experiences related to that phase were not significantly discussed during the interviews. Additionally, when comparing the different user groups (i.e., non-adopters, rejecters, discontinuers and users), there were no demographic or personality differences between the user groups as was expected from earlier findings. One very reasonable explanation for these results is the fact that the people who responded to this study's call for participation were already interested in using a robot in their own homes. However, the users groups each provided different reasons for non-use, and different acceptance variables explained their non-use.

A second step in providing insight into the long-term process of social robot acceptance was to investigate how, when and why users' evaluations of social robots fluctuate over time. This investigation was guided by the sixth underlying research question, part one: *How do the ratings of the acceptance variables for a social robot evolve in a process of long-term acceptance in the context of domestic use?* Examining the acceptance phases separately shows that, in the expectation phase, the central theme was control beliefs, of which the most discussed topic was the participant's previous experiences with robots or other technologies. Previous experiences with either the robot or other technologies means that all the participants had to create some type of mental image of what having and using a robot in the home could entail. In the remaining acceptance phases, the participants most discussed the utilitarian and hedonic factors. Usefulness was the most commonly noted utilitarian topic, and the hedonic factors noted were social presence, enjoyment and attractiveness. In none of the acceptance phases were personal or social norms among the most frequently noted acceptance variables in the interviews.

Additionally, both an expectation gap and a mere-exposure effect were observed in the quantitative data of the long-term Karotz Home Study. The expectation gap was caused by participants' high expectations for the robot that were not realized in their actual experiences with it. Rejecters, who had even higher expectations for the robot than any other user group, especially experienced the expectation gap. A mere-exposure effect was observed with the increasing user ratings of the robot over time. Although the ratings of the acceptance variables initially dropped after some first actual experiences with the robot, all ratings increased again after each acceptance phase, and in some cases, ratings even increased beyond the initial rating measured in the expectation phase. Somewhat surprisingly, our findings suggest that people living in mature families evaluated the robot more positively compared to people living alone, with a spouse or with young children. One explanation for our findings could be that teenagers are more willing to experiment with new technologies, which resulted in a more positive evaluation of the robot by both their parents and them. Another explanation could be that the different living situations provide different use contexts. The results from the SERA project indicated that aspects of the use context, such as the presence of other people, affected the user experiences and evaluations of a social robot (de Graaf, Ben Allouch & Klamer, 2015). The difference in use context could also explain the differences in results and thus could be an important factor for long-term social robot acceptance.

A third and final step in providing insight into the long-term process of social robot acceptance was investigating how the influence of the acceptance variables on the users' intentions to continue the use of the robot changed over time. This was guided by the sixth underlying research question, part two: *How does the influence of the acceptance variables for a social robot evolve in a process of long-term acceptance in the context of domestic use?* Overall, the acceptance variables incorporated in this dissertation could very well explain the participants' use intention and their actual use of the robot in the Karotz Home Study. One of the most important acceptance variables for social robots seems to be usefulness, given that it was part of almost all of the regressions and was often the strongest predictor for use intention and actual use. The importance of usefulness was also stressed in an earlier long-term study with the Roomba vacuum cleaner robot (Fink et al., 2013). This result is not surprising, given that usefulness was also strongly linked to use intention in the empirical analysis of the data from the online survey, in which both concepts loaded evenly onto the same factor.

HUMAN-ROBOT RELATIONSHIPS

In the future, robots are expected to serve humans in various social roles, such as companions, coaches, educators, nurses, and user interfaces for smart homes. The socially interactive components of social robots, in addition to their functional requirements, may foster the formation of human-robot relationships. Furthermore, establishing a type of relationship between the user and the robot increases the long-term acceptance of robots (de Graaf, Ben Allouch, & Klamer, 2015; Kanda et al., 2007). Therefore, part IV of this dissertation aimed to provide some initial insights into the possible relationships between robots and their human users.

As a first step, the foundations of the human need to socially connect with others were explored guided by the seventh underlying research question: *What can existing the scientific knowledge on human friendship formation, attachment to objects and parasocial relationships tell us about the possibility of establishing human-robot relationships?* Because humans are conceived within relationships, born into relationships, and live their lives within relationships with others, relationships with others lie at the very core of human existence (Berschied & Peplau, 1983). As computer technologies increasingly interact with us in complex and humanlike ways through robots, wearable devices, PDAs, and various other ubiquitous interfaces, the psychological aspects of our relationships with them take on an increasingly important role (Bickmore & Picard, 2005). The need to belong (Baumeister & Leary, 1995) is a fundamental human motivation to socially bond with others and predicts that people, in principle, are capable of bonding with robots, on the precondition that robots are adequately social to satisfy the relationship with respect to regular and meaningful interactions. Multiple human-robot interaction studies show that people are willing to socially respond to and initiate bonding with simple robotic technologies (Kerepesi et al., 2006) and seemingly build relationships following the same rules as in human-human interactions (Banks, Willoughby, & Banks, 2008; Bickmore, 2005); thus, it seems unnecessary to depart from these rules when evaluating human-robot interactions (Krämer, von der Pütten, & Eimler, 2012). Therefore, it is assumed that there will be more similarities between human-human and human-robot interactions than differences.

As the exploration of human-robot relationships is a fairly new field of research, there is to date no common knowledge on why some people are willing to treat social robots as companions. Therefore, as a second step, this dissertation investigated whether people's willingness to treat robots as companions can be explained by the same preconditions typically found in human-human interpersonal relationships guided by the eighth underlying research question: *Which influential variables for human friendship formation may explain people's willingness to treat social robots as companions?* The known preconditions for why people establish relationships with other humans are proximity, attractiveness, similarity, reciprocal liking and intimacy. Proximity, or functional distance, is how often people cross paths. Attractiveness is the positive evaluation of the physical appearance of the other (Berscheid & Reis, 1998). Similarity is where people concern themselves with the ways of describing an overlap between one's own personality and personality characteristics and those of the designated other. The phenomenon of reciprocal liking is grounded in Heider's (1958) balance theory: we like those who like us or who like the same things we like (one of which is ourselves). Finally, intimacy results from a dynamic, interpersonal process when one discloses personal information with a significant other, who in turn responds in an empathic way (Reis & Shaver, 1988).

In an experiment, people's willingness to bond with a zoomorphic robot was investigated with two experimental conditions: having high vs. having low expectations for the robot's lifelikeness. The results showed that, when having high expectations for a robot's lifelikeness, people not only evaluated that robot more positively but also were more likely to initiate relationships with the robot following the same rules as in human-human relationships. When examining the quantitative results from the long-term Karotz Home Study, intimacy was one of the most important preconditions that explained the willingness to treat a zoomorphic robot as a companion. Thus, the possibility for people to share personal information with a robot and having that robot respond to that information in an empathic way are very important for the establishment of human-robot relationships.

11.2 MAIN CONCLUSIONS

This dissertation has its foundation in the findings from the EU-funded Social Engagement with Robots and Agents (SERA) project, which provided several directions for further research on social robot acceptance. These research directions focused on the influence of the acceptance variables in a long-term process of social robot acceptance (RQ_a) and on the establishment of type sort of relationship with social robots during longer-term use (RQ_b). The following two sections answer the main research questions of this dissertation.

IMPORTANT DETERMINANTS FOR SOCIAL ROBOT ACCEPTANCE

The first main research question (RQ_a) seeks an answer to which acceptance variables are the most important determinants for social robot acceptance in domestic environments. The studies presented in this dissertation not only pinpoint usefulness as a requirement for social robot acceptance but also refer to some other important variables for social robot acceptance.

USEFULNESS AS A REQUISITE FOR SOCIAL ROBOT ACCEPTANCE

One of the main findings in this dissertation is the prominent role of usefulness for social robot acceptance in both the online survey on the anticipated acceptance of social robots and the long-term Karotz Home Study. In the Karotz Home Study, usefulness is part of almost all of the regressions and is often the strongest predictor for use intention and actual use. In the online survey, usefulness is very strongly related to use intention and loads onto the same factor in an exploratory factor analysis of the online survey data. Furthermore, with usefulness measured with items that focus on utility moving from utilitarian attitudes to the concept of use intention, all other regression paths from utilitarian attitudes are insignificant. Thus, the other utilitarian attitudes (i.e., ease of use and adaptability) seem to have lost their relevance in the users' intention to use a social robot.

OTHER IMPORTANT VARIABLES OF SOCIAL ROBOT ACCEPTANCE

In addition to the central importance of usefulness in both the anticipated acceptance and long-term acceptance of social robots, this dissertation points to some other important variables for social robot acceptance.

The results of the online survey indicate that the acceptance of a social robot for domestic use increases when future users believe that they possess the necessary skills to use a social robot, when they perceive that having such a robot enhances their status, and when they expect that such a robot provides more enjoyable interactions, behaves less sociably, and causes fewer privacy concerns. Examining all the direct and indirect effects in the model of social robot acceptance suggests that there seems to be a main role for the acceptance variables of enjoyment, privacy, status and self-efficacy. Enjoyment has by far the largest direct effect on use intention. Although privacy does not have a large direct negative effect on use intention, it also influences use intention indirectly via enjoyment. Similarly, self-efficacy has both a direct effect on use intention and an indirect effect via enjoyment and sociability. Finally, status has a direct effect on use intention. However, status has an indirect effect on use intention not only via privacy and self-efficacy but also via privacy through enjoyment, which in turn has an indirect effect on use intention.

The results of the Karotz Home Study indicate that the importance of the acceptance variables in explaining social robot acceptance changes over time. Before being introduced to the robot, people are mainly focused on control beliefs, with special attention to previous experiences with other technologies and prior expectations of the robot. However, from the moment that actual use begins, both utilitarian, i.e., usefulness, and hedonic attitudes, i.e., enjoyment, attractiveness and social presence (i.e., experiencing the robot as another entity), play by far the most significant roles in social robot acceptance. Personal and social norms only play a minor role in social robot acceptance in the Karotz Home Study.

The determinants that best predict and explain the adoption and use of a new technology strongly depend on the development stage of the technology (Peters, 2011). For example, in explaining the adoption and use of fully accepted media, such as a mobile phones, use intention especially plays an important role. However, in explaining the adoption of new innovative media, such as a social robot, the outcome expectancies especially play an important role. Furthermore, assuming that the user is familiar with the characteristics of the new technological innovation, the perceived social influence from friends and family is a stronger predictor of use intention than the attitudinal beliefs concerning that particular technology (Peters, 2011). Additionally, when technology use can more strongly be explained by habitual use, the effects of outcome expectancies weaken because the user is no longer aware of the relative importance of the outcome expectancies or because there are no more outcome expectancies, given that the outcomes are already known (Peters, 2011). Therefore, the importance of the roles that the acceptance variables play in explaining social robot acceptance should be repeatedly investigated in the future as the technology matures and its diffusion within society increases.

ASSESSING HUMAN-ROBOT RELATIONSHIPS BEFORE AND AFTERADOPTION

The second main research question (RQ_b) focuses on how the users assessed their willingness to treat the robot as a companion before and after the adoption of a social robot. The studies presented in this dissertation indicate that people are initially reluctant to build a relationship with a robot and deny the possibility that such a relationship will occur for them. However, after people have adopted a social robot and have begun to use it in their own homes, some people acknowledge that they have established some type of relationship with the robot.

The participants in the acceptance survey negatively evaluated the sociability and the companionship possibilities of future scenarios for robots. Thus, these data suggest that, at this stage of social robot diffusion, people do not want robots to behave socially. Similarly, the results from the Karotz Home Study also indicated that people are initially reluctant with respect to the possibility of perceiving robots as companions. As is further explained in the general discussion of this dissertation (chapter 12), it may be the case that people are not yet familiar with the social interactions of companionship with robots and that relationships with robots are accepted according to prevailing social norms. Actually, the participants in the acceptance survey provided some inconsistent assessments of social robots by indicating that a more expensive robot increases the user's status and is expected to provide more companionship. Furthermore, the participants indicated that a more sociable robot could better adapt to their needs. Thus, actual use behavior is necessary to draw further conclusions concerning how people assess human-robot relationships.

Indeed, different results were found among people who had the opportunity to use a social robot for a long time within their own homes. After people had begun to use a social robot, they experienced some type of bond with the robot. The participants in the Karotz Home Study engaged socially with the robot, talked to it, gave it a name, and interpreted its behavior in a social way. Some of the participants indicated that they would prefer social interaction with robots on a higher level than that offered by the Karotz robot.

Although initially skeptical about having robots as our companions, the participants in the Karotz Home Study were open to this possibility as robots would develop into more intelligent and social beings. Additionally, under certain conditions (e.g., for people without an active social life), the Karotz robot could even be perceived as a companion, according to the participants. Despite their reservations concerning human-robot relationships, some participants agreed that the relationship they felt with the robot resembled a relationship that one could have with a pet or that the robot brought some companionableness into their homes.

However, not all people seemed to appreciate a robot's social behavior. When the robot initiated unsolicited conversations, some participants in the Karotz Home Study experienced certain feelings of uncanniness and reduced the social features of the robot to a minimum.

Taking the findings from the online survey and the Karotz Home Study together, it seems that people are still unfamiliar with the possibilities of human-robot relationships and that the actual use and interactions with social robots reveals what type of relationships people are willing to establish with these types of interactive technologies.

12

DISCUSSION

“All our knowledge has its origins in our perceptions.”
– Leonardo da Vinci –

This chapter translates the conclusions drawn from the different studies presented in this dissertation into various discussion points. The first paragraph focuses on the implications of the conclusions from a theoretical perspective. The second section presents certain methodological limitations and suggestions for future research. The third paragraph discusses the practical implications of the conclusions of this dissertation, which may guide the future development of social robots and their acceptance within our society. This chapter ends with some final remarks on the research in this dissertation.

12.1 THEORETICAL DISCUSSION

This dissertation contributes to future research on social robot acceptance in home environments and to the broader context of research on the acceptance of technologies in domestic environments. A first set of theoretical implications are related to the sociability of robots. Second, certain theoretical implications related to user experiences during the process of social robot acceptance are discussed. A third section asserts certain implications for future research to further develop the conceptual model of social robot acceptance. Fourth, the acceptance variables that play a role in the user's acceptance of social robots provide certain interesting theoretical implications. Fifth, certain theoretical implications for future research on human-robot relationships are addressed.

THE SOCIABILITY OF ROBOTS

Social robotics researchers are aiming to build robotic machines that interact socially in a natural humanlike manner with their users. However, the question remains about whether robots can actually be social. If so, do users want robots to behave socially? Additionally, do potential social interactions with robots imply that researchers can apply theories of human-human interpersonal communication to human-robot interaction?

CAN ROBOTS ACTUALLY BE SOCIAL?

An important point for discussion is the potential sociability of robots. Social roboticists are attempting to program robots with social behaviors that are similar to those of human beings. Chapter 2 presented a list of behaviors that are essential for robots to behave socially. The reasons why robots should behave socially are that natural and fluent interactions with robots increase their acceptance by human users (Breazeal, 2002). Yet, some people may argue that robots cannot behave socially and cannot have emotions or an appealing personality. Robots can only act as though they are social and pretend to empathize with our emotions. However, following the research on the media equation (Reeves & Nass, 1996), human users interacting with robots themselves interpret the robot's behavior as social, and they respond to robots in ways that are similar to how would respond to other people. These social responses to robots have been reported in several studies (e.g., Bartneck, Reichenback, & Carpenter, 2008; Eyssel, Kuchenbrandt, & Bobinger, 2011; Kerepesi et al., 2006). Although most people would reasonably agree that robots are programmed machines that only simulate social behavior, the same people seem to 'forget' this while interacting with these machines. Thus, the question whether robots are social beings seems to depend on how human users perceive these robots.

The doubts of people who think otherwise can be neutralized by altering the well-known Turing test devised by Alan Turing (1950). The Turing test is a proposed method for determining whether a machine should be regarded as intelligent. During the test, a person engages in natural conversations with both a human and a machine designed to generate a performance that is indistinguishable from that of a human being. The conversations are limited to text-based interactions via a keyboard and a screen. If a person cannot reliably discern which of the two conversations was with the machine, then the machine is said to have passed the test. Thus, if a machine appears to be intelligent according to the human user, then we should assume that that machine is indeed intelligent. Levy (2008) proposes that we can apply a similar argument to other aspects of being human, such as emotions, personality, and behavior. Furthermore, acting is also a part of human social behavior (Goffman, 1957). In this line of thought, robotics researchers and developers should acknowledge that robots are social entities when human users perceive them as such.

THE UNWANTED SOCIABILITY OF ROBOTS?

An interesting finding of the Acceptance Survey was that, overall, the robot's social behaviors were not appreciated. The participants in the Acceptance Survey negatively evaluated the sociability and the companionship possibilities of future robot scenarios. Thus, these data suggest that at this stage of social robot diffusion, people do not want robots to behave socially. There may be several explanations for these results. One explanation is that people do not prefer robots that behave socially and that the development of such robots should not be pursued. The results of the Acceptance Survey reveal that potential future users seem to have a higher intention to use a social robot in their own homes when the robot is less sociable. Additionally, the participants indicated that they believed that a social robot could better adapt to their needs when it provided less companionship. In this manner, it is suggested that people do not want robots to behave socially or provide companionship and that the development of these types of robots may be pointless. However, this statement should be reevaluated after discussing the findings of the Karotz Home Study, in which people actually used a robot and engaged with it.

However, the participants in the Acceptance Survey provided some inconsistent assessments of social robots by indicating that a more sociable robot could better adapt to their needs, i.e., increase its adaptability. Thus, a second explanation for the more negative evaluation of the robot's social behavior could be that people fear or are not yet familiar with social interactions and companionship with social robots. Examining the average scores of the acceptance variables in the online Acceptance Survey shows that the participants had very high concerns about their privacy when using a social robot in their own homes. Additionally, the results show that when the participants believed that they were more competent to interact with a social robot and could better trust a social robot, they perceived the robot's behavior as more sociable. Furthermore, the results indicate that when participants believed that they were more competent in their own skills to properly interact with social robots, they expected to feel less fear when talking to a social robot, and when they expected to feel safer in the presence of a social robot, they believed that a social robot could provide more companionship. Privacy concerns may play a role, and people fear the sociability of future social robots that are capable of providing companionship. This fear, then, is caused by people's privacy concerns, their lack of competence in properly interacting with social robots, their expected fear of talking to robots, or the expected lack of safety when in the presence of a social robot. Above all, the participants indicated that when a social robot is more expensive and increases the user's status, they expect such a social robot to provide more companionship.

A third explanation for the more negative evaluations of sociability and companionship is that admitting to treating social robots as companions is perceived as not socially desirable by the participants. Just as depending on television for companionship has been characterized as an inappropriate motivation for use (Rubin, 1983), it is possible that using a robot for companionship is not acceptable according to prevailing social norms. Social desirability is the tendency of participants to answer questions in a manner that will be viewed with favor by others (Paulhus, 1991), which causes over-reporting of 'good' behavior and under-reporting of 'bad' or 'undesirable' behavior. From the social sciences, it is known that a social desirability bias may occur in self-reported data, including data collected from questionnaires (Huang, Liao, & Chang, 1998), especially when inquiring about sensitive topics (King & Brunner, 2000). In an online study measuring both people's implicit and explicit associations with domestic robots (de Graaf, Ben Allouch, & Lutfi, submitted), it was found that these two measures had conflicting outcomes, which may have been due to social desirability. Although people explicitly reported that they have positive associations with robots, the implicit measures revealed that they had negative associations. Furthermore, people's implicit associations negatively correlated with their attitudes towards robots and positively correlated with their anxiety towards robots. Yet, people's explicit associations did not significantly correlate with their attitudes towards robots and negatively correlated with anxiety towards robots.

Based on these combined results, de Graaf, Ben Allouch, and Lutfi (submitted) concluded that people implicitly have opinions about robots that are different from what they want to explicitly reveal. The difference between people's implicit and explicit associations with robots may be because people feel a social pressure to be positive towards robot technology, but in fact, they are not. The study on implicit and explicit associations with robots was an online-based study without any real-world human-robot interactions. Future research on implicit and explicit associations with robots should further investigate the predictive power of implicit and explicit measures in relation to actual behavior in human-robot interaction scenarios to draw further conclusions concerning the explanatory power of implicit and explicit associations with robots. Observational methods may result in different findings because they are less sensitive to social desirability. Such studies will become increasingly important as robotic technology advances, is widespread in society and is employed in home environments for the long run.

To further explore why the participants in the online Acceptance Survey indicated that they did not want robots to behave socially or provide companionship, we must turn to other methods, such as observations and interviews, to be able to determine how people interact with social robots. In contrast to the results of the online Acceptance Survey, the results from the Karotz Home Study indicate that people actually do behave socially with robots in their own homes despite their skepticism concerning perceiving robots as social actors and companions. The participants engaged in social interaction with the robot, talked to it, gave it a name and interpreted the robot's behavior in a social way. Furthermore, some participants indicated that they would appreciate it when future robots are able to interact more socially with their users. Some participants attempted to increase social interactions with the Karotz robot used in the long-term home study. However, not all participants appreciated the robot's social behavior. Some participants experienced certain feelings of uncanniness when the robot initiated unsolicited conversations, and those participants reduced the social features of the robot to a minimum. Taking the findings from the Acceptance Survey and the Karotz Home Study together, the social behavior of robots has a long way to go with respect to their proper development and their full social acceptance by potential future users.

It is being argued that robots, because they are physically embodied and enabled with sociable interaction, create a unique and affectively charged sense of active agency that is similar to that of living entities (Young et al., 2011). This may cause human-robot interaction, in a sense, to be more similar to interacting with another living entity than to interacting with a machine. Thus, it may be the case that human interactions with robots follow the principles of human-human interpersonal communication in parallel with the principles of human-machine interaction. Indeed, the results of this dissertation, along with many earlier findings (e.g., Bartneck, Reichenback, & Carpenter, 2008; Eyssel, Kuchenbrandt, & Bobinger, 2011; Kerepesi et al., 2006), indicate that people respond socially to robots and treat them as social entities. If human-robot interaction researchers continue to draw similar conclusions concerning people's interacting with robots as though they were interacting with other living entities, then communication theories with a focus on the interaction between two parties become more important for human-robot interaction studies.

Therefore, researchers investigating human-robot interactions should be careful when directly applying findings and theories from human-computer interaction to research that explores the interactions between humans and robots. Because people tend to respond to and treat robots as social actors in the interaction, i.e., the media equation (Reeves & Nass, 1996), these interactions go beyond the practical applications of technologies typically under study in human-computer interaction. Human-robot interaction involves simulated social interactions elicited by the robot and created by the human user during the interaction. In this manner, the robot becomes another interaction partner in the eye of the human user. This results in certain similarities between human-robot interactions and face-to-face communication. If interactions between humans and robots are mostly completely guided by the media equation, then future research on human-robot interaction should mainly focus on theories of interpersonal communication.

THE PROCESS OF LONG-TERM SOCIAL ROBOT ACCEPTANCE

The temporal dimension of acceptance is under-studied in human-robot interaction research. To date, only a few studies have investigated the long-term use of a robot in home environments (e.g., de Graaf & Ben Allouch, 2014; Ferneaus et al., 2010; Fink et al., 2013; Sung et al., 2009; Sung et al., 2010). Yet, even the traditional technology acceptance literature does not include a significant body of long-term research, despite its long history of information systems research (Taylor & Todd, 1995). Long-term user studies are necessary to gain a better understanding of the long-term acceptance of social robots in domestic environments. The conclusions drawn from the Karotz Home Study raise several interesting points for discussion that are addressed below.

THE NEED FOR LONG-TERM RESEARCH IN HOME ENVIRONMENTS

Conducting a long-term home study reveals that the permanent presence of a robot in the user's own home raises challenges for research that are unlikely to be revealed in one-day laboratory human-robot interaction studies or even in multiple observations of short-term interactions between humans and robots. However, involving end-users in the early stages of development helps robotics researchers understand the cultural and social contexts of acceptance and enables researchers to apply this gained knowledge to the design. The involvement and importance of users in the process of acceptance has increased since it has been recognized that users shape technology (Silverstone & Hirsch, 1992; Lie & Sørenson, 1996). Discovering people's perceptions, expectations and impressions of robots in their private domestic environments over a longer period of time is vital for informing the design and acceptance of these technologies. Thus, further research that investigates the long-term acceptance of social robots in domestic environments is necessary for a successful diffusion of these types of robots within society.

AVOIDING THE NOVETLY EFFECT

Furthermore, researchers who are interested in exploring the sustained use of a robot after its initial adoption should be aware of the novelty effect. Most people are very excited the first time they interact with a robot, which may be reflected in the evaluations gathered directly after an initial interaction.

Therefore, employing multiple interactions with the same robot, and preferably the continued presence of a robot in a person’s natural environment, such as the home, is recommended.

Some researchers suggests that longitudinal studies need to last for at least two continuous months when one aims to observe sustained use after initial adoption and beyond the novelty effect. Stable or sustained use, consisting of recurring use routines, occurs when the novelty effect ends, which is presumed to happen after two months of use according to Sung et al. (2009). The end of the novelty effect after approximately two months of use has been confirmed in other long-term robot studies (Kanda et al., 2007; Fink et al., 2013). Similarly, the results of the Karotz Home Study also indicate that the end of the novelty effect occurs after approximately two months of use. However, another study focusing on user experiences with a smart phone (Karapanos et al., 2009) describes similar user experiences and acceptance phases, but its participants already reached the end of the novelty effect and sustained use after four weeks. Furthermore, even though the novelty effect had ended after approximately two months in the Karotz Home Study, the establishment of sustained use or habitual use did not occur at that time for most of the participants. Thus, the end of the novelty effect and the establishment of habitual use behavior seem to be two separate processes and must be regarded as such in technology acceptance research.

Ronis, Yates, and Kirscht (1988) have argued that habitual behavior has been established once it has been performed frequently (i.e., at least twice a month) and extensively (i.e., at least 10 times). However, research on the establishment of new behaviors (Lally et al., 2009) indicates that it takes much longer for a repeated behavior to reach its maximum level of habituation. In their study, which investigated a wide range of behaviors, people needed approximately two months (i.e., 66 days on average) to establish a new behavior. However, given that the researchers examined a wide range of behaviors, there was a marked variation ranging from 18 (drinking a daily glass of water) to 254 (doing 50 push-ups after morning coffee) days before behaviors had become habits. Because the satisfactory repetition of behavior in the past may result in habit formation (Ajzen, 2002; Ronis, Yates, & Kirscht, 1989; Triandis, 1979; Verplanken, Aarts, & Knippenberg, 1997), the duration of each acceptance phase may depend on the type of technology and is most likely related to the frequency and intensity of technology use. Therefore, caution is necessary in linking the acceptance phases to actual time frames.

However, it is acknowledged that long-term research in real-world settings is time-consuming and not always possible for every interaction scenario or robot. Nevertheless, when researchers are not interested in people's first impressions of a robot, allowing the participant to familiarize themselves with the robot before the start of the actual study is suggested. Some researchers recommend introducing participants to the experiment and the robot, offering them the time to experiment with the robot along with assistance in running the tasks before starting the actual interaction protocol (Chong et al., 2009; Kidd & Breazeal, 2005; Shang et al., 2011; Wang et al., 2014). In this manner, researchers may avoid some initial novelty effects in the evaluations in their study.

A MERE-EXPOSURE EFFECT FOR ACCEPTANCE VARIABLES

In the quantitative data from the Karotz Home Study, it was observed that for most acceptance variables, the evaluations of the robot first dropped after being introduced to the robot but later increased again as the participants gained experience and became familiar with it. This is called a mere-exposure effect, which is the tendency for novel stimuli to be liked more or rated more positively after someone has been repeatedly exposed to them.

This effect can be explained by a novelty effect in the beginning that fades away after some time. For example, earlier findings (Venkatesh, 2000) suggest that system experience influences individual user's playfulness with the system and that this increase significantly influences an individual's perception of the complexity of the system. Thus, when users first interact with a computer system, they typically feel intimidated and stressed, and as a result, their degree of playfulness is low. As they obtain some level of familiarity with the system, they are more apt to explore the system and interact spontaneously with it. This is similar to the finding that playfulness mediates the effect of system experience on perceived ease of use (Hackbarth, Grover, & Li, 2003). The effect that when people gain experience with a system, they feel more joy when using the robot and find it easier to use has also been reported in a human-robot interaction study (Kim et al., 2013) and has been found in our study as well. This result can be explained by a novelty effect in the beginning that fades away after some time, but enjoyment increases again when people see the robot as something familiar.

Furthermore, familiarizing oneself with a robot causes an individual to experience more meaningful social interactions with the robot, as earlier findings suggest (Kim et al., 2013). A similar pattern is observed in the questionnaire data from the Karotz Home Study. Although the evaluation of sociability initially decreases, near the identification phase, this evaluation increases again beyond its initial rating measured in the expectation phase. Furthermore, familiarizing oneself with a robot causes an individual to experience more meaningful social interactions with the robot, as earlier findings suggest (Kim et al., 2013).

Together, these results suggest that a mere-exposure effect can emerge for all types of technology evaluations. This finding emphasizes the relevance of long-term studies because the evaluations of technologies evolve over time. Therefore, future researchers should be aware that collecting technology evaluation data at one time point consists of a snapshot of the measures incorporated in their study.

THE ACCEPTANCE PROCESS

Mainly based on these two visions of long-term acceptance, together with findings from earlier long-term studies on technology use in the home (e.g., Demiris et al., 2008; Karapanos et al., 2009; Sung et al., 2009; Sung et al., 2010), six acceptance phases are formulated: expectation, confrontation, adoption, adaptation, integration and identification. These acceptance phases are linked to the experiences of acceptance from the users’ perspective and are not linked to the phases of technology diffusion, as is the case in Roger’s (2003) diffusion of innovations theory, for example.

The expectation phase begins after people have heard about a new technology but before they have been physically confronted with it. In the expectation phase, people want to know more about the technology and its purpose and therefore seek information about the technology. Based on the gathered information, people form an initial opinion about the technology and establish initial expectations. The expectation phase concerns the anticipation of and preparation for obtaining a technology. In the confrontation phase, people encounter the technology for the first time. This is when people may try out the technology if possible or simply observe others using the technology. The adoption phase is when people actually begin to use the technology in their private environment and gain their first serious user experiences with the technology. In the adaptation phase, which was theorized here to begin one month after the initial confrontation with the technology, users have a broad idea of what the technology is and what it does. However, they still encounter novel features, and this may occur along with some learnability flaws. Yet, while exploring the functionalities of the technology and making attempts to adapt these to their personal needs, the users increasingly become familiarized with the technology. In the integration phase, which was theorized here to begin two months after the initial confrontation with the technology, the technology has become meaningful to a user's life. The technology is modified or personalized by the users to adapt to their preferences. Users no longer notice the presence of the technology and have fully integrated its use into their everyday lives. In the identification phase, which was theorized here to begin six months after the initial confrontation with the technology, a technology exceeds its functional purpose and becomes a personal object. People may use a technology to express a certain lifestyle, to differentiate or connect to other groups. Furthermore, in this phase, users seek supportive information that favors continuance of use and therefore confirms their initial decision to adopt the technology.

The occurrences of most acceptance experiences, which were theoretically related to a certain acceptance phase, corresponded to the theorized timeline for social robots in this dissertation. However, in general, it seems that the participants did not fully reach the identification phase. One very reasonable explanation for this finding is that only three of the remaining seven participants in the last round of interviews were still using the robot at that moment and intended to continue to use the robot after the study. However, some researchers argue that it is difficult for technology to penetrate people's traditional ways of living, especially with respect to everyday routines and chores in and around the house (Leppänen & Jokinen, 2003). People have a fixed lifestyle, and the arrival of a new technology cannot easily persuade them to change their everyday routines. Additionally, the participants indicated that the robot did not offer many new features that were not already represented by the other technologies that they were using. Combining these two facts may provide another reason why not all participants fully accepted the robot and only a few reached the identification phase.

Further research is necessary to confirm what types of user experiences are associated with the defined acceptance phases presented in this dissertation and how these acceptance phases can be linked to timelines. In addition, future research may investigate the user experiences of different technologies in a long-term home study and compare the timelines that the users needed to evolve from phase to phase.

DEFINING AND DISTINGUISHING USERS AND NON-USERS

One of the most influential explanations of the societal adoption of technologies can be found in the diffusion of innovations (Selwyn, 2003). The diffusion of innovations theory, which was developed by Rogers (2003), points to a recurring s-curve of the expansion of technology adoption in society, from the innovators and the early adopters to the early majority and late majority and eventually to those individuals characterized as laggards. This s-curve can be interpreted as a technologically deterministic perspective that asserts that the availability of a technology inevitably leads to use, which results in a somewhat negative positioning of non-users as an impediment to the saturation of a technology in society (Selwyn, 2003). Simply defining non-users as not yet users (e.g., Rogers, 2003), as 'have-nots' (e.g., Howland, 1998) or as 'information poor' (e.g., Wilson, 1986), together with concerns that focus on turning non-users into users, only provides a narrow view on the spectrum of non-use (Satchell & Dourish, 2009; Selwyn, 2006). Another shortcoming in today's research on technology acceptance lies in the definition of non-users. Defining non-use by asking people whether or not they use a certain technology at this point in time with a yes or no question is the most straightforward method of definition, used by Phillips and Zhao (1993), among others. Some researchers apply a more refined definition of non-use and distinguish between degrees of non-use (e.g., Rogers, 2003; Satchell & Dourish, 2009; Wyatt, Thomas, & Terranova, 2002). However, the incoherence in the definition of non-use that is currently in use (Selwyn, 2004; Wessels et al., 2003) results in a weak academic understanding of the non-use of technology.

There is a need for the development of a more dynamic and nuanced conceptual framework for users and non-users, which conceptualizes users along a continuum with degrees and types of involvement that may change depending on life changes (Wyatt et al., 2005). Furthermore, groups of users and non-users need to be refined to include, in addition to non-use, rejection, discontinuance, forced use, reluctant use, partial use, and selective use (Wyatt, Thomas, & Terranova, 2002). A study on people's health information-seeking practices allowed for further insights into users and non-users of digital media (Wyatt et al., 2005). The authors found that patterns of use and non-use change over time and life circumstances; that some people experience a digital imperative and feel guilty about not using digital technologies; that some people genuinely do not like digital technologies and strongly express this; and that simply because a digital technology is available in the house does not imply that all people in that household actually use it. Thus, researchers should acknowledge that there are different types or categories of non-users and that these groups have their own sometimes well-motivated reasons for why they are non-users.

Furthermore, non-users are just as important as users for the development of future social robots. The non-adopters, who actively refuse to adopt a technology in active and deliberate ways due to concerns about privacy or a need for control over one's time, for example, are contributing to the debates (re)shaping cultural interpretations of that technology just as much as eager adapters, albeit in different ways (Satchell & Dourish, 2009). As addressed in chapter 7, users and the different groups of non-users each provided different reasons for either continued use or discontinuous use. Thus, both users and non-users are important for shaping and reshaping future technologies.

Finally, what types of consequences are related to the use and non-use of social robots in our future society should be further investigated. It is widely assumed in research on the digital divide that non-users are falling into existing and deep-rooted patterns of social and economic inequalities (Selwyn, 2003). It should be noted that the participants in the Karotz Home Study were provided with robots without any attached cost. Therefore, the motivations of the users in the Karotz Home Study somewhat differ from the motivations of ‘real’ future users who will buy and employ social robots themselves. This makes it impossible to draw any conclusions on this perspective in this dissertation. Thus, remaining questions for robotics research are whether this phenomenon will continue for non-users of robotic technologies and what types of individual motivations and consequences are attached to the non-use of robotic technologies.

THEORETICAL MODEL OF SOCIAL ROBOT ACCEPTANCE

This dissertation proposed a conceptual research model for social robot acceptance. To build a general model for social robot acceptance, a second-order structure was proposed to create a more parsimonious theory-based account of the correlations among the included acceptance variables (Brown, 2006). These specifications assert that the second-order factors have direct effects on the first-order factors. These direct effects and correlations among the second-order factors are responsible for the covariation among the first-order factors. However, the data from the Acceptance Survey did not support the proposed second-order factor model. This finding indicates that several concepts related to the second-order structure should be reassessed in future research. The findings in this dissertation may guide this reassessment because they provide insight into the important acceptance variables that influence social robot acceptance within different phases.

Chapter 4 addresses several shortcomings of two earlier attempts to define a model for social robot acceptance. The proposed conceptual model of social robot acceptance in this dissertation overcomes these drawbacks by the following: (1) using a stronger theoretical bases for the model; (2) hypothesizing the interrelationships between concepts in the model based on theory; (3) testing the model on a general population; (4) drawing a single sample of participants for the data set; and (5) only incorporating those modifications to the model that can be supported by theory. Therefore, it is believed that the proposed conceptual model of social robot acceptance in this dissertation provides a strong basis for the further development of a model that may help explain why people would accept social robots in their domestic environments.

Additionally, given that this is simply one of the first attempts to build a theoretical model of social robot acceptance, further research on what acceptance variables could be included in such a model is necessary. An extensive literature review on acceptance variables from a wide variety of research fields resulted in the inclusion of many variables, which were then tested in the Acceptance Survey among people who anticipated accepting a social robot within their own homes. However, when people actually began to use a robot within their own homes (i.e., in the Karotz Home Study), other acceptance variables emerged that also played a role in the long-term acceptance process. It is possible that some variables may have a larger impact when people anticipate accepting a social robot, but the same variables may have minor effects when the same people use that same robot for a longer period of time. A large body of future social robotics research is necessary to identify the variable that possess the most explanatory power in certain acceptance phases and how their influences change across the phases in the long-term process of social robot acceptance.

ACCEPTANCE VARIABLES

This dissertation provided interesting findings related to the variables of social robot acceptance. Discussions on the conceptualization of usefulness, the interrelationship between attitudes and behavior, the influential relationship of use intention on actual use, and the understanding of habitual use follow below.

CONCEPTUALIZATION OF USEFULNESS

In the Acceptance Survey, usefulness is very strongly related to use intention and loaded onto the same factor in an exploratory factor analysis of the Acceptance Survey data. The occurrence of high correlations (e.g., > .68 according to Taylor, 1990) and the high cross loading of items in the factor analysis (e.g., > .45 according to Pornpitakpan, 1998) between usefulness and use intention in research on technology acceptance have been reported before. The study by Limayem, Hirt, and Cheung (2007) on the continued use of the internet reports a correlation of .74 between usefulness and use intention, and the factor loadings of their items of usefulness onto the factor of use intention ranges from .65 to .73. However, further discussions on these high correlations fail to appear in their article, and the researchers continue to treat the two concepts as separate constructs in further data analyses.

One explanation of the empirical overlap between the two theoretical concepts may be that the psychological consideration of the theoretical concepts of use intention and usefulness is made simultaneously and therefore cannot be empirically distinguished. In other words, for the participants, the decision to use a social robot is the same as evaluating whether a social robot is useful. In this manner, usefulness functions as a requirement for social robots before their users even consider using them in the first place. The results of this research are based on prediction of future use. Because people remain unfamiliar with social robotic technologies, some variables, such as status and societal impact, remain unknown for potential future users. This is reflected by their minor role in the model of social robot acceptance at this stage of the diffusion of these technologies in our society. Real experiences with a technology are better predictors of future use of that technology. Therefore, the concept of usefulness needs further attention in human-robot interaction research as the technology matures and the diffusion of social robots within society increases.

Another explanation lies in the conceptualization of the measurement of usefulness. To measure usefulness, the construct of usefulness from Heerink et al. (2010) was used in this dissertation. However, it may be argued that this construct only measures the objective and utility part of the concept of usefulness and does not include the subjective and user-friendliness part. In this manner, we have only objectively envisioned the possibilities that a social robot has to offer. The definition of a technology, at least at a basic level, is for it to help people to do things (Orlikowski, 1992), which tightly links the meaning of a technology to the evaluation of its meaning, significance and utility, which is the crucial underlying factor for the potential user (Silverstone, 1996). Hence, the overlap between the measures of usefulness and use intention in the Acceptance Survey and the strong explanatory power of usefulness on use intention in the Karotz Home Study are not surprising. Future technology acceptance research may further investigate the underlying concepts that together cause users to evaluate a technology as useful. Some researchers indicate that usefulness is not a unidimensional concept (Jaschinski & Ben Allouch, submitted). A suggestion for future research is to conceptualize usefulness by defining a multi-dimensional concept and to divide several benefits that together account for usefulness. For this process, a method similar to that proposed by the model of media attendance (LaRose & Eastin, 2004), which defines several expected outcomes of technology use, may be used.

THE INTERRELATIONSHIPS BETWEEN ATTITUDES AND BEHAVIOR

This dissertation only focuses on theories that incorporate the perspective that attitudes predict behavior. However, other communication theories suggest the opposite, arguing that people's behaviors may very well predict their attitudes. For example the cognitive dissonance theory (Festinger, 1957) denotes that a conflict may occur when an individual's attitudes and behaviors are not congruent. This results in an attempt to align the attitudes with the behavioral outcomes to reduce the conflict between attitude and behavior. When people repeatedly perform the same behavior, such as using a robot, they become better at it (Ronis, Yates, & Kirscht, 1989) and may result in higher evaluations of ease of use and perceived behavioral control. This suggests that using a robot provides a further input for the user's attitudinal beliefs regarding the use of the robot. Thus, research on attitudes and human behavior should account for the fact that there is an interrelationship between the two concepts, not a fixed causal relationship from one concept to the other.

THE RELATIONSHIP BETWEEN USE INTENTION AND ACTUAL USE

Based on the data from the Karotz Home Study, use intention may explain only part of the explained variance for actual use in the integration phase and is one of the two most influential variables for actual use only in the identification phase and not at all in the other acceptance phases. This is in contrast with the theory of planned behavior (Ajzen, 1991), which states that use intention is the main predictor of actual behavior and functions as a mediator for the separate belief structures. The results from the Karotz Home Study indicate that the separate belief structures exert a strong direct influence on use intention. This suggests that the underlying belief structures directly influence actual behavior and (partially) omit use intention.

A meta-analysis of the technology adoption literature (Wu & Du, 2012) shows that use intention may not be an appropriate and justifiable surrogate for actual use. Inconsistent findings on the intention-behavior relationship have been found in both the technology adoption and psychology literatures. First, it appears that the type of behavior influences the intensity of the relationship between intention and behavior. When people are not consciously performing a behavior, but act based on non-cognitive habits and impulsivity, the predictive accuracy of intentions on behavior is reduced (Warshaw & Davis, 1985). However, the participants in the Karotz Home Study have not fully created a habitual pattern of use because habit could only explain a small part of the variance of actual use in the adoption and adaptation phase and no longer affected actual use in the integration and identification phase. Therefore, it is concluded that it was not habit that replaced the effect of use intention on actual use in this study. It is possible that the strong relationship between use intention and actual use failed to appear because some participants had stopped using the robot in the preceding period but also completed the questionnaire together with the participants who indicated the continued use of the robot. However, even when controlled for users (i.e., participants who indicated their intention to continue to use the robot after the study), use intention had only a minor effect on actual use throughout all of the acceptance phases.

Indeed, a second explanation for a weak relationship between use intention and actual use was found in the time gap between forming the intention and performing the behavior. This time gap may jeopardize the intention-behavior relationship. When people change their minds in the time gap, the original intention no longer corresponds to actual behavior (Pieters & Verplanken, 1995). In the Karotz Home Study, the measures for use intention, actual use and habit were administered during the several acceptance phases in which the users indicated that they were still using the robot. However, given that some participants admitted during the interviews that they had not used the robot for some time, it may be that there was a gap between the actual use behavior and the measured use intention and habitual use.

Third, environmental and personal factors may hinder a person from performing the behavior. Thus, controlling for these factors may strengthen the relationship between use intention and actual use (Warshaw & Davis, 1985). The Karotz Home Study included several control beliefs that could facilitate or impede the use of the robot. Some of these beliefs (e.g., self-efficacy, robot related experiences and personal innovativeness) indeed occurred among the acceptance variables that explained the variance of actual use, sometimes along with use intention. However, these control beliefs only had a minor impact in explaining the total variance of actual use. Yet, the explanatory power of use intention for actual use increased when controlled for gender, household type or user group. For both use intention and actual use, this was especially the case for mature families after one month of use.

This is in contrast with an earlier short-term study in which participants who were assigned to the individual interaction condition, compared to participants in the group conditions, developed a stronger sense of responsibility and attachment to the robot because they did not have to share the robot with other group members (Lee, Park, & Song, 2005). Indeed, it was expected that people living alone or people with young children would evaluate the robot more positively. However, it seems that with long-term use, the results are different. One explanation for our findings could be that teenagers are more willing to experiment with new technologies, which resulted in both their and their parents' evaluating the robot more positively. Another explanation could be that the different living situations provided different use contexts. The results from the SERA project indicated that aspects of the use context, such as the presence of other people, affected the user experiences and evaluations of a social robot (de Graaf, Ben Allouch & Klamer, 2015). The difference in use context could also explain the differences in results in this dissertation and thus could be an important factor for long-term social robot acceptance.

Fourth, the method of measuring behavior may affect the magnitude of the intention-behavior relationship. There is an inconsistency in how studies measure actual use behavior, which may be due to a lack of theoretical basis for system use or its conceptualization and operationalization in the technology acceptance literature (Venkatesh et al., 2008). This gap may be because most studies that use either the technology acceptance model (Davis, 1989) or the theory of planned behavior (Ajzen, 1991) investigate behavior in the future and therefore can only make conclusions about anticipated use. A suggestion for future research is to investigate actual technology use behavior through observations to further build on the conceptualization and operationalization of actual use.

The lack of a theoretical basis for conceptualizing and operationalizing actual use has resulted in three different categories for measuring system use: actual use, reported use, and assessed use (Wu & Du, 2012). At a conceptual level, actual use refers to the system-recorded amount of time or number of times a system is used. Reported use may be defined as the user-reported amount of time or number of times a system is used. And assessed use contains the ordinal-scale-measured intensity and diverse use of a system. These categories of actual use result in different conclusions on the relationship between intention and behavior (Lee et al., 2003; Straub & Burton-Jones, 2007). According to Podsakoff et al. (2003) assessed use results in the highest correlation with behavioral intention due to the similar methods of data collection and thereby avoiding common method bias. For this reason, the Karotz Home Study incorporated assessed use behavior in the questionnaires. However, use intention only played a minor role as an explanatory factor for actual use in the Karotz Home Study. Thus, incorporating assessed use did not result in high correlations between use intention and actual use in this study. Other researchers argue that self-reported measures of system use are likely to be biased (Lee et al., 2003). This may be an effect of poor recalls of one's own past use (Devaray & Kohli, 2003), or it could be that, when reporting system use, light users overestimate and heavy users underestimate their system use (Collopy, 1996). This might provide an explanation for the weak role of use intention in explaining actual use in the Karotz Home Study.

Hitherto, four reasons for the inconsistent findings on the intention-behavior relationship in technology acceptance research have been discussed. Together, these reasons indicate that the intention-behavior relationship is not stable in these contexts and remains open for questioning. One direction for future research is to integrate the expectation-confirmation model (Bhattacherjee, 2001) into the model of the theory of planned behavior (Ajzen, 1991). The expectancy-confirmation model does not assume a correlation between initial adoption and continued use as traditional models and theories, e.g., the technology acceptance model (Davis, 1989) and the diffusion of innovations theory (Rogers, 2003). The principles of expectations versus satisfaction may be valuable for the investigation of social robot acceptance. Some human-robot interaction studies (Fink et al., 2013; Lohse, 2011) report a gap between people's prior expectations of a robot system and the system performance in reality. Additionally, prior expectations have been found to affect the evaluation of the robot system once people have been introduced to it (Komatsu, Kurosawa, & Yamada, 2012; Paepcke & Takayama, 2010). Including the evaluation of prior expectations and their influence in the evaluation of social robot acceptance may provide additional insights into what types of people will and will not accept social robots in the future. This course of action may account for the expectation gap often reported in human-robot interaction studies and may represent possible mutual shaping effects. In this manner, actual use behavior is reconnected to the preceding belief structures of the theory of planned behavior. Together, the theory of planned behavior and the expectation-confirmation model may constitute a promising research direction for providing insights into the discontinuance of technology use.

UNDERSTANDING THE CONCEPT OF HABITUAL USE BEHAVIOR

Despite attempts to understand habit-forming activities, research on habitual behaviors has progressed slowly (Verplanken, 2004). By researching prior use behaviors separately from habitual use behavior, as was done in the longitudinal Karotz Home Study, it is shown that prior use behaviors influence habitual use behavior and that habit influences continued use behavior. Furthermore, separating both concepts allows for the identification of the determinants of habitual use behaviors.

Across disciplines, habits are commonly understood as “learned sequences of acts that become automatic responses of specific situations, which may be functional in obtaining certain goals end states” (Verplanken et al., 1997, p. 540). Previous use behaviors, especially frequency of use and diversity of use, may create a pattern of habitual use. The higher the frequency of past uses, the more likely it is that the cognitive process involved will take on an automatic nature (Ronis, Yates, & Kirscht, 1989) and the user will establish a pattern of habitual use. However, when the use context shifts or when the behavior is difficult or not performed on a daily or weekly basis, previous use behavior is unlikely to result in a habit (Ouellette & Wood, 1998). Furthermore, habit is dependent on the comprehensiveness of technology use. It has been proposed that people who use a system in many different ways will tend to develop stronger habits with respect to the use of that system compared to other people who use the system in more limited ways (Limayem, Hirt, & Cheung, 2007; Peters & Ben Allouch, 2005). Thus, the diversity of use, which is a component of actual use, also results in habitual use. Habits might thus provide additional explanatory power in explaining long-term social robot acceptance behavior.

Again, criticisms focus on the habit construct. Given that, in everyday language, the term habit is used interchangeably with behavior performed on a regular basis, Aarts et al. (1998) have defined three characteristics to narrow the scope of the concept of habit. First, although not meeting all criteria of automaticity (Bargh, Chen, & Burrows, 1996), habits comprise a goal-directed type of automaticity. This means that, in the presence of a specific goal, habitual behaviors are triggered. Second, in the traditional view of habit formation, people repeat the same course of action when the experiences are satisfactory because the association between the action itself and the goal people initially attempt to accomplish tends to grow. Third, the frequent performance of a behavior in a specific situation makes it easier to activate the mental representations of that behavior and, thus, the resulting behavior itself, by situational or environmental cues. This is because cognition plays an important role in the direct control of environments over habitual behavior (Bargh & Gollwitzer, 1995; Triandis, 1979). Thus, when conceptualizing habitual behaviors, researchers should incorporate notions of automaticity in goal-directed behavior, the user's perception of the relationship between the behavior and the prospective goal, and the user's perception of the ease of the performance of the behavior in certain contexts.

HUMAN-ROBOT RELATIONSHIPS

This dissertation presented two studies that investigated human-robot relationships. Both a short-term experiment (i.e., the Pleo study) and a long-term home study (i.e., the Karotz Home Study) investigated people's willingness to treat a robot as a companion. It has already been stated in this dissertation that people seem to interact with robots similarly to how they interact with other people (e.g., Kerepesi et al., 2006) and seemingly build relationships following the same rules as in human-human interactions (Banks, Willoughby, & Banks, 2008; Bickmore & Pickard, 2005). Furthermore, it was concluded that it seems unnecessary to depart from these rules when evaluating human-robot interactions (Krämer, von der Pütten, & Eimler, 2012). Given that the research field of human-robot relationships is fairly young, the known preconditions from human friendship formation were therefore investigated to ascertain whether they could also help explain why some people are willing to treat social robots as companions.

IMPORTANT VARIABLES FOR HUMAN-ROBOT RELATIONSHIP DEVELOPMENT

The robot's social ability seems to be one of the most important factors for the realization of human-robot relationships. Intimacy appears to be one of the most important preconditions explaining the willingness to treat a zoomorphic robot as a companion in long-term interactions in the Karotz Home Study. Thus, the possibility for people to share personal information with a robot and to have the robot respond to that information in an empathic way is very important for the establishment of human-robot relationships in long-term interactions. Other human-robot interaction researchers have already noted the importance of empathy in interactions with robots, pointing to the robot's capability to respond empathically to the human user (Leite et al., 2014) and the user's empathic response to the robot (Kwak & Kim, 2009). These evaluations of the robot's empathic responses by the human user are influenced by the humanlike appearance of the robot (Riek et al., 2009). When a robot looks more humanlike and less machinelike, people show higher empathic responses to the robot.

Indeed, the robot's perceived lifelikeness seems to be another important aspect of human-robot relationship development. One of the main findings from the Pleo study is that people with prior high expectations for the robot are more willing to treat the robot as a companion.

Nevertheless, the preconditions of human friendship formation may only explain part of the variance of companionship in both the Pleo study (i.e., 58%) and the Karotz Home Study (i.e., ranging from 37% to 67%). Furthermore, the preconditions failed to explain any variance of companionship after six months of use in the Karotz Home Study even though the evaluation of perceived companionship from the robot had increased to that point. This finding indicates that there are other variables that may explain people's willingness to treat robots as companions. Thus, further research is necessary to explore the different variables that help explain human-robot relationship development.

For example, there are studies that suggest that loneliness may be a reason why certain people are more willing to treat zoomorphic robots as companions. Zoomorphic robots are just as qualified to reduce loneliness as real pets (Banks, Willoughby, & Banks, 2008), and lonely people tend to anthropomorphize robots more (Eyssel & Reich, 2013). For lonely people, these robots become better than nothing in certain situations (Turkle, 2011). The empirical evidence of the need to belong indicates that people need a certain number of meaningful relationships (Baumeister & Leary, 1995). Given that these numbers may vary from person to person, an interesting research topic is to test whether people who feel shortcomings in their regular and meaningful interactions with others will be more willing to bond with social robots. Human-robot relationships are a relatively new research topic, and further investigation into the different variables that help explain people's willingness to treat robots as companions in addition to those measured in these studies is necessary.

Additionally, future researchers could deviate from the preconditions of human-human friendships by incorporating attachment theory along with the findings from attachment to objects, as presented in chapter 9. Future studies may especially focus on how people are able to attach to objects as 'living objects', which entails attachment to an object because it is seen as "a companion that has been with a person for so long that it is perceived as having personality, soul, character, is loved and cared for" (Battarbee & Mattelmaki, 2002, p. 4). Certainly, because of people's natural social reactions to autonomous objects (Reeves & Nass, 1996), this type of attachment to objects may be triggered more easily in human-robot interactions. Thus, further developing attachment theory may be fertile ground for future research on human-robot relationships and for seeking explanations for the social engagement that some people have with social robots.

Another direction for future research on companionship with zoomorphic robots specifically could be to incorporate findings from human-pet relationships. Today, many companion robots resemble animals (e.g., Pleo the dinosaur, Karotz the rabbit, Paro the baby seal, Furby a fantasy animal), and even though there seem to be similarities between human-human relationships and human-pet relationships (ref.) and people can fill the gap between humans and animals by assigning humanlike attributes to animals (Eply, Waytz, & Cacioppo, 2007), there are also differences between both types of relationships. Thus, further exploring companionship with zoomorphic robots by using the literature on human-pet relationships could deepen our understanding of these types of relationships between humans and robots.

A MERE-EXPOSURE EFFECT IN HUMAN-ROBOT RELATIONSHIP VARIABLES

Similar to the evaluations of the acceptance variables in the Karotz Home Study, the preconditions for explaining people's willingness to treat a zoomorphic robot as a companion also evolved over time. Furthermore, similar to the evaluation of the acceptance variables, a mere-exposure effect was also observed for the preconditions of human-friendship formation in explaining why some participants were willing to treat the robot as a companion. Although the evaluation of companionship initially decreased, in the end, this evaluation increases again beyond its initial rating measured before the introduction to the robot. Similarly to what has been stated above with respect to the mere-exposure effects of the acceptance variables, future researchers of human-robot relationships should be aware that a mere-exposure effect can emerge for all types of evaluations of technologies and thus should be aware that collecting technology evaluation data at one time point consists of a snapshot of the measures incorporated in their study.

THE EFFECTS OF PRIOR EXPECTATIONS IN HUMAN-ROBOT RELATIONSHIPS

The Pleo study indicates the effects of prior expectations (high vs. low) on the influence of the known preconditions of human friendship formation on people's willingness to treat a social robot as a companion. The results show that when people have high expectations for a robot's lifelikeness, similar variables that explain why people establish relationships with each other may better explain the participants' willingness to treat a zoomorphic robot as a companion. These findings provide an indication that people may be more likely to initiate relationships with robots following the same rules as in human-human-relationships when they have high prior expectations of a robot's lifelikeness.

Additionally, the results of the Pleo study also show that people with high expectations of a robot's lifelikeness evaluate the robot more positively compared to people who have low expectations. This is contrary to previous findings (Paepcke & Takayama, 2010) that indicate the opposite and recommend low expectation settings to prevent disappointment of users. Both studies had comparable experimental conditions (low vs. high prior expectations) and used the same robot (the robotic dinosaur Pleo); however, the evaluation variables differed from one another, which may explain the different outcomes. Peapcke and Takayama (2010) asked for the users' general evaluation of the robot, whereas the focus here was on the users' willingness to treat the robot as a companion.

A theoretical explanation for the results in this dissertation can be found in the self-fulfilling prophecy (Merton, 1948) and confirmation bias theory (Nickerson, 1998). These two psychological principles together explain why someone is perceived as more competent when we have prior high expectations of that person: we only process evidence in favor of our prior expectations. Additionally, the first impression we have of something often shapes our final appraisal of that object (Rabin & Schrag, 1999). In our study, the participants were conditioned to have either a high or a low expectation of the robot's lifelikeness, which, in turn, affected their evaluations of that robot after their first interaction with it. Given that contradictory findings and explanations occur in human-robot interaction studies, further research is necessary to explore the effect of expectation setting on the various evaluative aspects of robots. Future research should further investigate how prior expectations, including other aspects in addition to the robot's lifelikeness, influence the long-term acceptance of social robots. One direction for such research is to use the expectation-confirmation model (Bhattacherjee, 2001), which hypothesizes that, in addition to the performance of a technology, the confirmation of a user's prior expectation leads to satisfaction with the technology interaction that results in an intention to continue using that technology.

GENDER DIFFERENCES IN HUMAN-ROBOT RELATIONSHIPS

Men and women focus on different preconditions of human friendship formation when they evaluate their willingness to treat zoomorphic robots as companions. This result is not surprising, given that gender differences have been found in earlier human-robot interaction research (Forlizzi, 2007; Nomura et al., 2008; Schermerhorn, Scheutz, & Crowell, 2008; Turkle, 2011). The preconditions of human friendship formation could better explain why men would be more likely to initiate companionship with a zoomorphic robot compared to females. Thus, it may be that females focus on different aspects when evaluating future human-robot relationships. Some researchers have already expected that, especially in the early years of human-robot relationships, men are more likely to emotionally bond with robots (Levy, 2008). However, a concept needs to be formulated regarding the type of zoomorphic robot used in the Pleo study. Given that Pleo resembles a dinosaur, it may be that males are more engaged by these types of zoomorphic robots than females.

Indeed, when examining the results on companionship from the Karotz Home Study, there were no gender effects in the evaluation of the preconditions of friendship formation. The Karotz robot resembles a rabbit, which is a common domestic animal and may therefore be more neutral for affection from both genders. Additionally, the results indicate that, although both genders mainly focused on intimacy, overall, the preconditions for human friendship formation from the earlier acceptance phases to the adaptation phase may better explain why females (i.e., explained variance ranged from 42% to 61%) were willing to treat the robot as a companion compared to males (i.e., explained variance ranged from 20% to 59%). However, in the later acceptance phases (i.e., the integration phase), the preconditions may better explain why males (i.e., explained variance was 81%) perceived the robot as a companion compared to females (i.e., explained variance was 55%). The contradictory findings on gender differences in human-robot relationship development between the two studies may be related to the type of robot used in the studies, even though they were both zoomorphic robots. Further discussions on the effect of the robot’s appearance follow in the next section. However, especially because the research field of human-robot relationships remains young, further research is necessary to pinpoint the existing gender differences in human-robot relationships. Such research should focus not only on differences in the evaluation of companionship between different types of robots but also on the differences in the variables that may explain why males or females are willing to treat a social robot as a companion.

THE INFLUENCE OF THE ROBOT'S APPEARANCE

Both a short-term experiment and a long-term study investigated human-robot relationships with zoomorphic robots. However, both studies employed different types of zoomorphic robots. Therefore, the evaluations of the companionship variables of both studies were compared. For this comparison, the overall means from both conditions in the experiment and the overall means from the confrontation phase in the long-term home study were used. The results presented in chapter 10 show that the robotic dinosaur Pleo was better evaluated than the rabbit-shaped Karotz robot for companionship, in addition to most of the preconditions, with the exception of similarity. A logical explanation for these results is the more diverse sociable interaction modalities of the Pleo robot.

Nevertheless, the preconditions of human friendship formation may better explain why people are willing to treat the zoomorphic robot as a companion. Furthermore, no gender differences were found in the evaluation of the Karotz robots, as found in the Pleo study. As stated above, this may have been an effect of the familiarity with rabbits as pets.

These results indicate that even though they were both zoomorphic robots, the specific robot used may provide different results. Therefore, caution is needed when generalizing the results with one category of robot (i.e., humanoid, zoomorphic, caricatured or functional, according to Fong et al., 2003), at least with respect to human-robot relationships.

12.2 METHODOLOGICAL DISCUSSION

A number of drawbacks regarding the methods used in this dissertation and certain lessons learned are discussed below. First, a methodological discussion on the measurement of the dependent variables of acceptance is presented. Second, the limitations of structural equation modeling and the model of social robot acceptance are outlined. Third, a recommendation for using multiple methods when studying acceptance is described. Fourth, the limitations concerning the robots used in the studies presented in this dissertation are addressed, in addition to some statements on the generalizability of the conclusions to other types of robots. Fifth, and finally, this paragraph presents some lessons learned about conducting research in people's private home environments.

MEASURING THE DEPENDENT VARIABLES OF ACCEPTANCE

In the technology acceptance literature, there are many debates on the measurement of the concept of actual use behavior and habitual use behavior. Here, these debates are considered in relation to the methods applied in the current dissertation.

MEASURING ACTUAL BEHAVIOR

Technology acceptance, indicated as actual use behavior in the technology acceptance model (Davis, 1989), is mostly measured as a self-assessment of the frequency of use (Bensabat & Barki, 2007), and sometimes combined with the diversity of use (Venkatesh & Davis, 2000). Although some research suggests that self-report usage measures correlate well with actual usage measures (Taylor & Todd 1995), a review of technology acceptance research indicates that self-reported usage measures are the most critical limitation in technology adoption research (Lee, Kozar & Larson, 2003). Another meta-analysis further investigating the difference between self-report usage measures and actual usage measures notes that these differences seem to depend on the manner of collecting self-reported data (Sharma et al., 2004). A study comparing self-reported measures and the log data from mobile phone use concluded that a categorical variable of actual use behavior is far more reliable than an open-ended response approach (Boase & Ling, 2013). Following this debate on measuring actual use behavior, it seems that the Karotz Home Study incorporated an appropriate method of measuring because we utilized a combination of use frequency and diversity of use to measure actual use behavior, both on Likert scales. However, given that self-report biases are likely to occur in reporting use behavior (Collopy, 1996), it is suggested that researchers should administer both self-reported and computer-generated measures to be able to compare the results (Yi & Hwang, 2003).

However, other researchers assert that conceptualizing actual use as the frequency of use combined with the diversity of use has a narrow focus. This conceptualization neglects other user behaviors, such as reinvention (Papa & Papa, 1992; Rice & Rogers, 1980) and learning (Vandenbosch and Higgins, 1996), that are important for studying technology acceptance. Including these aspects of actual use allows for a more accurate representation of the use activities that users engage in and strengthens the links with salient outcome variables, such as individual performance (Bensabat & Barki, 2007). Although the aspects of reinvention and learning are not represented in the quantitative measure of actual use, qualitative data on these concepts were collected in the Karotz Home Study, in addition to many other aspects of long-term use experiences. Reinvention was conceptualized as an acceptance experience that is part of the integration phase, in which people have familiarity with a technology and attempt to devise new functionalities or applications for that technology. Additionally, elements of learning were reflected in the concepts of exploration and familiarization. Through the exploration of the features of the robot, people learned about the technology and familiarized themselves with it. Together, all the acceptance experiences helped to define the rich descriptions of the use behaviors of the participants during the different acceptance phases. Future research may use these acceptance experiences to refine the measurements of use behavior in quantitative studies that investigate the user acceptance of domestic technologies.

MEASURING HABIT

The technology acceptance literature lacks a strong foundation with respect to the role of habit in technology acceptance due to the empirical shortcomings of its construct and effects. First, there are no convincing theoretical justifications for the indirect influence of habit on use behavior (Limayem, Hirt, & Cheung, 2007). Second, studies that investigate this influence have used imprecise measurements and/or conceptualizations of the habit constructs (e.g., Bagozzi & Warschaw, 1990, Oullette & Wood, 1998). Third, certain studies exploring the influence of habit have omitted a measurement of actual behavior (e.g., Quine & Rubin, 1997; Trafimow, 2000). Another line of research proposes that habit directly influences actual use. There are studies that indicate that both behavioral intention and habit directly influence actual behavior (Mittal, 1988; Tuorila & Pangborn, 1988). Habit directly influences technology use, and the integration of habit into a user acceptance model weakens or limits the strength of the relationship between behavioral intention and technology use (Venkatesh, Thong, & Xu, 2012), especially when habit becomes stronger (Lymayem, Hirt, & Cheung, 2007). Furthermore, the influence of habitual use differs with age, gender and experience (Venkatesh, Thong, & Xu, 2012). However, the strength of either effect on actual use is mixed and seems to be dependent on the type of behavior being researched. Additionally, other researchers question the manner in which habit has been conceptualized and measured in some of these studies (Lymayem, Hirt, & Cheung, 2007). It may be the case that there is more to the effect of habit than is commonly assumed, given that the relationship between habit and intention is more complex than an additional simple independent effect (Limayem & Hirt, 2003; Ouellette & Wood, 1998). Thus, the interrelationship between habit and actual behavior remains unclear.

The satisfactory repetition of behavior in the past may result in habit formation (Ajzen, 2002; Ronis, Yates, & Kirscht, 1989; Triandis, 1979; Verplanken, Aarts, & Knippenberg, 1997). Although it is not surprising that habit is mostly measured as the frequency of past behavior, this does not seem adequate when one understands habit as a psychological construct rather than a past behavior frequency (Verplanken & Orbell, 2003). This frequently applied, but most likely inappropriate, way of measuring habit strength may have caused the unstable results regarding the influence of habit on actual behavior.

LIMITATIONS OF STRUCTURAL EQUATION MODELING

This dissertation presented and tested a model of social robot acceptance that provided interesting results for future research on the acceptance of domestic social robots. However, despite the observed acceptable values for internal consistency and construct validity, there were certain problematic issues within the data. This section addresses some specific limitations of the current model of social robot acceptance and addresses some general limitations related to the methodology of structural equation modeling.

SPECIFIC LIMITATIONS OF THE CURRENT MODEL

First, some cross loadings were observed between the constructs of adaptability and enjoyment, sociability and adaptability, sociability and companionship, and privacy and cost. Most of these cross loadings can be explained by earlier findings. For example, Shin and Choo (2011) confirm the effect of adaptability on enjoyment for social robots. Furthermore, the concepts of adaptability and sociability are closely related, given that sociability entails the capability to successfully adapt to social situations (Rubin & Martin, 1994). The cross loadings between sociability and companionship can be explained by the finding that an increased evaluation of a robot's sociability results in higher social presence (Heerink et al., 2010), which in turn causes some people to perceive robots as social companions (Lee et al., 2006; Melson et al., 2009). Yet, even though most of the cross loadings can be explained by earlier findings, future research is needed to better empirically distinguish these concepts.

A second problem in the proposed model of social robot acceptance is related to the inclusion numerous variables into the structural model. This is a consequence of the main goal of this dissertation, which is to determine the most important determinants for social robot acceptance in domestic environments. The research field for social robot acceptance is relatively new, and it remains unclear what variables have the greatest impact on social robot acceptance in domestic environments. Furthermore, a suitable theory or model for social robot acceptance has not been developed to date. Therefore, it was decided to begin building the measurement model with exploratory factor analysis. However, the inclusion of numerous variables and their interrelationships impeded proper and straightforward model building. Therefore, it was decided to move forward with the development of a confirmatory factor analysis and conventional structural equation modeling. The main reason for this decision was the goal to build a theory-based model of social robot acceptance. Although continuing data analysis with a confirmatory factor analysis is not an uncommon approach (Morin, Marsh, & Naggengast, 2013) and the fit of the first-order factor structure in the model remained acceptable, the second-order factor structure did not. As a consequence, it was impossible to study the interrelationships between the higher order factors of the conceptual model.

Because the second-order factor structure did not fit the data in the Acceptance Survey, two options remained for continuing. One option was to come to the conclusion that there was no empirical evidence for the hypothesized conceptual model and stop further analysis. The second option was to continue data analysis with another method that would allow some insights into the influential factors of social robot acceptance. Although one should be aware that the data were used twice, it was decided to continue testing the same interrelationships in a full model as hypothesized between the second-order factors directly and between the underlying first-order factors. It must be acknowledged that the current version of the model of social robot acceptance remains far from being final. Therefore, additional replication studies are necessary to further develop a more valid and reliable model of social robot acceptance, preferably implementing the second-order factor model.

A third limitation of the methodology used can be found in the fact that the Acceptance Survey relied on constructs with three items. Although three items are enough for building a reliable scale (DeVellis, 2003), beginning with three items per construct is sometimes not adequate. Despite the large sample (n= 1148) used in the Acceptance Survey, it was necessary to remove a few items from further data analysis, which left only two items for the constructs of adaptability and anxiety towards robots. Therefore, our advice for researchers performing quantitative data analysis is to begin with at least five items per construct to allow for the possible and legitimate exclusion of items with poor loadings or cross loadings.

A fourth limitation of the model of social robot acceptance is that the Acceptance Survey tested social robot acceptance with use scenarios for the possible future roles of domestic social robots. Therefore, the Acceptance Survey does not allow for an empirical evaluation of the actual use of robots. Future research may extend the proposed model of social robot acceptance with usability components and other design aspects that may be related to or help explain the effects between the components in the current proposed model in this dissertation.

GENERAL LIMITATIONS FOR ALL STRUCTURAL EQUATION MODELS

In addition to these specific limitations in the model of social robot acceptance presented in this dissertation, some general remarks are raised related to the methodology and are thus applicable to all structural equation models must be made. First, as is true for any study on complex behavioral phenomena, the current model, without question, is incomplete. The possible inclusion of other variables to further extend the proposed model should be actively pursued by future research. Future studies should reconsider the inclusion of variables in the model of social robot acceptance currently presented in this dissertation and decide whether, in their own specific situation, there might be other relevant variables that may play a role in the user's acceptance of the robot and its role being evaluated. One suggestion for future research is to further look into the results of the Karotz Homes Study, which has revealed some additional factors that influence the continued use of social robots after initial adoption.

Second, the Acceptance Survey only measured the participants' opinions at one point in time, missing out on possible long-term use effects. Therefore, this dissertation conducted the Karotz Home Study to investigate the long-term effects on acceptance. However, due to the small sample size, the performance of structural equation modeling was not possible. As soon as social robots are adopted by a larger number of people within our society, future research should conduct a longitudinal study among actual users of social robots in home environments and repeatedly test the proposed model of social robot acceptance on actual users of social robots.

Third, as is true for any given structural equation model, there are alternative models that are equivalent in terms of overall model fit with the same set of data and that may produce substantially different explanations of the same data (Chin, 1998). However, the model currently presented has a sound theoretical basis that has been validated using this set of collected data. Although it is acknowledged that other possible, and perhaps better, fitting empirical solutions are achievable, it may be difficult to support the parallel findings with the existing theoretical findings.

TRIANGULATION: COMBINING DIFFERENT METHODS

A standard approach in addressing issues in human-robot interaction research is to conduct short-term experiments that employ questionnaires (Bethel & Murphy, 2010). Furthermore, human-robot interaction research often focuses on testing the technical operation of (parts of) the robotic system without investigating whether potential users actually want the technical features that are being tested. However, as discussed in the introduction, most of the experimental designs in human-robot interaction often lack control groups (Broekens et al., 2009) which are necessary for interpreting the effects of the stimulus. Additionally, employing self-assessment research methods, such as questionnaires, may introduce certain biases. It has been argued that it is inadequate to rely solely on explicit opinions (MacDorman et al., 2009) for two reasons. First, people are not always aware of the attitudes that affect their behavior. Second, people may conceal their genuine attitudes, which can lead to self-presentational biases. However, people’s attitudes, whether concealed or not, influence people’s behavior (Ajzen, 1991), including their use of domestic robotics.

One approach for overcoming these self-assessment biases is to conduct observational studies by exploring log data and video analysis of the participants’ use behavior. For example, researchers may include gaze behavior and facial expressions or register the time spent interacting with the robot. Data on the participants’ use behavior have the advantage that the measures are objective. However, gathering these data is time-consuming, and the analysis requires independent coders for data analysis. Another approach for overcoming these self-assessment biases is to adopt physiological measures, for example, wearable biofeedback sensors that detect the affective state of the human. The advantage of physiological measures is that people are incapable to consciously control autonomic activities. The drawback of such measures is the difficulty to gather reliable data from a sensor attached to participants in a real-world context (Kidd & Breazeal, 2005). Another inconvenience related to this type of measure is that there are multiple explanations for most physiological signals. Although these objective measures have certain drawbacks, they can be used to complement self-assessment measures, and together they may provide a more integral view of technology use behavior.

Furthermore, the field of human-robot interaction has adopted some evaluation methods from other research fields, such as psychology and human-computer interaction, and modified these methods to the context of robotics. However, only a few scales have been adjusted to human-robot interaction, and even fewer have been validated by multiple studies. Researchers in human-robot interaction have proposed different characterizations of psychological 'benchmarks' to measure success in building increasingly humanlike robots, such as privacy, reciprocity, imitation, intrinsic moral value, conventionality, creativity, authenticity or relation, and autonomy (Kahn & MacDorman, 2007). However, the validations of these measures in the context of human-robot interaction have been criticized because the psychometric approach to these measures is only one of many and oftentimes may not be the most applicable for validating acceptance variables. It is often best to take multiple approaches, e.g., a literary approach, modeling approach, philosophical approach or structuralist approach, when confirming which factors influence the human-robot interaction and the acceptance of these robots by their users (Dautenhahn & Saunders, 2011). For a holistic understanding of the user experiences of robots in people's own homes, it is necessary to use different research methods to elicit issues that enable participants to focus on different aspects of their experiences.

More appropriate methods are available, such as qualitative measures, behavioral measures, psychophysiological measures, and task performance metrics, for studying human-robot interaction. Given that all methods have their advantages and disadvantages, researchers should not rely solely on one method. While none of the methods can be seen as superior, implementing multiple methods, known as triangulation (Lazar, Feng & Hochheiser, 2010), may combine each method's advantages and disadvantage. These improvements in HRI research can be accomplished with careful planning and utilizing study design techniques, which are the state-of-the-art practices in the (social) psychology and communication sciences (Bethel & Murphy, 2010). Without a shared set of definitions, topics and concepts, there can be no cumulative tradition. Thus, the field of robotics needs well-defined constructs based on theory that are operationalized and measured with high degrees of validity and reliability as a prerequisite for the beginning of a cumulative tradition.

LIMITATIONS RELATED TO THE ROBOTS USED IN THIS DISSERTATION

Most of the studies reported in this dissertation employ a zoomorphic robot. Zoomorphic robots exhibit characteristics that users associate with domestic animals and are designed to imitate living creatures (Fong, Nourbakhsh, & Dautenhahn, 2003). Such robots may benefit from the mechanisms behind the establishment of human-creature or owner-pet relationships because people tend to behave similarly around zoomorphic robots as they do around pets (Friedman, Kahn, & Hagman, 2003; Kerepesi et al., 2006). Robots have limited perceptual, cognitive, and behavioral abilities compared to humans, and at least for now, there will continue to be a significant imbalance in social sophistication between humans and robots. People find interactions with zoomorphic robots more satisfying than interactions with humanoid robots because they do not expect full responsiveness from animals (Kahn et al., 2006). Thus, especially until robotic technology is able to mimic human behavior more realistically, a zoomorphic appearance may be more appropriate for robots that need to work alongside or with humans. Furthermore, it is easier to avoid the uncanny valley (i.e., the eeriness experienced by human users when a robot looks and behaves almost, but not exactly, as human beings do) because human-creature relationships are simpler than human-human relationships and the users' expectations for what constitutes 'realistic' animal morphology tend to be lower than those for human morphology (Fong, Nourbakhsh, & Dautenhahn, 2003). For these three reasons, it is believed that mainly employing the zoomorphic robots for the studies presented in this dissertation is appropriate. However, the employment of zoomorphic robots imposes some limitations on the generalizability of the current results to other types of robots (i.e., humanoid, caricatured and functional robots). Therefore, replication of the studies reported in this dissertation with different types of robots is needed.

Furthermore, the interaction capabilities of the robots used for this dissertation, especially the Karotz robot used in the Karotz Home Study, are somewhat limited. The choice of this robot is a fundamental result of the goal of that study, to investigate long-term social robot acceptance in multiple households ($n = 70$). This goal resulted in the employment of a commercially available domestic robot with some social features, a type of robot that has been successfully applied in other studies investigating user experiences and perceptions of human-robot interaction (Ferneaus et al., 2010). Furthermore, the limited interaction possibilities of the Karotz robot resulted in certain insights on essential social behaviors for future social robots (see chapter 2). Therefore, replication of the studies reported in this dissertation with more sophisticated robots to ascertain whether similar results on the sociability and acceptance of robots occur is needed.

THE CHALLENGES OF RESEARCH IN REAL HOMES

Investigating the acceptance of robots within people's own homes presents certain challenges additional to the challenges of the lab experiments that are associated with this context. Researchers need to be aware of these challenges before and while they conduct their studies.

INVESTIGATING TRADITIONS AND ROUTINES

When researchers conduct research within people's own homes, they need to comprehend the meaning of the home for the human users. Given that the home is a human constitution, a social arena for human action, the home evokes feelings (Leppänen and Jokinen, 2003). Households contain specific social norms and traditions that frame people's actions and their everyday lives. People are somewhat traditional in their lifestyle, at least in regard to everyday routines and household chores, which are not necessarily easily penetrated by technology (Leppänen and Jokinen, 2003). To obtain an in-depth understanding of the users, researchers need appropriate methods (O'Brien et al.,, 1999) and must explore new ideas with the users (Bernhaupt et al., 2008) and investigate the appropriation and incorporation of robots in real-world contexts (Silverstone & Haddon, 1996).

SAMPLING FOR LONG-TERM STUDIES

Another challenge in (long-term) user studies is the selection of participants. Given that the samples in long-term studies are typically small, researchers should think very carefully about the selection of their samples. Participants in the Karotz Home Study were recruited by various methods, such as word of mouth, advertising in public locations (e.g., libraries, leisure centers and supermarkets), and snowball sampling by asking assigned participants for referrals to other people who might participate. During recruitment, I attempted to balance the households' demographic profiles to seek diversity and to equalize participants from each household type. Tightly specifying the participant group provides more reliability given the small group size. We compensated our participants involving in both the questionnaires and the interviews by allowing them to keep their robots after completion of the study. Furthermore, to increase both homogeneity and convenience, most participants lived within 10 square kilometers of our university, the University of Twente in The Netherlands.

Although the participants in the Karotz Home Study consisted of a well-selected group, some remarks about this group of participants and its relationship to the reported findings must be made. First, all participants voluntarily joined the study and were able to use the robot for free. Therefore, the motivations of the users in the Karotz Home Study were somewhat different from the motivations of 'real' future users who will buy and employ social robots. Although this dissertation was able to reveal the underlying variables that explain social robot acceptance, the strength of the effects may be different for 'real' users of social robots. Therefore, further research is necessary to investigate the interrelationships among the acceptance variables as the technology of social robotics matures and the diffusion of social robots within society increases.

PLANNING AND COORDINATING A LONG-TERM STUDY

A third challenge in long-term user studies entails the fact that the planning and coordination of all the different steps in the research process turned out to be somewhat time- and resource-consuming. Scheduling all the home visits at several times during the project caused certain problems. Participants were busy, cancelled at the last minute or were not home at the scheduled time. These instances resulted in delays in the project, and researchers should anticipate these issues when planning their research projects. Additionally, unexpected technological complications, device errors and other influencing external factors were additional barriers that we encountered when conducting research in a real-world context. Although we attempted to resolve problems as soon as possible, some participants went a step further by claiming us as a 24/7 helpdesk for all their major and minor problems.

ROBUSTNESS AND RELIABILITY OF THE ROBOTIC SYSTEM

A fourth challenge in long-term user studies in robotics can be found in the employment of the robot itself. Human-robot interaction studies entail challenges that are not encountered in human-computer interaction studies. In addition to incorporating a well-designed method for the study, investigating social robot acceptance in real home settings requires having a reliable robotic system. Human-robot interaction researchers must confirm that the robot is prepared to engage in the interaction (Kidd & Breazeal, 2005), especially because long-term use in real homes does not allow for Wizard-of-Oz scenarios. Given that robotics technology has only recently become adequately robust to allow for the adoption of long-term evaluations in home settings (Ferneaus et al., 2010; Nguyen et al., 2013), this is one of the reasons why research in domestic environments as a context of use remains in its infancy. Nevertheless, with the arrival of commercial robotic products such as robotic vacuum cleaners and robotic toys, the domestic use of robots is currently a reality.

PENETRATING THE USER'S PRIVATE SPACES

A fifth and final challenge in long-term user studies concerns the penetration of the private environment of the participants. When researchers conduct research within people's own homes, they need to comprehend the meaning of the home for the human users. Given that the home is a human constitution, a social arena for human action, the home evokes feelings (Leppänen and Jokinen, 2003). Households contain specific social norms and traditions that frame people's actions and their everyday lives. People are somewhat traditional in their lifestyle, at least in regard to everyday routines and household chores, which are not necessarily easily penetrated by technology (Leppänen and Jokinen, 2003). Researchers thus must be aware of these challenges when conducting research in people's private spaces.

PEOPLE'S RETICENCE TOWARDS SOCIAL RESPONSES TO ROBOTS

Furthermore, researchers investigating the socially evoked responses by robots and human-robot relationships need to adequately introduce this topic in their interviews. It seems that people need to discard any reticence that they may have with respect to interacting with these robots before they can allow themselves to build a relationship with them. In one of our studies, some participants expressed their concern that others would find them crazy for thinking of the robot as a person or companion (de Graaf, Ben Allouch, & Klamer, 2015). Similar findings were reported by Turkle (2011). It seems that participants need to trust the researcher and trust that he or she will understand their 'relationship' with the robot before openly discussing this relationship during interviews. Once the researcher had asked questions about giving the robot a name and about the possibility of having a relationship with the social robot, the older adults seemed to refer to the robot as 'him' or 'her' more frequently and talked more freely about their relationships with it than before these types of questions were asked (de Graaf, Ben Allouch, & Klamer, 2015). Kidd (2008) reported having the same experience, that is, that he needed to earn the trust of his participants in order for them to talk about their relationship with the social robot. These findings stress the need for a well conceptualized research design that takes participants' reservations into account before being able to draw conclusions about human-robot relationships. Researchers exploring the relationships that people build with social robots need to be aware of people's reticence when talking about their relationships with an artificial companion. Otherwise, researchers will not be able to uncover all the details concerning what is transpiring between the users and their social robots, leading them to false and premature conclusions. Thus, researchers should not underestimate the necessity of good social skills (Ogonowski, Ley, & Stevens, 2013). Entering people's personal spaces for research requires researchers to take a sensitive and empathic approach in order for the participants to open up.

12.3 PRACTICAL DISCUSSION

Based on the findings of this dissertation, some practical implications can be drawn to guide the future development of social robots and their acceptance within society. A first set of practical implications to increase the acceptance of social robots among the general public is discussed, followed by a second set of practical implications on how robots can be better companions.

INCREASING THE ACCEPTANCE OF SOCIAL ROBOTS

This dissertation has yielded certain interesting suggestions for increasing the acceptance of social robots among the general public. These suggestions are presented below.

CLEAR PURPOSE OF THE ROBOT

One of the most important variables for social robot acceptance is most likely its utility, its usefulness (Davis, 1989) or its relative advantage (Rogers, 2003). The purpose of the robot must be clear for a successful acceptance that leads to continued use. The importance of usefulness has also been stressed in an earlier long-term study with the Roomba vacuum cleaner robot (Fink et al., 2013), with the majority of the households in their study failing to perceive the robot as useful. Similarly, the participants in the Karotz Home Study who discontinued using the robot indicated that they had replaced (the functionalities of) the robot with another device. These other technological devices not only fulfilled similar goals, but also did so in a more satisfying way. Together, these results indicate that developers of social robots should aim for clear applicability in their robots.

INCREASING THE ROBOT'S SOCIABILITY

Given that the results of the Acceptance Survey indicate that a more sociable robot increases the user's perception of the adaptability of that robot, social robots need to further develop their sociable behavior. Furthermore, similar findings were found in the Karotz Home Study. Not surprisingly given the simple dialog of the Karotz robot, the participants found the interactions with the robot to be somewhat simple and repetitive. The need to first press a button before you could speak to the robot especially felt very unnatural and uneasy. However, some participants preferred to have additional conversations. Most participants would have liked it if they could simply call the robot by name to get its attention, followed by a command or short conversation. Additionally, a socially behaving robot should be able to show and interpret emotions. Other desired adjustments, according to the participants, were awareness of their presence so that the robot would know when someone was in the room and could ask for your attention when needed. Together, these results indicate that users would like to see more sociable behaviors from social robots.

CONSIDERING THE PROCESS OF LONG-TERM ACCEPTANCE

Acceptance is long-term decision-making process, and each phase has its own focus on certain acceptance variables that influence social robot acceptance. For the initial adoption of social robots, people seem to focus on control beliefs, such as previous experiences with similar technologies and self-efficacy (i.e., results from both the Acceptance Survey and the Karotz Home Study), and normative beliefs, such as status and privacy concerns (i.e., results from the Acceptance Survey). Subsequently, after the initial adoption, the focus of the decision to continue the use of social robots shifts to the evaluation of the utilitarian and hedonic attitudes associated with the use of the robot. By far the most important utilitarian attitude was the robot's usefulness. For the hedonic attitudes, the enjoyable interactions it has to offer and the social presence experienced by the users were important variables during initial acceptance. However, the main hedonic reasons for continued use was the robot's sociability. Thus, for the successful diffusion and acceptance of social robots within society, developers should provide potential buyers with the necessary information that would make them feel more familiar with robot technologies and enhance their self-assessment of their abilities to use social robots. After people have bought the robot, developers of social robots should ensure that the users perceive the robots as useful, enjoyable and sociable.

CONSIDERING THE USE CONTEXT

In addition to the variables related to the robot, the research undertaken in this dissertation has found that the use context influences the long-term acceptance of social robots. Examples of use contexts include the user's living situation, the time of day, and the location where the robot is used. From the control beliefs, participants in the Karotz Home Study mostly indicated that the context of the interaction had an impact on their experiences with the robot. For example, periods around major events, such as vacation holidays, but also at specific moments during the day or week, such as during a morning ritual, had an influence on their use of the robot. Developers of social robots should be aware of the aspects of the use context associated with the use of a robotic system.

THE EFFECT OF MERE-EXPOSURE

The diffusion of social robots within society will increase familiarization with these technologies. However, the end of the novelty effect, when people are familiar with robots or when robots have become ubiquitous in society, does not necessarily mean that people will embrace social robots. Actual user experiences with robots serve as inputs that reshape people's attitudes towards robots and may or may not have a positive effect. Thus, developers of social robots should be aware of both the positive and negative effects associated with the diffusion of social robots within society.

HOW TO MAKE BETTER ROBOTIC COMPANIONS

This dissertation has yielded certain interesting suggestions for creating better robotic companions. These suggestions are presented below.

FOLLOWING THE SOCIAL RULES OF HUMAN-HUMAN INTERPERSONAL COMMUNICATION

People interact and build relationships with robots following the same rules as in human-human interactions (e.g., Banks, Willoughby, & Banks, 2008; Bickmore & Pickard, 2005; Kerepesi et al., 2006). Other researchers argue that it seems unnecessary to depart from these rules when evaluating human-robot interactions. Therefore, developers should investigate theories of human-human interpersonal communication to create better robotic companions.

BEING PERCEIVED AS LIFELIKE

For social robots to flourish as companions for humans, the results of the Pleo study indicate that people are more willing to treat a robot as a companion when they have high expectations for the robot's lifelikeness. In this dissertation, this result is related to the self-fulfilling prophecy and confirmation bias that explain the human response to preserving prior high expectations in the evaluation of current events. However, the influence of lifelikeness, which was found to be the most important variable for companionship with robots in the Karotz Home Study, has also been related to people's empathic responses to a robot (Riek et al., 2009; Rosenthal - von der Pütten et al., 2013). These findings suggest that developers of companion robots should aim for a lifelike appearance, which does not necessarily mean a humanlike appearance.

INCREASING SOCIAL INTERACTION

The main finding of the sociability of social robots is that the participants in the Karotz Home Study indicated that two-way interaction and having a consciousness are the two most essential parts of social behavior to pursue for social robots at this stage of development. Two-way interaction consists of receiving spoken feedback to what a user tells the robot, and having a consciousness means possessing thoughts, feelings and emotions and being capable of sense the social environment. These two characteristics of social behavior overlap with the social characteristics of learning and developing social competences, exhibiting a distinctive personality, and social learning that were presented by Fong, Nourbakhsh, and Dautenhahn (2003) and Mutlu (2012). Learning and developing social competences entail that robots should possess a considerable amount of social skills for interacting with their human counterparts. Exhibiting a distinctive personality entails that robots should have a compelling personality (Breazeal, 2005) that can be expressed through emotions, embodiment, motion, manner of communication, and the tasks that they perform (Fong, Nourbakhsh, & Dautenhahn, 2003; Severson-Eklund, Green, & Hüttenrauch, 2003; Yoon et al., 2000). Social learning and imitation partly entail the robot's ability to understand human mental models (Multu, 2011). Thus, developers of social robots should focus on increasing a robot's social behavior by first addressing these issues.

ENGAGING EMPATHICALLY

The possibility of sharing personal information with a robot and having that robot respond to this personal information in an empathic manner was observed in the Karotz Home Study as the most important variable for explaining companionship with a robot. The importance of empathic behavior for companionship with social robots and the user's empathic responses to the robot (Kwak & Kim, 2009) have been noted by other researchers (Leite et al., 2014). Thus, to be better robotic companions, social robots need to be perceived as empathic.

ZOOMORPIC ROBOTS NEED TO RESEMBLE DOMESTIC ANIMALS

Based on the findings concerning human-robot relationships in this dissertation, it is advised that developers of robot companions with zoomorphic appearances should focus on common domestic animals. Where the results of the Pleo study indicated that males evaluate companionship with the robotic dinosaur Pleo more positively than females, the results of the Karotz Home Study did not find any significant gender difference related to companionship with a robotic rabbit. Therefore, when building zoomorphic robots, developers should consider common domestic animals for the appearance because doing so increases the acceptance of these types of companion robots for both genders.

12.4 FINAL REMARKS

Over the most recent decades, the field of social robotics has advanced rapidly. There are a growing number of different types of robots, and their roles within society are expanding. This dissertation has argued that investigating the long-term acceptance of social robots in home environments is necessary for the successful diffusion of these types of robots within society.

The findings of this dissertation indicate that usefulness is a requisite for social robot acceptance and that certain additional important acceptance variables may further explain why people continue to use a social robot in their own homes. These additional acceptance variables show that the acceptance of a social robot for domestic use increases when future users believe that they possess the necessary skills to use a social robot, when they perceive that having such a robot enhances their status, and when they expect that such a robot provides more enjoyable interactions, behaves less sociably, and causes fewer privacy concerns. However, when examining the long-term use of social robots in home environments, it appears that the importance of the acceptance variables in explaining social robot acceptance changes over time, shifting from control beliefs to attitudinal beliefs. It is believed that the importance of the acceptance variables depends on the development stage in which the technology is located (Peters, 2011). When people gain experiences with a social robot, other acceptance variables explain people's intention to continue using it compared to the acceptance variables that explained their initial adoption.

Concerning human-robot relationships, the studies presented in this dissertation indicate that people are initially reluctant to build a relationship with a robot and deny the possibility that such a relationship will occur for them. However, after people have adopted a social robot and have begun to use it in their own homes, some people acknowledge that they have established some type of relationship with the robot. However, not all people seem to appreciate a robot's social behavior, and it seems that people remain unfamiliar with the possibilities of human-robot relationships and that the actual use and interactions with social robots reveal what types of relationships people are willing to establish with these robots.

The findings of this dissertation may help both researchers and developers of social robots to further develop an integrated theory or model of social robot acceptance that can describe and explain this acceptance in more real-world contexts, such as the home.

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APPENDICES

APPENDIX A:

ITEMS USED FOR ACCEPTANCE VARIABLES

Construct	Code	Item	Source
Use Intention	UI01	Assuming I have a robot, I would use it on a regular basis in the future.	Moon & Kim, 2001
	UI02	Assuming I have a robot, I will frequently use it in the future.	
	UI03	I will strongly recommend others to use the robot.	
Usefulness	PU01	I think the robot is useful to me.	Heerink et al., 2008
	PU02	I would be convenient for me to have the robot.	
	PU03	I think the robot could help me with many things.	
Ease of Use	PEOU01	I think I will know quickly how to use the robot.	Heerink et al., 2008
	PEOU02	I find the robot easy to use.	
	PEOU03	I think I can use the robot without any help.	
	PEOU04	I think I could use the robot when there is someone around to help me.	
	PEOU05	I think I can use the robot when I have a good manual.	
Adaptability	PAD01	I think the robot can be adaptive to what I need.	Heerink et al., 2008
	PAD02	I think the robot will only do what I need at that particular moment.	
	PAD03	I think the robot will help me when I consider it to be necessary.	
Enjoyment	PENJ01	I enjoy the robot talking to me.	Heerink et al., 2008
	PENJ02	I enjoy doing things with the robot.	
	PENJ03	I find the robot enjoyable.	
	PENJ04	I find the robot fascinating.	
	PENJ05	I find the robot boring. (reversed item)	
Attractiveness	PA01	I think the robot looks quite pretty.	Lee et al., 2005
	PA02	The robot is very good looking.	
	PA03	I find the robot very attractive physically.	
	PA04	I don't like the way this robot looks. (reversed item)	
Social Presence	SP01	Interacting with the robot feels like interacting with an intelligent being.	Biocca et al., 2001
	SP02	While I used the robot, I felt as if I was alone. (reversed item)	
	SP03	While I used the robot, I felt as if I was with an intelligent being.	
	SP04	While I used the robot, I felt as if the robot and I were communicating with each other.	
Animacy	AN01	Semantic differential: The robot is dead vs. alive.	Bartneck et al., 2009b
	AN02	Semantic differential: The robot is stagnant vs. lively.	
	AN03	Semantic differential: The robot is mechanical vs. organic.	
	AN04	Semantic differential: The robot is artificial vs. lifelike.	
	AN05	Semantic differential: The robot is inert vs. interactive.	
	AN06	Semantic differential: The robot is apathic vs. responsive.	

Sociability	SB01	The robot allows me to see who it really is.	Rubin & Martin, 1994
	SB02	The robot can put itself in other's shoes.	
	SB03	The robot is comfortable in social situations.	
	SB04	When the robot has been wronged, it confronts the person who wronged it.	
	SB05	The conversations with the robot are pretty one-sided. (reversed item)	
	SB06	The conversations with the robot are characterized by smooth shifts from one topic to the next.	
	SB07	I can tell when the robot is happy or sad.	
	SB08	The communication of the robot is usually descriptive, not evaluative.	
	SB09	I truly believe that the robot cares about me.	
	SB10	The robot accomplishes its communication goals.	
Companionship	COM01	I think this robot can be a friend of mine.	McCroskey et al. (1974)
	COM02	I think I could spend a good time with this robot.	
	COM03	I would like to spend more time with this robot.	
	COM04	I could establish a personal relationship with this robot.	
Privacy Concerns	PR01	It usually bothers me when the robot asks me personal information.	Malhotra et al., 2004
	PR02	When the robot asks me for personal information, I sometimes think twice before providing it.	
	PR03	It bothers me to give personal information to the robot.	
	PR04	I am concerned that the robot is collecting too much personal information about me.	
Trust	TR01	Semantic differential: The robot is dishonest vs. honest.	McCroskey & Teven, 1999
	TR02	Semantic differential: The robot is untrustworthy vs. trustworthy.	
	TR03	Semantic differential: The robot is dishonorable vs. honorable.	
Societal Impact of Robots	SOCI01	I would feel uneasy if robots ANly had emotions.	Nomura et al., 2008
	SOCI02	Something bad might happen if robots developed into living beings.	
	SOCI03	I feel that if I depend on robots too much, something bad might happen.	
	SOCI04	I am concerned that robots would be a bad influence on children.	
	SOCI05	I feel that in the future society will be dominated by robots.	
Social Influence	SI01	People will find it interesting to play with the robot.	Lee et al., 2006a
	SI02	People will find the robot attractive.	
	SI03	Assuming that they can afford it, people are likely to buy the robot.	
Media Influence	MI01	My opinion about robots is influenced by programs about news and current events.	Brown & Venkatesh, 2005
	MI02	My experiences with robots are influenced by science fiction.	
	MI03	My perception on robots are based on what I watch and read in the media.	
Status	ST01	People who own a robot have more prestige than those who do not.	Venkatesh & Davis, 2000
	ST02	People who own a robot have a high profile.	
	ST03	Owning a robot is a status symbol in my 'social network' (other word is required).	

Self-Efficacy	SE01	I could use the robot if there was no one around to tell me what to do as I go.	Bandura, 1977
	SE02	I could use the robot if I had never used a robot like this before.	
	SE03	I could use the robot if I had only the manual for reference.	
	SE04	I could use the robot if I had seen someone else using it before trying it myself.	
	SE05	I could use the robot if I could call someone for help if it got stuck.	
	SE06	I could use the robot if someone else had helped me get started.	
	SE07	I could use the robot if I had a lot of time to complete my interaction with the robot.	
	SE08	I could use the robot if I had just the built-in help facility for assistance.	
	SE09	I could use the robot if someone showed me how to do it first.	
	SE10	I could use the robot if I had used a similar robot like this one before.	
Personal Innovativeness	PIIT01	If I heard about a new information technology, I would look for ways to experiment with it.	Aragwal & Karahanna, 2000
	PIIT02	In general, I am hesitant to try out new information technologies.	
	PIIT03	Among my peers, I am usually the first to try out new information technologies.	
	PIIT04	I like to experiment with new information technologies.	
Anxiety towards Discourse with Robots	RAS01	I feel anxious about how I should talk to the robot.	Nomura et al., 2008
	RAS02	I feel anxious about how I should respond when the robot talks to me.	
	RAS03	I feel anxious about whether the robot will understand what I am talking about.	
	RAS04	I feel anxious about whether I will understand what the robot is talking about.	
Safety	SAFE01	Semantic differential: Being near the robot makes me feel anxious vs. relaxed.	Bartneck et al., 2009b
	SAFE02	Semantic differential: Being near the robot makes me feel agitated vs. calm.	
	SAFE03	Semantic differential: Being near the robot makes me feel quiescent vs. surprised.	
Cost	CST01	Robots that are available today are too expensive.	Brown & Venkatesh, 2005
	CST02	I think robots are quite pricy.	
	CST03	I consider a robot to be a big-ticket item.	

APPENDIX B:

ITEMS USED FOR COMPANIONSHIP VARIABLES

Construct	Code	Item	Source
Companionship	COM01	I think this robot can be a friend of mine.	McCroskey et al. (1974)
	COM02	I think I could spend a good time with this robot.	
	COM03	I would like to spend more time with this robot.	
	COM04	I could establish a personal relationship with this robot.	
Attractiveness	PA01	I think the robot looks quite pretty.	Lee et al., 2005
	PA02	The robot is very good looking.	
	PA03	I find the robot very attractive physically.	
	PA04	I don't like the way this robot looks. (reversed item)	
User's extraversion	EXT01	I am someone who is talkative.	John & Srivastava, 1999
	EXT02	I am someone who tends to be quite. (reversed item)	
	EXT03	I am someone who generates a lot of enthusiasm.	
	EXT04	I am someone who is outgoing, sociable.	
	EXT05	I am someone who is reserved. (reversed item)	
	EXT06	I am someone who is sometimes shy, inhibited. (reversed item)	
	EXT07	I am someone who is full of energy.	
	EXT08	I am someone who has an assertive personality.	
User's agreeableness	AGR01	I am someone who is considerate and kind to almost everyone.	John & Srivastava, 1999
	AGR02	I am someone who has a forgiving nature.	
	AGR03	I am someone who is helpful and unselfish with others.	
	AGR04	I am someone who starts quarrels with others. (reversed item item)	
	AGR05	I am someone who is sometimes rude to others. (reversed item)	
	AGR06	I am someone who can be cold and aloof. (reversed item)	
	AGR07	I am someone who is generally trusting.	
	AGR08	I am someone who tends to find fault with others. (reversed item)	
	AGR09	I am someone who likes to cooperate with others.	
User's conscientiousness	CON01	I am someone who does a thorough job.	John & Srivastava, 1999
	CON02	I am someone who perseveres until the task is finished.	
	CON03	I am someone who tends to be disorganized. (reversed item)	
	CON04	I am someone who tends to be lazy. (reversed item)	
	CON05	I am someone who is a reliable worker.	
	CON06	I am someone who does thing efficiently.	
	CON07	I am someone who makes plans and follows through with them.	
	CON08	I am someone who is easily distracted. (reversed item)	
	CON09	I am someone who can be somewhat careless. (reversed item)	

User's emotional stability	EMO01	I am someone who worries a lot. (reversed item)	John & Srivastava, 1999
	EMO02	I am someone who can be tense. (reversed item)	
	EMO03	I am someone who is relaxed, handles stress well.	
	EMO04	I am someone who gets nervous easily. (reversed item)	
	EMO05	I am someone who is emotionally stable, not easily upset.	
	EMO06	I am someone who remains calm in tense situations.	
	EMO07	I am someone who is depressed, blue. (reversed item)	
	EMO08	I am someone who can be moody. (reversed item)	
User's openness	OPEN01	I am someone who likes to reflect, play with ideas.	John & Srivastava, 1999
	OPEN02	I am someone who is inventive.	
	OPEN03	I am someone who values artistic, aesthetic experiences.	
	OPEN04	I am someone who is original, comes up with new ideas.	
	OPEN05	I am someone who is ingenious, a deep thinker.	
	OPEN06	I am someone who has an active imagination.	
	OPEN07	I am someone who is curious about many different things.	
	OPEN08	I am someone who is sophisticated in art, music, or literature.	
	OPEN09	I am someone who has few artistic interests. (reversed item)	
	OPEN10	I am someone who prefers work that is routine. (reversed item)	
Robot extraversion	EXT01	The robot is extraverted, enthusiastic.	Gosling et al., 2003
	EXT02	The robot is reserved, quiet. (reversed item)	
Robot agreeableness	AGR01	The robot is critical, quarrelsome. (revised item)	Gosling et al., 2003
	AGR02	The robot is sympathic, warm.	
Robot conscientiousness	CON01	The robot is dependable, self-disciplined.	Gosling et al., 2003
	CON02	The robot is disorganized, careless. (reversed item)	
Robot emotional stability	EMO01	The robot is anxious, easily upset. (reversed item)	Gosling et al., 2003
	EMO02	The robot is calm, emotionally stable.	
Robot openness	OPEN01	The robot is open to new experiences, complex.	Gosling et al., 2003
	OPEN02	The robot is conventional, uncreative.	
Self-disclosure	SELDIS01	How much do you disclose thoughts to the robot?	Laurenceau et al., 1988
	SELDIS02	How much do you disclose information to the robot?	
	SELDIS03	How much do you disclose your feelings to the robot?	
Partner disclosure	PARDIS01	How much did the robot disclose thoughts and feelings?	Laurenceau et al., 1988
	PARDIS02	How much positive emotions dis the robot disclose?	
	PARDIS03	How much negative emotions did the robot disclose?	

Partner responsiveness	RESP01	To what degree do you feel accepted by the robot?	Laurenceau et al., 1988
	RESP02	To what degree do you feel understood by the robot?	
	RESP03	To what degree do you feel cared for by the robot?	
Reciprocal liking	RECIP01	Do you like the robot? (yes vs. no)	Laurenceau et al., 1988
	RECIP02	Do you think the robot likes you? (yes vs. no)	

APPENDIX C:

FIRST EFA SOLUATION INCLUDING ALL ITEMS

Code	UIPU F1	PEOU F2	PAD F3	PENJ F4	PA F5	SP F6	AN F7	SB F8	COM F9	PR F10	TR F11	NARS F12	SI F13	ST F14	SE F15	PIIT F16	RAS F17	SAFE F18	CST F19
UI01	**.891**	.026	.029	-005	.003	.056	-.009	.006	-.026	-.004	-.012	.002	.030	.013	.002	.014	-.013	.007	.011
UI02	**.897**	.036	.004	-006	.000	.008	-.017	.018	.007	-.014	.000	.017	.030	.044	.006	-.001	-.043	-.027	-.001
UI03	**.653**	.016	-.038	.066	.005	.071	.034	-.005	.070	-.052	.005	-.025	.041	.044	.021	.018	.057	.019	-.018
PU01	**.620**	-.006	.126	.066	.033	.028	.020	.093	.030	.021	.011	-.036	.040	-.043	.030	.026	-.022	.024	-.009
PU02	**.804**	-.003	-.004	.056	-.009	-.010	.030	-.002	.028	.013	-.009	.006	.004	.064	.053	.012	.003	.029	.002
PU03	.213	.197	**.528**	.070	-.006	.005	.029	-.016	.085	-.011	.040	.008	.010	.029	.019	.000	.030	.003	.034
PEOU01	.009	**.695**	.082	-.054	.037	.020	-.044	.067	.003	-.005	.036	.007	-.004	-.044	.053	.065	-.054	.045	.052
PEOU02	.211	**.460**	.217	.182	-.031	.011	-.007	.021	.020	-.006	.013	-.032	.042	.062	-.043	-.015	.049	-.008	-.037
PEOU03	-.030	**.806**	-.023	.047	-.001	-.014	.039	-.016	-.002	-.010	-.016	-.024	.016	.003	.016	.027	-.016	.078	.005
PAD01	-.004	**.343**	**.494**	.003	.010	.118	.081	-.044	.044	-.012	.003	-.002	.019	.030	.013	-.004	-.036	.018	-.008
PAD02	-.007	.037	**.369**	.241	.004	-.012	-.028	.208	-.037	.023	.013	.009	.054	.012	.088	-.007	.012	.102	.020
PAD03	.012	.009	**.371**	**.322**	.019	.010	.000	.172	-.013	-.018	.002	.005	.085	.017	.039	.012	-.054	.023	.007
PENJ01	.074	.018	-.018	**.598**	.005	.020	.020	-.028	.298	-.027	-.013	.026	-.032	.023	.021	.004	-.030	.034	.026
PENJ02	.118	.041	.025	**.641**	.007	.011	.055	-.062	.166	-.015	.028	-.004	.013	.035	-.002	-.005	.005	.043	-.017
PENJ03	.015	-.002	.095	**.660**	.042	-0.14	-.014	.094	.075	-.004	-.002	-.047	.067	-.011	.032	.086	-.019	-.043	.012
PA01	-.022	-.030	-.044	.146	**.826**	-.048	.073	.024	.002	-.006	.005	.002	.058	.014	.011	-.014	-.008	.016	-.027
PA02	.030	-.005	.033	.001	**.874**	.057	-.060	-.022	-.037	.011	.051	-.040	-.016	.004	-.036	.007	-.008	.055	.019
PA03	-.039	.002	-.016	-.029	**.916**	.014	.005	-.023	.075	-.050	-.047	.018	.028	.025	.018	.001	.011	-.006	.026
AN01	.044	.022	.030	.001	**.604**	.003	**.467**	-.001	.025	-.022	-.028	-.035	-.016	-.009	-.004	.025	.028	.012	.008
AN02	-.024	-.019	.055	.029	**.458**	.004	**.707**	.033	001	.019	.003	.002	.026	-.018	-.003	.015	.017	-.013	.013
AN03	.049	.052	-.038	-.004	**.387**	.015	**.644**	.025	-.012	.003	.002	.024	-.035	.012	.032	-.006	-.031	-.024	-.040
SP01	.023	.034	-.007	.025	-.009	**.892**	-.003	.014	-.019	.007	-.002	.007	.005	.012	.027	.021	-.007	-.031	-.012
SP02	.274	-.062	.060	.040	.022	-.017	-.037	-.172	.063	-.185	.075	-.153	-.060	-.053	-.008	-.012	.005	.060	.000
SP03	-.009	.001	-.001	.004	.025	**.820**	.014	.022	.036	-.001	.018	-.017	.006	.061	.018	.011	.008	.021	-.001
SP04	.057	.000	.036	.086	-.002	**.582**	.009	.035	.143	-.023	-.014	.012	.059	-.032	.010	-.015	-.009	.023	.014
SB01	-.001	-.031	.006	.011	-.024	.020	.115	**.687**	.117	-.064	.011	-.075	-.011	.059	-.008	.012	.058	.030	.056
SB02	.085	.045	-.008	.012	.013	.046	.048	**.634**	-.012	-.009	.042	-.017	.004	.004	.019	-.006	-.017	.097	.002
SB03	.007	.014	.027	-.003	.084	.017	-.064	**.442**	**.325**	.058	-.004	.088	.027	-.020	.008	.002	-.145	.002	-.022
COM01	.025	.014	-.006	-.034	.033	.014	.006	.029	**.894**	-.017	-.019	.019	.016	.017	-.013	-.005	-.026	-.007	-.004
COM02	.086	-0.21	.080	.176	-.006	.049	.004	.066	**.587**	-.057	-.007	.010	-.009	-.039	.076	.047	-.019	.017	.016
COM03	.067	.006	.010	.069	-.027	.012	.016	-.027	**.718**	-.018	-.005	-.036	.010	.046	.061	.023	.061	.036	-.018
COM04	-.047	.031	-.002	.022	-.008	.009	.012	.011	**.855**	.034	.025	-.042	.025	.078	-.008	-.001	.021	-.028	-.042

Factor loadings > .3 are depicted in bold.

	UIPU	PEOU	PAD	PENJ	PA	SP	AN	SB	COM	PR	TR	NARS	SI	ST	SE	PIIT	RAS	SAFE	CST
Code	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**	**F12**	**F13**	**F14**	**F15**	**F16**	**F17**	**F18**	**F19**
PR01	-.031	-.034	-.007	-.028	-.019	.011	-.006	-.018	-.005	**.816**	.034	.012	-.027	.043	.013	-.025	-.010	.046	.046
PR02	.035	-.050	.038	.001	-.037	-.005	.009	-.018	-.021	**.916**	-.002	-.052	.042	-.036	-.008	.026	.032	.016	-.019
PR03	-.064	.063	-.010	.032	.028	-.067	-.002	.062	.079	**.364**	-.016	.085	-.019	-.052	.006	-.003	-.014	-.042	.404
PR04	-.016	.051	-.050	-.029	.060	.017	-.016	-.011	.015	**.367**	-.011	.161	-.054	.028	-.015	-.018	.007	-.072	.327
TR01	.000	.007	.006	.002	**.704**	.000	.082	.002	.006	.009	**.338**	-.004	.016	.025	-.016	-.048	-.024	.029	.004
TR02	-.019	.020	-.008	.020	**.673**	.030	-.042	.021	-.006	.007	**.553**	-.010	-.014	-.024	.012	.013	.008	-.018	-.013
TR03	.035	.005	.027	-.016	**.685**	-.046	.001	.003	-.010	-.005	**.424**	.006	.025	-.017	.019	.031	-.020	-.009	.022
NARS01	.035	.064	.058	-.008	.024	-.102	-.127	.066	-.103	.025	.019	**.430**	-.056	-.025	.001	.034	.045	-.093	.024
NARS02	-.002	-.033	.018	-.030	-.083	.144	.066	-.063	.061	-.025	.025	**.598**	.034	.016	-.045	.015	-.019	.016	.032
NARS03	.048	.042	-.023	.044	.104	-.095	-.107	.035	-.047	.094	-.015	**.491**	-.043	-.068	.002	-.011	.132	-.024	.026
NARS04	-.016	-.044	.042	.025	.007	.024	-.002	-.044	-.041	.002	-.052	**.733**	-.019	.012	.038	.012	.012	.039	-.016
NARS05	.016	-.026	-.087	.044	-.034	.035	.011	-.015	.001	.084	.006	**.568**	.017	.013	-.038	-.039	.193	.007	-.011
SI01	.022	.023	.129	.165	.029	.048	-.070	.044	-.033	-.002	.027	-.001	**.599**	.036	.013	.030	-.007	-.019	.022
SI02	.011	.035	-.051	.048	.022	.042	.004	-.026	.178	.019	-.014	-.037	**.704**	.013	-.010	-.011	.046	.033	-.011
SI03	.213	-.010	.084	-.050	.011	-.043	.030	.010	.023	-.026	.009	.037	**.644**	-.021	.094	.000	-.056	.023	.028
ST01	.044	-.005	.015	.061	-.017	-.017	.020	.022	.033	.015	.006	.044	.047	**.758**	.025	.018	-.019	-.031	.014
ST02	-.008	.013	.003	.029	.009	.010	-.020	-.005	.012	.003	-.019	-.015	.006	**.891**	-.005	-.028	-.001	.035	-.026
ST03	.044	.004	.028	-.038	.031	.034	-.003	.019	.004	-.019	-.011	-.016	-.018	**.850**	.023	.035	.022	-.023	.001
SE01	.107	.032	.121	.023	.035	.269	-.005	.068	.073	.004	-.030	.003	-.023	-.020	**.334**	-.020	.047	-.007	-.027
SE02	-.005	-.007	-.004	-.011	-.008	.004	.003	-.052	.028	-.012	.030	-.010	.012	.015	**.941**	-.009	.010	.028	.022
SE03	.023	.030	.002	.148	-.002	.028	.018	.101	-.035	.021	-.010	-.003	.146	.038	**.528**	.024	-.026	-.033	-.035
PIIT01	-.014	-.026	.029	-.011	.021	.114	.020	-.057	-.037	.012	.020	.049	-.014	.014	-.018	**.438**	.025	.102	.015
PIIT02	-.035	.052	-.073	.039	-.047	.052	.063	.005	.020	-.041	.031	.033	.021	.084	-.032	**.747**	.040	.055	-.043
PIIT03	.029	-.025	.019	-.010	.021	-.025	-.062	.015	.033	.028	-.012	-.014	-.025	-.002	.058	**.813**	-.051	-.005	.035
PIIT04	.045	.086	.003	.005	.019	-.011	.012	.004	-.021	.002	-.024	-.169	.032	-.098	-.012	**.466**	**-.356**	-.119	-.020
RAS01	-.096	-.030	-.034	-.031	-.082	.035	.046	-.022	.055	-.051	.002	**.477**	.049	.035	.013	-.005	.299	-.013	-.021
RAS02	-.059	-.015	.044	-.017	-.001	-.039	-.021	.102	.013	-.028	-.018	**.383**	.001	-.055	-.010	.001	.257	-.025	-.003
RAS03	.007	.024	-.010	-.041	.019	.019	-.008	.003	-.006	.025	-.028	.098	.004	.008	.024	-.034	**.809**	-.056	.003
RAS04	.023	-.023	.021	.006	.006	-.020	.004	-.013	-.020	.019	-.008	.014	-.021	-.023	-.021	.027	**.847**	-.012	-.001
SAFE01	.013	.055	.098	.085	.060	.062	-.027	.032	.010	-.011	-.033	-.077	.029	-.010	.016	.064	-.065	**.612**	-.005
SAFE02	-.006	.013	.042	-.043	.038	-.001	.027	.022	-.005	.027	.007	.003	-.028	.001	-.006	-.026	-.034	**.777**	.047
SAFE03	.065	.051	-.081	.022	-.034	-.035	-.022	.024	.021	-.012	.019	.022	.046	-.011	.008	.031	.032	**.727**	-.057
CST01	.017	-.005	-.008	-.003	.011	.007	-.025	-.007	-.015	.016	.028	.010	-.007	.032	.000	.007	.008	.021	**.881**
CST02	-.003	-.058	.048	-.006	.018	-.010	.015	.010	-.016	-.036	.020	-.058	.043	.007	-.009	.026	.018	.020	**.894**
CST03	.018	.041	-.010	.025	-.016	.015	.005	-.002	-.031	.039	-.034	.003	.022	-.051	.008	-.043	-.016	-.009	**.778**

APPENDIX D:

CODING SCHEME OF THE KAROTZ HOME STUDY

Code	Description
User experiences	
- Adjustment	User is adapting to the robot and how to use it.
- Anticipation	User expresses expectations about the robot or its use.
- Association	User compares the robot or its use with something else.
- Attitude formation	User forms an opinion about the robot or its use.
- Confirmation	User seeks confirmation for or validates his/her opinion about the robot or its use.
- Curiosity	User is curious about what the robot has to offer.
- Discuss with others	User has shared his/her experiences with the robot with others.
- Emotional attachment	User is emotionally attachment to the robot.
- Excitement	User is excited / enthusiastic about the robot.
- Exploration	User is exploring how the robot works.
- Familiarization	User is getting familiar with how the robot work and what the robot has to offer.
- Identification	User identifies him-/herself with the robot or its use.
- Incorporation	User has incorporated (the use of) the robot into his/her daily activities / routines.
- Information seeking	User is seeking information about the robot or its use.
- Maintenance	User is maintaining the way he/she is using the robot.
- Novelty	User perceive the robot as something new.
- Personality attribution	User is ascribing the robot with humanlike characteristics, such as personality, emotions, intentions and needs.
- Personalization	User is customizing the robot and its settings to his/her personal needs.
- Preparation	User is preparing him-/herself for the robot that is about the be delivered.
- Promotion to others	User is recommending the robot to other people.
- Recognize benefits	User acknowledges the benefits the robot has to offer.
- Reinvention	User is inventing new applications / utilizations for the robot.
- Trial and error	User is trying how the robot works and encounters some frustrations.
- Use routines	User has acquired a routine of using the robot.

Sample incident
“[The robot] was annoying at night, because it made noise. But I have learned that I can make him be quiet.” “To see what fits me and how I can incorporate a learning moment together with the children.”
“For me, [the robot] is some sort of computer, something that is programmed.”
“I am not very enthusiastic about [the robot].”
“I have Googled some blogs of people who have both the same robot… And I thought, yes they are really talking about the same experiences.” “I am really excited about what it can do with [the robot].”
“I have talked a lot about [the robot]. A friend of mine has a similar robot.”
“You get used to having it… It is just like having a pet, when you talk about it like that… He has become a part of our family.” - Excitement
“The next day [after the installation] we have sat down on the couch with the iPad and looked up what kind of apps there are. Tried it out a bit.” “A little bit of astonishment… when it first arrived here… But that is getting used to, that is just a habituation process.” “Together with the children we have looked at the stickers and thought about which to apply. And then we put some feet on it and a zipper.” “[The robot] belongs with us now.”
“I need more time to dive into that, to read about it.”
“I just continue with what I am already doing with the robot.”
“In the beginning, everything with the robot was new.”
“When [the robot] is flattening its ears. Then he is a little bit scared.”
“I have programmed [the robot] to automatically provide the weather forecast in the morning and evening.” “That is difficult to say [what the robot would mean to me]. I don’t know exactly how it will all go.” “If someone would ask me, I would… make that person enthusiastic about the robot.”
“I is just easier to use [the robot] as an alarm clock and for listening to music.”
I know that [the robot] can make sounds. And that he has a camera, that you can record something. But how you can profit the most from that.” “I still find it a bit difficult how you can install new apps in a proper manner.”
“Every morning, when I wake up between 7 o’clock of half past seven, [the robot] makes some noises and I recognize that now.”

Code	Description
Acceptance variables	
- Adaptability	User thinks that the robot can adapt to his/her needs or that it should be able to do that.
- Animacy	User thinks that the robot looks realistic or behaves realistically or that the robot should be.
- Attractiveness	User thinks the robot looks attractive or that it should be.
- Companionship	User thinks that he/she has some sort of relationships with the robot or wishes that he/she could have one.
- Cost	User tells about the cost associated with (the use of) the robot.
- Diversity of use	User thinks that one can use the robot in diverse ways or that it should be possible to do that.
- Ease of use	User thinks the robot is easy to use or that it should be.
- Enjoyment	User thinks the robot is enjoyable or that it should be.
- Intelligence	User thinks the robot is intelligent or that it should be.
- Media influence	User tells about the influence of the media on his/her opinion about robots.
- Pers. innovativeness	User thinks he/she likes to use new technologies.
- Previous experience	User tells about previous experiences with robots or other technologies related to the use of the robot.
- Prior expectations	User tells about his/her expectations of the robot or its use.
- Privacy	User is concerned about his/her privacy related to the use of the robot.
- Reliability	User thinks the robot is reliable or that it should be.
- Situational factors	User tells about the situation or use context in which he/she uses the robot and how that affects the use.
- Sociability	User thinks that the robot behaves socially or that it should be able to do that.
- Social influence	User tells about other people's opinions.
- Social presence	User thinks that the robot has a social presence or talks about the robot as having body parts, bodily processes, mental status or moral status.
- Self-efficacy	User thinks he/she has the necessary capabilities to properly use the robot or his/her lack of those.
- Status	User thinks that having robot can enhance once social status.
- Trust	User thinks he/she can trust the robot or that he/she should be able to do that.
- Usefulness	User thinks the robot is useful or that it should be.

Sample incident
“Basically, it come down to making it to my liking. Just like you personalize other objects”
“Just something that is somewhat alive.”
“[The robot] looks quite neat, a little bit neutral, nice ears.”
“[The robot] gives the feeling of an animal. He is always standing there.”
“I don’t know how much I would be willing to pay for a robot.”
“I had expected to be able to do more things with it.”
“I think I understand how [the robot] works, that is not very difficult.”
“[My son] really enjoys that and says ‘mom the ears, the ears’. That is fun.”
“I just think [the robot] should be more intelligent”
“In the movies [robots] are portrayed as creatures with feelings.”
“I just like it to try out new technologies, I am just curious about that.”
“I have seen such a vacuum cleaning robot on the internet once, and also one that mows the lawn.”
“I had expected that [the robot] had moods.”
“I wouldn’t want a robot of which I think it is spying on me.”
“That [the robot] did not work every other day.”
In the weekends I have more time. So I use [the robot] more often then.”
“I think you should be able to really communicate with [the robot]. That you can really talk to him.”
“We had some visitors and they saw what the robot could do and wondered what we were doing with that.”
“I noticed that [the robot] has become somewhat moody. He sometimes says something, he grumbles a little bit.”
“Every time I want to work on [the robot], I am not succeeding.. things go wrong.”
“When I put on FaceBook that I have got a social robot, I hope to get a lot of reactions.”
“I just assume that what comes out of [the robot] is trustable.”
“I don’t see any advantages compared to my mobile phone.”

Code	Description
Non-use	
- Disenchantment	User thinks that the robot can adapt to his/her needs or that it should be able to do that.
- End of novelty	User thinks that the robot looks realistic or behaves realistically or that the robot should be.
- Lack of motivation	User thinks the robot looks attractive or that it should be.
- Need not satisfied	User thinks that he/she has some sort of relationships with the robot or wishes that he/she could have one.
- Reliance on others	User tells about the cost associated with (the use of) the robot.
- Replaced by other device	User thinks that one can use the robot in diverse ways or that it should be possible to do that.
- Restrictions and problems	User thinks the robot is easy to use or that it should be.
Perceptions of robots	
- Appearance: humanoid	User thinks a robot should look humanlike.
- Appearance: zoomorphic	User thinks a robot should look like an animal.
- Appearance: caricatured	User thinks a robot should resemble the human body, but not too humanlike.
- Appearance: functional	User thinks that the appearance of the robot should resemble its functionalities.
- Appearance: other	User tells about other aspects of a robot's appearance.
- Utility: assistant	User thinks that domestic robots should serve as assistants.
- Utility: companion	User thinks that domestic robots should serve as companions.
- Utility: information source	User thinks that domestic robots should serve as information source.
- Utility: entertainment	User thinks that domestic robots should serve as a form of entertainment.
- Utility: gadget	User thinks that domestic robots are gadgets.
- Utility: other	User tells about other utilities of the robot.
- Other: capability	User talks about the capabilities of a domestic robot.
- Other: cost	User talks about the cost of a domestic robot.
- Other: moral standing	User thinks that domestic robot should have a moral standing.
- Other: natural language	User thinks that it should be possible to talk to a domestic robot using natural language.

Sample incident
“Often acts weird. Awake when I do not want it.”
“The novelty is gone. You just use it a lot less.”
“He [the robot] is standing in de living room, but I am not doing anything with it myself.”
“We heard what we had programmed […] we did not use it [the robot] actively. […] It was standing in the way and has no added value.”
“I have not installed everything yet. I cannot do it myself and am waiting for my daughter to have time for it.”
“He [the robot] cannot do much and what he can do my smartphone does as well, and more.”
“Too difficult to make it [the robot] understand what to do.”
“When I think purely about robots, then I see a robot with a humanlike shape.”
“In the shape of a pet, I would like that.”
“I image some sort of puppet, but not really very much a human being.”
“With a touch screen for the interaction.”
“But [the robot] can be bigger so that I can ride on it.”
“A robot should be doing all kinds of household chores. Vacuum cleaning, clean up.”
“When you are watching television in the evenings, that you and [the robot] are watching together and that he comments on the television shows.”
“A nice walking encyclopedia that can look up stuff, like recipes which he could read out loud.”
“To listen music with… and that it repeats songs because it knows what kind of songs I like.”
“It reminds me of a robot of former times, on caterpillars tracks. … children’s toys with a lamp on its head.”
“[A robot] needs to be multifunctional.”
“That [the robot] can distinguish family member with facial detection, and that he can sense their emotions.”
“What I would be willing to pay for [a robot] depends on what it can do.”
“I think it is absurd to consider [robots] as some sort of slaves.”
“May be including a language package. That I can say certain words to [the robot] and that he goes off to do something.”

Code	Description
Social abilities	
- Autonomy	User thinks that a companion robot should be able to do things on its own.
- Coziness	User thinks that a companion robot looks should offer some sort of coziness or companionableness.
- Mutual respect	User thinks that mutual respect is necessary for a companion robot to be treated as such.
- Similarity	User thinks that a companion robot should show some similar interests to be able to be treated as such.
- Social awareness	User thinks that a companion robot should be aware of its social environment.
- Social support	User thinks that a companion robot should offer social support.
- Thoughts and feelings	User thinks that a companion robot should have consciousness or thoughts and feelings.
- Two-way interaction	User thinks that is should be possible to say something to a companion robot and that it can say some back that makes sense.

Sample Incident
"It needs to be a completely movable robot. More in the direction of humans instead of something static. Then it would be more suitable for companionship." "Coziness off course. Just to talk to each other and have some drinks." "[The robot]… can't say anything back. I also think you make shorter sentences, or even talk to him in stop words. Because he doesn't understand it anyway." "What I like about people is that they talk and have feeling that are similar to mine." "[The robot] should react better to what he does… That his ears turn when you come in... That would make you perceive it more as something alive." "That you share stuff. That you have the feeling you can count on each other." "When such a device becomes intuitive, gets more emotions, becomes more intelligent or something. Than it will be different… Then you will treat it differently too." "[For the robot to be perceived as a social companion] he needs to interpret the things I say."

LIST OF PUBLICATIONS

2015

de Graaf, M.M.A., & Ben Allouch, S. (2015). The evaluation of different roles for domestic social robots. *Paper presented at the International Symposium on Robot and Human Communication, Kobe, Japan*.

de Graaf, M.M.A., Ben Allouch, S., & Klamer, T. (2015). Sharing a life with Harvey: Exploring the acceptance of and relationship building with a social robot. *Computers in Human Behavior, 43*, 1-14.

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de Graaf, M.M.A., Ben Allouch, S., & van Dijk, J.A.G.M. (2014). Long-term evaluation of a social robot in real homes. *Paper presented at the AISB Workshop on New Frontier in Human-Robot Interaction, London, UK*.

de Graaf, M.M.A., & Ben Allouch, S. (2014). Expectation setting and personality attribution in HRI. *Poster presented at the International Conference on Human-Robot Interaction (pp. 144-145), Bielefeld, Germany*.

de Graaf, M.M.A., & Ben Allouch, S. (2014). Users' Preferences of robots for domestic use. *Poster presented at the International Conference on Human-Robot Interaction (pp. 146-147), Bielefeld, Germany*.

de Graaf, M.M.A., & Ben Allouch, S. (2014). Evaluation of a socially assistive robot in eldercare. *Poster presented at the Workshop on Socially assistive robots for the aging population at the International Conference on Human-Robot Interaction, Bielefeld, Germany*.

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de Graaf, M.M.A., Ben Allouch, S., & Lutfi, S. (2014). People's implicit and explicit associations with and attitudes towards robots. *Paper presented at Het Etmaal van de Communicatiewetenschap (24-hours of Communication Science), Wageningen, The Netherlands*.

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de Graaf, M.M.A., & Ben Allouch, S. (2012), Harvey's last appearance: Long-term use and acceptance of social robots. *Paper presented at the International Communication Association Annual Conference, Phoenix, AZ, USA.*

2011

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Manuscripts under review

de Graaf, M.M.A. (submitted). The Ethics of Human-Robot Relationships. *New Friends: International Conference on Social Robotics in Therapy and Education*.

de Graaf, M.M.A., Ben Allouch, S., & van Dijk, J.A.G.M. (submitted). The unwanted sociability of robots? *International Conference on Social Robotics*.

de Graaf, M.M.A., Ben Allouch, S., & Lutfi, S. (submitted). What are people's associations of robots?: Comparing implicit and explicit measures. *International Journal of Human-Robot Interaction*.

de Graaf, M.M.A., & Ben Allouch, S. (under review). The influence of prior expectations of a robot's lifelikeness on companionship with a zoomorphic robot. *International Journal of Social Robotics*.

DUTCH SUMMARY

In de laatste decennia heeft de ontwikkeling van robots grootse sprongen gemaakt. Er bestaan steeds meer verschillende soorten robots en de rollen die zijn vervullen in onze samenleving is groeiende. Belangrijke individuen in het veld, waaronder Bill Gates (2007), voorspellen dat robottechnologie binnen enkele decennia net zo gewoon zullen worden in onze samenleving als computers vandaag de dag. Deze snelle ontwikkeling van robottechnologie zal ervoor zorgen dat robots gecompliceerdere taken kunnen gaan uitvoeren en in de nabije toekomst zelfs onze volwaardige teamleden, assistenten, gidsen en metgezellen worden. Juist in dit soort rollen, waarbij robots veel in aanraking komen met alledaagse mensen, is het van belang van robots sociaal zijn. Een algemene aanname in mens-robot onderzoek is dat een natuurlijke en vloeiende interactie tussen mens en robot ervoor zorgt dat men deze technologie eerder zal accepteren (Dautenhahn, 2003). In plaats van dat we mensen dwingen om de taal van de robot te leren spreken, ontwikkelt men robots die onze menselijke taal en sociale gedragingen kunnen begrijpen. Hierdoor zal eenieder in staat zijn om in de toekomst een robot te kunnen gebruiken.

Hoofdstuk 1 beschrijft dat een groeiende aanwezigheid van robots in onze samenleving niet automatisch betekent dat iedereen deze technologie zomaar accepteert en robots vanzelf gaan gebruiken (Bartneck en anderen, 2005). Voor een succesvolle introductie van robots in onze samenleving is het noodzakelijk dat toekomstige gebruikers deze technologie accepteren. Bovendien is het belangrijk om toekomstige gebruikers vroegtijdig te betrekken in het ontwerpproces om zodoende tegemoet te komen aan de wensen en eisen van potentiële gebruiker. Dit proefschrift heeft als doel om: (1) inzicht te verkrijgen in de factoren die de meeste invloed uitoefenen op de acceptatie van sociale robots in huiselijke omgevingen; (2) te onderzoeken hoe de gebruikerservaringen met een sociale robot ontwikkelen in de tijd; en (3) enkele eerste inzichten te presenteren van de factoren die verklaren waarom sommige mensen bereid zijn om robots te behandelen als metgezellen. Ik beweer dat het evalueren van de percepties en gedragingen van mensen tijdens het langdurige acceptatieproces van sociale robots in dagelijkse omgevingen noodzakelijk zijn voor het correct beoordelen en verweven van de diverse maatschappelijke, wetenschappelijke en technologische problemen die relevant zijn voor het ontwerpen van acceptabele sociale robots bestemd voor huiselijke doeleinden. De volgende onderzoeksvragen staan centraal in dit proefschrift:

(A) Welke acceptatie variabelen vormen in welke fase van acceptatie de meeste belangrijkste voorspellers van sociale robot acceptatie in huiselijke omgevingen?
(B) Hoe evalueren gebruikers hun bereidheid om sociale robots als metgezellen te behandelen voor en na de adoptie van een sociale robot?

Hoofdstuk 2 geeft een definitie van sociale robots en presenteert een classificatie van sociale robots op basis van sociale intelligentie, uiterlijk, en functionele duidelijkheid. Het doel van onderzoek naar sociale robotica is om robots te ontwikkelen die kunnen deelnemen in sociale interacties met mensen op een natuurlijke, herkenbare, effectieve en bovenal intuïtieve manier. Dit proefschrift definieert sociale robots als robots die sociale interactie simuleren omdat ze zijn op dusdanige manier zijn geprogrammeerd dat menselijke gebruikers worden gestimuleerd om de sociale regels van menselijk gedrag toe te passen in de interacties (gebaseerd op een combinatie van de definities van Lee, Park en Song, 2005, en Bartneck en Forlizzi, 2004). Er zijn een aantal basis sociale vaardigheden die essentieel zijn voor sociale robots, welke door zowel sociale robotici als toekomstige gebruikers worden erkend. Hoewel ontwikkelaars ernaar streven om de ideale sociale robots te creëren zijn de sociale capaciteiten van robots vandaag de dag nog uiterst beperkt. Bovendien moeten sociale robotici zich realiseren dat robots in essentie niet sociaal kunnen zijn. Sociale robots zijn machines die dusdanig zijn geprogrammeerd dat hun gedrag door gebruikers wordt geïnterpreteerd als sociaal. En deze sociale interpretaties zorgen ervoor dat gebruikers zich ook sociaal gaan reageren. De sociabiliteit van robots leeft dus eigenlijk in de verbeelding van de gebruiker. Dit fenomeen wordt verklaard door de media equatie (Reeves & Nass, 1995), een theorie die omschrijft hoe mensen apparaten menselijke eigenschappen toekennen. En juist deze sociale reacties van mensen tijdens de interactie met robots zorgt ervoor dat de acceptatie dit type technologie het traditionele ontologische onderscheid tussen bezielend en anorganisch ter discussie stelt.

Hoofdstuk 3 behandelt verschillende relevante theorieën voor onderzoek naar de acceptatie van sociale robots vanuit een communicatiewetenschappelijk, psychologisch en sociologisch perspectief. Verder maakt het hoofdstuk duidelijk dat de meeste theorieën en modellen technologie acceptatie niet erkennen als een langdurig beslissingsproces. Om hier meer duidelijkheid in te scheppen, presenteert dit hoofdstuk een raamwerk van neutrale acceptatiefasen en koppelt de acceptatie theorie aan een specifieke fase. Het hoofdstuk eindigt met de aanbeveling om voor het opstellen van een conceptueel model voor sociale robot acceptatie verder voort te bouwen op de principes van de theorie van gepland gedrag (Ajzen, 1991). Drie redeneringen onderbouwen deze beslissing: (1) de theorie is met name geschikt voor het verklaren en voorspellen van vrijwillig gedrag waaronder technologie acceptatie (Mathiesson, 1991; Taylor & Todd, 1995; Venkatesh & Brown, 2001); (2) de theorie is succesvol toegepast voor het verklaren van een breed scala aan gedragingen (Ajzen, 1991); en (3) de oorsprong van de theorie nodigt onderzoekers uit om het originele model aan te passen aan een specifiek gedrag (Ajzen, 1991) wat het opnemen van aspecten uit andere theorieën mogelijk maakt (Bensabat & Barki, 2007).

Hoofdstuk 4 begint presenteert het conceptuele model voor sociale robot acceptatie welke al voortbouwend op de principes van de theorie van gepland gedrag deze zowel uitbreid als verdiept. Hiervoor baseert het model zich op een uitgebreid overzicht van voorspellers van (technologie acceptatie) gedrag gekeken vanuit verschillende onderzoeksdisciplines. Gebaseerd op deze literatuur review zijn er drie soorten overwegingen geïdentificeerd die een belangrijke rol spelen bij het evalueren van sociale robot acceptatie in huiselijke omgevingen. Allereerst de attitude overtuigingen, welke de positieve en negatieve consequenties van het gedrag, in dit geval sociale robot acceptatie, omvat. Ten tweede de normatieve overtuigingen, welke de (verwachte) goedkeuring of afkeuring van het gedrag omvat zoals beoordeeld volgens de gelden normen en waarden in de ogen van de gebruiker. In het kader van dit proefschrift zijn dit de normen en waarden met betrekking tot het gebruik van sociale robots. En tenslotte de controle overtuigingen, welke de contextuele factoren omvatten die de uitvoering van het gedrag, hier het gebruik van een sociale robot, kunnen bevorderen of belemmeren.

De theorie van gepland gedrag (Ajzen, 1991) beperkt zich door menselijk gedrag te benaderen vanuit het rationalisme en een puur psychologisch perspectief. Door het toevoegen van affectieve evaluaties van (het gebruik van) de robot, de normatieve context van het robot gebruik, als ook gedragsgewoontes in het conceptuele model van sociale robot acceptatie is een poging gedaan om deze tekortkomingen van de theorie van gepland gedrag te overwinnen. Zodoende draagt dit proefschrift bij aan de literatuur over mens-robot interacties door het modeleren van gedragsprocessen die de intentie tot sociale robot gebruik kunnen verklaren.

Hoofdstuk 5 test het conceptuele model van sociale robot acceptatie door middel van het uitzetten van een online vragenlijst die de geanticipeerde acceptatie van sociale robots in huiselijke omgevingen afneemt. Omdat de diffusie van sociale robots in de maatschappij zich slechts in een beginstadium bevindt, is ervoor gekozen om te richten op geanticipeerde acceptatie. Dit heeft als gevolg dat de concepten van daadwerkelijk gebruik en gebruiksgewoontes, samen met de gerelateerde effecten, niet kan worden verhandeld in dit onderzoek. De resultaten geven aan dat de acceptatie van sociale robots bedoeld voor huiselijke toepassingen kan worden vergroot als toekomstige gebruikers ervan overtuigd zijn dat zij de benodigde vaardigheden bezitten om een dergelijke robot te gebruiken, wanneer zij denken dat het hebben van een dergelijke robot hun status verhoogd, en wanneer zij aannemen dat een sociale robot aangename interactie aanbiedt, zich minder sociaal gedraagt, en weinig zorgen over privacy bezorgd.

Naast de resultaten van het sociale robot acceptatie model, presenteert hoofdstuk 5 ook een aantal resultaten over de evaluatie van verschillende toekomstige rollen voor sociale robots in huiselijke omgevingen en de voorkeur voor een bepaald type uiterlijk voor een dergelijke robot. Hierbij is gekeken naar de rol als butler, informatiebron en metgezel, en of een dergelijke rol meer geschikt is voor een robot met een menselijk uiterlijk, een dierlijk uiterlijk, een cartoonesk uiterlijk of een puur functioneel uiterlijk. Meer dan de helft van het totaal aantal ondervraagden (n= 1162) geeft een voorkeur voor een robot met een menselijk uiterlijk, ongeacht toekomstige de rol van de robot. Echter blijkt dat de rol die de robot in de toekomst zal gaan vervullen wel degelijk invloed heeft of deze voorkeur voor het uiterlijk. Zo vindt men een functioneel uiterlijk meer geschikt voor een robot die gebouwd is als butler, en een dierlijk uiterlijk minder geschikt voor een dergelijke robot. Volgens de deelnemers in de online vragenlijst zou een robot, die gebouwd is met het doel een metgezel te worden voor zijn gebruiker, het best een dierlijk uiterlijk kunnen hebben, en juist niet een cartoonesk of een functioneel uiterlijk. Wanneer een robot is gebouwd voor de rol als informatiebron, vindt men een cartoonesk uiterlijk meer geschikt en een dierlijk uiterlijk minder geschikt. Deze bevindingen komen overeen met eerder onderzoek en geven aan dat het uiterlijk van een robot moet passen bij zijn voorgenomen toepassing.

Hoofdstuk 6 behandelt de achtergrond en methode van de langdurige studie. Omdat technologie acceptatie in dit proefschrift wordt erkend als een langdurig beslissingsproces, is er een langdurig onderzoek uitgevoerd naar hoe de evaluatie van acceptatie factoren veranderen in de tijd. Onderzoekers in sociale robotica erkennen dat er langdurige effecten bestaan voor technologie gebruik en dat gebruikspatronen veranderen in de tijd (Sung en anderen, 2009). Desondanks zijn er maar weinig langdurige onderzoeken uitgevoerd op het gebied van sociale robot acceptatie en is er weinig bekend over deze langdurige effecten.

Gebaseerd op twee theorieën, te weten de domesticatie theorie (Silverstone & Haddon, 1996) en de diffusie van innovaties theorie (Rogers, 2003), samen met een aantal bevindingen uit eerder langdurig technologie acceptatie onderzoek in huiselijke omgevingen, zijn er zes acceptatiefasen gedefinieerd. In de verwachtingsfase willen mensen meer te weten komen over de technologie en zijn toepassingen. Om deze reden zoeken mensen naar informatie over de technologie en vormen op basis daarvan een eerste mening en verwachtingen over de technologie. In de confrontatie fase komen mensen voor het eerst in aanraking met de technologie. Dit is het moment waarop mensen de technologie voor het eerst uitproberen of alleen toeschouwer zijn van het gebruik door een ander persoon. De adoptie fase volgt waarin mensen de technologie daadwerkelijk gaan gebruiken in hun eigen omgeving en hun eerste serieuze gebruikerservaringen opdoen met de technologie. In de adaptatie fase hebben mensen een algemene indruk verkregen van wat de technologie ongeveer inhoudt, hoewel ze nog wel enkele nieuwe eigenschappen van de technologie kunnen tegenkomen. Desalniettemin raken de mensen wel gewend aan de technologie en doen hun eerste pogingen om de functionaliteiten van de technologie aan te passen aan hun persoonlijke voorkeuren. In de integratie fase heeft de technologie een betekenisvolle plaats ingenomen in iemands leven omdat de technologie volledig is gepersonaliseerd. Men is zich niet langer bewust van de aanwezigheid van de technologie in zijn dagelijkse omgeving omdat het gebruik ervan is opgegaan in de dagelijkse routine. In de identificatie fase overstijgt een technologie zijn functionele toepassing en wordt een persoonlijk object. Mensen kunnen de technologie gebruiken om een bepaalde leefwijze te onderschrijven, bijvoorbeeld door zich te associëren met of juist differentiëren van bepaalde groepen. Bovendien zoeken mensen in deze fase naar bevestiging voor hun initiële adoptiekeuze.

Voor de langdurige thuisstudie naar sociale robot acceptatie, met een looptijd van ruim 6 maanden, is gebruikgemaakt van de Karotz robot, een 30-cm grote robot met internet-connectie in de vorm van een konijn. De robot werd geïnstalleerd met een basis set aan applicaties om een vergelijkbare interactie scenario te creëren. Zowel kwantitatieve als kwalitatieve data is verzameld om een omvangrijk beeld te krijgen van het langdurige acceptatieproces van sociale robots bij mensen thuis. Aan het begin van elke acceptatiefase zijn bij alle deelnemers vragenlijsten afgenomen, en een gedeelte (n= 21) van de deelnemers is op die momenten ook geïnterviewd. In totaal deden 70 huishoudens met daarin 168 bewoners mee aan het onderzoek. De deelnemers zijn geworven op verschillende manier waaronder het plaatsen van advertenties in openbare ruimten. Bij de werving is rekening gehouden met het profiel van de huishoudens zodat de verschillende groepen evenredig vertegenwoordigd zijn in de sample: alleenstaanden, samenwonenden, gezinnen met jonge kinderen (tot 12 jaar) en gezinnen met oudere kinderen (ouder dan 12 jaar).

Hoofdstuk 7 presenteert de kwalitatieve resultaten van de langdurige thuisstudie gerelateerd aan de gebruikerservaringen in de verschillende acceptatiefasen. De resultaten laten zien dat de gebruikerservaringen voor een groot deel overeenkomen met de voorgestelde koppeling van de tijdlijn met de verschillende acceptatiefasen. Een uitzondering hierop is de identificatie fase waarin de meeste deelnemers nog steeds praatten over het personaliseren van de robot en het opnemen van het gebruik in hun dagelijkse routine. Dit suggereert dat, na zes maanden gebruik, de meeste deelnemers zich nog steeds in de integratie fase bevonden. De meest logische verklaring voor deze bevinding is dat slechts drie van de zeven overgebleven geïnterviewde deelnemers hadden aangegeven de robot nog steeds te willen blijven gebruiken.

Omdat sommige deelnemers het gebruik van de robot zijn gestaakt tijdens de looptijd van het onderzoek, gaat het tweede gedeelte van hoofdstuk 7 dieper in op het non-gebruik van sociale robots in huiselijke omgevingen. Non-gebruik is een onderwerp dat vaak over het hoofd wordt gezien in technologie acceptatie onderzoek (Satchell & Dourish, 2009; Selwyn, 2004). Inzicht in wie deze non-gebruikers zijn en hun motivaties voor non-gebruik kunnen belangrijke inzichten opleveren voor beleidsmakers en aanbieders van sociale robots. In dit proefschrift zijn resultaten geanalyseerd voor *non-adopters*, mensen die de technologie nooit hebben willen gebruiken, *afweerders*, mensen die het gebruik van de technologie actief afkeuren, en *stakers*, mensen die hebben besloten het gebruik van de technologie te beëindigen nadat ze die eerst hebben geadopteerd.

Hoewel verwacht op basis van eerdere onderzoeksbevindingen, waren er geen significante demografische verschillen tussen de drie groepen non-gebruikers. Een logische verklaring voor dit resultaat is dat alle deelnemers vrijwillig hebben gereageerd op de oproep tot deelname aan het onderzoek. Echter, de redenen waarom men niet (meer) de robot wilden gebruiken verschillen wel per groep. De meest genoemde reden voor non-gebruik door de *non-adopters* was dat er geen Nederlandse taal beschikbaar was voor de robot. Dit is vergelijkbaar met eerdere resultaten (Selwyn, 2006) die aangeven dat non-gebruikers van computers ook vaak een barrière ervaren of een gebrek aan kennis hebben.

Voor *afweerders* was disillusie de voornaamste reden voor non-gebruik. Zij vonden het gebruik van de robot gewoonweg niet leuk. Dit resultaat wordt ook bevestigd in de kwantitatieve analyses waarin naar voren is gekomen dat *afweerders* het gebruik van de robot staakten wanneer zij de robot te intelligent vonden of niet nuttig. *Stakers* hebben aangegeven dat zij de robot niet meer wilden gebruiken omdat zij andere apparaten in huis hadden die de functionaliteiten van de robot beter konden uitvoeren. Of zij gaven aan dat de robot niet naar hun behoefte kon worden aangepast.

Hoofdstuk 8 beschrijft de verschillende onderzochte acceptatie factoren op basis van de verhalen die de deelnemers vertelden tijdens de interviews. Verder presenteert dit hoofdstuk zowel de evaluaties van de acceptatie factoren in de verschillende acceptatiefasen als ook de invloed van deze acceptatie op sociale robot acceptatie per fase. De resultaten geven aan dat, in de verwachtingsfase, de deelnemers zich voornamelijk bezighouden met controle overtuigingen, zoals eerdere ervaringen met robots of andere apparaten. Eenmaal geconfronteerd met en na ingebruikname van de robot, vertelden de deelnemers alleen nog maar over de attitude overtuigingen die hun acceptatie en gebruik beïnvloeden. Voornamelijk gebruiksnut is vaak besproken door de deelnemers, maar verder ook gebruiksplezier, de sociale aanwezigheid van de robot, en later in het acceptatieproces ook de sociale vaardigheden van de robot. In geen van de acceptatiefasen hebben de deelnemers het vaak gehad over de normatieve attitudes.

Bij het analyseren van de kwantitatieve gegevens is naar voren gekomen dat de deelnemers in de tijd de robot op alle acceptatie factoren steeds positiever zijn gaan beoordelen, het zogenoemde *mere-exposure* effect. Bovendien kon worden aangetoond dat deelnemers uit een gezin met oudere kinderen de robot positiever beoordelen dan deelnemers uit andere soorten huishoudens. Gebruiksnut blijkt de meest belangrijke factor die de acceptatie van sociale robots in huiselijke omgevingen kan verklaren. Het belang van gebruiksnut is al eens aangetoond in een eerder onderzoek naar het langdurig gebruik van huisrobots (Fink en anderen, 2013). Bij het verkennen van de invloed van de demografische verschillen op de acceptatie van sociale robots is naar voren gekomen dat mannen en vrouwen zich op verschillende acceptatiefactoren richtten. Voor de verschillende huishoudprofielen lijkt het erop dat bij samenwonenden andere acceptatie factoren een rol spelen dan die behandeld in dit proefschrift aangezien de verklaarde variantie in deze groep veel lager was dan bij andere soorten huishoudens. Ook het al dan niet hebben van een huisdier had invloed op sociale robot acceptatie. Deelnemers zonder huisdier richtten zich vaker op de sociale aspecten van de robot, zoals sociale aanwezigheid en kameraadschap, ten opzichte van deelnemers met een huisdier. Tenslotte spelen bij de deelnemers die de robot ook na het onderzoek wilden blijven gebruiker meer acceptatiefactoren een rol in het verklaren van sociale robot acceptatie ten opzichte van de afweerders en stakers.

Hoofdstuk 9 bespreekt verschillende soorten relaties die mensen kunnen hebben, waaronder relaties met andere personen, met objecten en televisiepersonages, en uiteindelijk ook met robots. Relaties spelen een cruciale rol in verschillende aspecten van onze leven (Perlman & Fehr, 1987). Verschillende robotonderzoeken tonen aan dat mensen sociaal reageren op robots en dat sommige mensen zelfs een soort relatie aangaan met hun robots. Aangezien computertechnologieën op steeds complexere manieren met ons omgaan, en robots steeds menselijkere kenmerken vertonen, is het van toenemend belang om onze relaties met robottechnologie te onderzoeken.

Mensen gaan om eenzelfde manier om met robots zoals zij omgaan met andere mensen in face-to-face interacties (Kerepesi en anderen, 2006). Bovendien lijken mensen op eenzelfde manier relaties aan te gaan met robots zoals zij dat doen met andere mensen (Banks, Willoughby, & Banks, 2008; Bickmore & Pickard, 2005). Blijkbaar zijn er meer overeenkomsten dan verschillen tussen mens-mens en mens-robot interacties en lijkt het onnodig om af te wijken van de interpersoonlijke omgangsregels wanneer we onderzoek doen naar mens-robot interacties (Krämer, von der Pütten, & Eimler, 2012). Wanneer deze veronderstellingen standhouden in toekomstig robotonderzoek, zouden de fundamenten uit de interpersoonlijke communicatie het uitgangspunt moeten worden voor de verdere ontwikkeling en implementatie van het sociale gedrag voor robots.

Hoofdstuk 10 presenteert enkele eerste bevindingen over de factoren die mens-robot relaties kunnen verklaren, zowel vanuit een lab-experiment als ook vanuit de langdurige thuisstudie. Het is moeilijk om te voorspellen of mensen in de toekomst in staat zijn langdurige relaties met robots aan te gaan. Eerste inzichten geven aan dat mensen in staat zijn relaties aan te gaan met robots en dat zelfs heel eenvoudige robots al sociale reacties van mensen oproepen. Omdat men voorspelt dat robots in toenemende mate sociale rollen in onze samenleving gaan vervullen waarbij een bepaalde relatievorm van belang zou kunnen zijn, onderzoekt hoofdstuk 10 of de voorspellers van mens-mens relaties ook kunnen voorspellen waarom mensen relaties aangaan met robots.

Mensen met hoge verwachtingen van de levendigheid van een robot eerder geneigd om een relatie aan te gaan met een robot dan mensen met lage verwachtingen van de levendigheid van een robot. Daarnaast richten mannen en vrouwen op andere aspecten van de robot wanneer zij overwegen een relatie aan te gaan met een robot. Wanneer mensen een robot in hun eigen huis gaan gebruiken komt naar voren dat intimiteit de belangrijkste voorspeller is van langdurige mens-robot relaties. Dus sociale robots die als doel hebben om een relatie op te bouwen met hun gebruikers moeten hun gebruikers in staat stellen om persoonlijke informatie te delen om vervolgens op een empathische manier te reageren op deze informatie.

Hoofdstuk 11 behandelt de belangrijkste conclusies van dit proefschrift. De resultaten uit de verschillende onderzoeken tonen aan dat gebruiksnut een vereiste is voor sociale robot acceptatie en dat bepaalde additionele factoren verder kunnen verklaren waarom mensen sociale robots in hus huis blijven gebruiken. Echter verandert het belang van deze additionele factoren in de tijd bij langdurig gebruik, waarbij in eerste instantie voornamelijk de aandacht ligt bij controle overtuigingen en later meer bij de attitude overtuigingen. Mogelijk speelt de ontwikkelingsfase van een technologie een rol bij de invloed van verschillende acceptatie factoren (Peters, 2011). Wanneer mensen meer ervaringen opdoen met sociale robots zullen andere acceptatie factoren een belangrijke rol gaan spelen bij het verklaren van blijvend gebruik dan de acceptatie factoren die de initiële adoptie hebben verklaard.

Met betrekking tot mens-robot relaties kan worden geconcludeerd dat mensen in eerste instantie relaties tussen mens en robot afkeuren en de mogelijkheid dat zij een relatie met een robot kunnen opbouwen verwerpen. Echter, wanneer mensen een robot daadwerkelijk gaan gebruiken in hun eigen huis, moeten sommige mensen erkennen dat zij wel degelijk een soort relatie met de robot hebben opgebouwd. Desalniettemin stellen niet alle mensen het sociale gedrag van de robot op prijs.

Hoofdstuk 12 bespreekt de theoretische discussie, de methodologische beperkingen en de praktische implicaties van het onderzoek gepresenteerd in dit proefschrift. In de theoretische discussie wordt allereerste besproken of robots wel sociaal kunnen zijn of dat het sociale van robots slechts leeft in de belevingswereld van de gebruikers. Vervolgens wordt er aandacht geschonken aan de negatieve evaluaties van de sociale aspecten van robots en of mensen wel zitten te wachten op robots die zich sociaal gedragen. Daarnaast wordt benadrukt dat er meer onderzoek nodig is naar het langdurige aspect van sociale robot acceptatie om zodoende het effect van nieuwigheid voorbij te gaan en het volledige acceptatieproces in kaart te kunnen brengen. Bovendien moeten daarbij zowel gebruikers als niet-gebruikers in het oog worden gehouden aangezien beide groepen invloed uitoefenen op het vormen en hervormen van robottechnologie.

Met betrekking tot het conceptuele model kan worden gesteld dat de bevindingen in dit proefschrift slechts als eerste opzet dienen om een dergelijk model verder theoretisch vast te stellen. Desondanks is het huidige model de tekortkomingen van bestaande modellen van sociale robot acceptatie voorbijgestreefd en vormt dus een gedegen basis voor toekomstig onderzoek. Vervolgens vindt er een discussie plaats over de conceptualisatie van het begrip gebruiksnut omdat dit concept sterke empirische overlap vertoont met gebruiksintentie. Achtereenvolgens wordt de samenhang tussen attitudes en gedrag bediscussieerd. De resultaten in dit proefschrift zijn geanalyseerd met de aanname dat attitudes een causaal verband heeft met daadwerkelijk gedrag. Echter moet worden erkend dat er ook theorieën bestaan die veronderstellen dat gedrag ook vorm geeft aan iemands attitudes. Daarnaast wordt de samenhang tussen gedragsintenties en daadwerkelijk gedrag besproken. Hoewel de theorie van gepland gedrag ervan uitgaat dat er een sterk verband bestaat tussen gedragsintenties en daadwerkelijk gedrag, geven de resultaten in het langdurige onderzoek een ander beeld. Mogelijke verklaringen voor deze bevinding worden bediscussieerd. Verder wordt ook aandacht besteed aan de conceptualisatie en operationalisering van het begrip gedragsgewoontes aangezien hierover diverse interpretaties bestaan in de huidige literatuur die het vergelijken van de verschillende bevindingen compliceren.

Tenslotte worden er een aantal theoretische discussiepunten benoemd ten aanzien van mens-robot relaties. Om een beter beeld te krijgen van de factoren die mens-robot relaties kunnen verklaren moet verder worden gekeken dan de bekende voorspellers die nu verklaren waarom sommige mensen onderling relaties met elkaar aangaan. Hoewel de huidige bevindingen aangeven dat de sociale vaardigheden van een robot een zeer belangrijke rol spelen bij het tot stand komen van mens-robot relaties, geeft de lange verklaarde variantie aan dat er nog andere factoren een rol spelen bij het tot stand komen van mens-robot relaties die niet in het huidige onderzoek zijn meegenomen. Een suggestie voor toekomstig onderzoek in dit domein is om verder voort te bouwen op de attachment theorie zoals toegepast op de relaties die mensen met objecten aangaan. Speciaal gericht op relaties tussen mensen en robots met een dierlijk uiterlijk zouden theorieën vanuit de mens-huisdier relaties een uitkomst kunnen bieden voor toekomstig onderzoek.

In de tweede paragraaf van hoofdstuk 12 worden de methodologische beperkingen van de onderzoeken in dit proefschrift besproken. Hierbij wordt gekeken naar het verbeteren van een aantal meetinstrumenten en meetmethoden, maar ook wordt de invloed besproken die de verschillende samples en de gekozen robots hebben gehad op de onderzoeksresultaten. Als aanbeveling voor toekomstige onderzoekers wordt meegegeven dat triangulatie ofwel het toepassen van verschillende onderzoeksmethoden een uitkomst kan bieden in het onderling vergelijken van de onderzoeksresultaten om zodoende bepaalde conclusies te kunnen onderbouwen met anderszins verkregen gegevens. Tenslotte worden de uitdagingen besproken die gerelateerd kunnen worden aan de huiselijke omgeving als onderzoekscontext als ook de terughoudendheid die mensen ondervinden bij het bespreken van het onderwerp mens-robot relaties. Er zijn hierbij een aantal aspecten waar toekomstige onderzoekers rekening mee moeten houden bij het verrichten van onderzoek op dit gebied.

In de derde paragraaf van hoofdstuk 12 worden de praktische implicaties besproken van het onderzoek zoals gepresenteerd in dit proefschrift. Een eerste set aan praktische implicaties is gericht op het vergroten van de acceptatie van sociale robots in de maatschappij. Allereerst wordt aanbevolen dat robotontwerpers een duidelijke toepassing voor hun robot voor ogen moeten hebben aangezien gebruiksnut een vereiste is voor acceptatie. Een tweede aanbeveling voor robotontwerpers is om de sociale vaardigheden van robots te vergroten aangezien een meer sociale robot zich beter kan aanpassen aan de wensen van de gebruiker. Ten derde wordt aanbevolen om het langdurige acceptatieproces in acht te nemen aangezien mensen zich in elke fase op andere acceptatie factoren lijken te richten welke ieder een andere informatiebehoefte vragen. Een vierde aanbeveling is om de invloed van de gebruikscontext te overwegen bij het ontwerpen van robots aangezien dit het gebruik van robots beïnvloed. Tenslotte wordt er gesteld dat, hoewel men vertrouwd zal raken met robots door de verspreiding ervan in onze samenleving, dit niet automatisch een positief effect heeft op de acceptatie van deze robots door de gebruiker.

Een tweede set van praktische implicaties bespreekt hoe men van robots een betere metgezel maakt. Hiervoor moeten robotontwikkelaars sociale robots bouwen die: (1) de sociale omgangsregels van interpersoonlijke communicatie laten volgen; (2) als levensecht worden beschouwd; (3) beschikken over een breder scala aan sociale vaardigheden; (4) een empathisch vermogen hebben; en in het geval van robots met een dierlijk uiterlijk (5) een huisdier nabootsen.

De bevindingen in dit proefschrift trachten onderzoekers en ontwikkelaars van sociale robotica te helpen bij het verder ontwikkelen van een geïntegreerde theorie of model voor sociale robot acceptatie in huiselijke omgevingen.

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