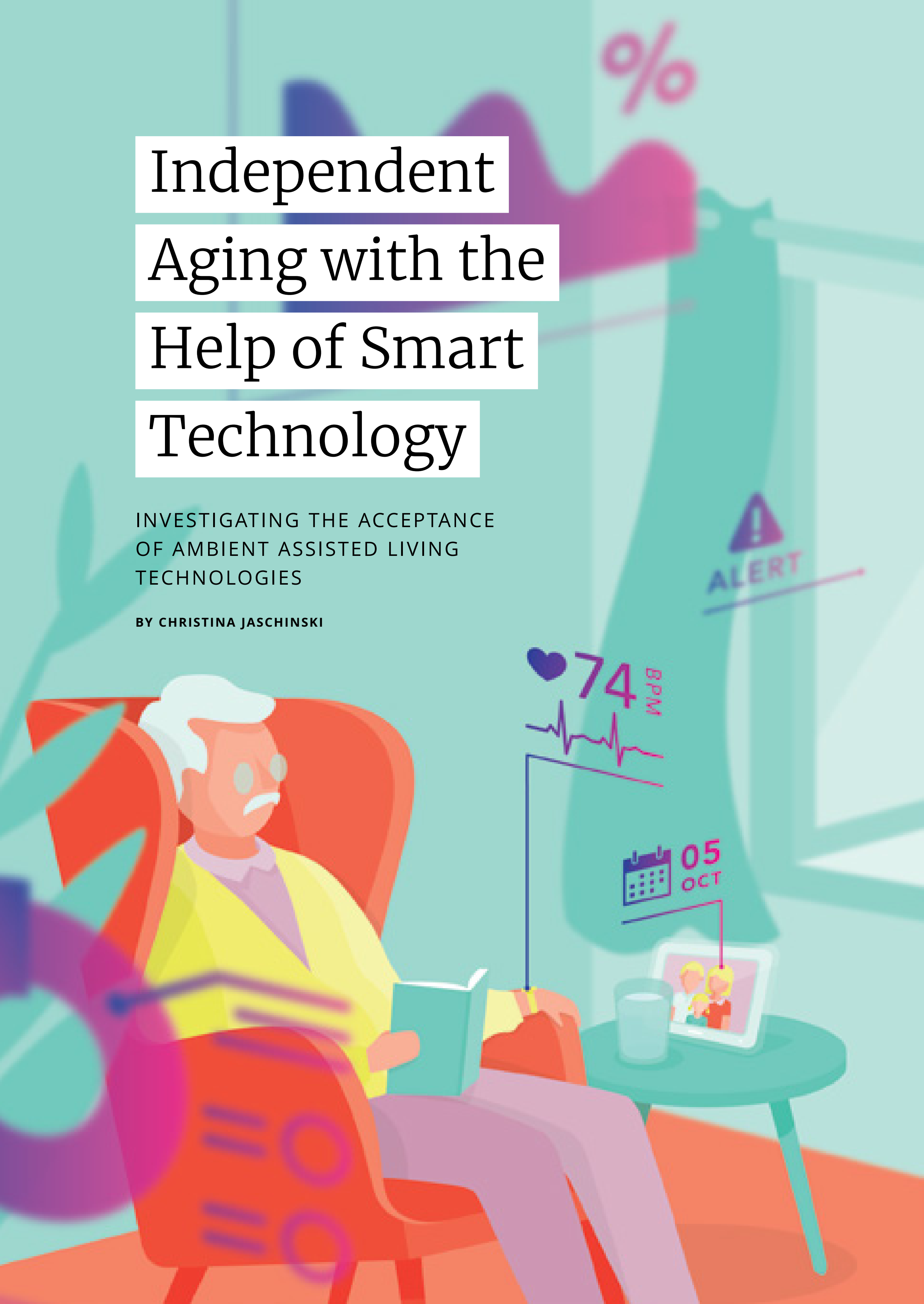
Independent Aging with the Help of Smart Technology

INVESTIGATING THE ACCEPTANCE OF AMBIENT ASSISTED LIVING TECHNOLOGIES

BY CHRISTINA JASCHINSKI



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Christina Jaschinski

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DISSERTATION

to obtain
the degree of doctor at the University of Twente,
on the authority of the rector magnificus,
prof.dr. T.T.M. Palstra,
on account of the decision of the graduation committee,
to be publicly defended
on Friday the 5th of October 2018 at 14.45 hours

by

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born on the 22nd of May 1987
in Herten, Germany

THIS DISSERTATION HAS BEEN APPROVED BY

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Printed by: Ipskamp Printing

Cover design and Lay-out by: Beeldgeneratie

ISBN: 978-90-365-4634-8
DOI: 10.3990/1.9789036546348
https://doi.org/10.3990/1.9789036546348

Part of the work described in this dissertation was financially supported by the AAL Joint Program (AAL-2012-5-187) and Saxion University of Applied Sciences.

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For my Dad,

who taught me to believe in myself, to be committed and to persevere.

I am sure you were with me every step of the way.

-

For my little one,

who decided to join me for the last part of this journey.

I can’t wait to meet you.

Table of Contents

Meet Charles

Charles is a retired tax advisor. Since his wife passed away last year, he has been living alone. Charles was always engaging in a lot of different activities together with his wife, but without his companion he simply lacks the motivation and energy to leave the house a lot. Except for his diabetes, Charles was always pretty healthy but since he stopped being active his physical health has deteriorated.

His only daughter Anne lives an hour away from him. Anne is very concerned about Charles, as he has been withdrawn and depressed since her mom died. She also worries about his health and safety. Anne does her best to support Charles remotely and visits him as often as she can. However, she is often exhausted from juggling her different roles as a caring daughter, mother, wife and career woman with a full-time job.

(Adapted from the SONOPA personas)

Similar to Charles, many older adults who still live independently and used to be healthy and active for most of their lives, are likely to need some form of social or physical support in the near future. Like Anne, family caregivers often feel emotionally and physically overburdened when taking care of their relative (Pinquart & Sörensen, 2003; Schulz & Beach, 1999; Snyder & Keefe, 1985). Professional care organizations already suffer budget cuts and personnel deficits, and prognoses state that this trend will continue in the future (Hussein & Manthorpe, 2005). With the aging population increasing at a rapid pace, the questions is: Who will take care of our older adults?

According to the European Union, smart technologies that support independent living and active aging introduced as 'Ambient Assisted Living' (AAL) can be the answer to the economic and societal challenges of the aging population. However, at this stage it is still unclear how these technologies will be received by older adults and their caregivers. Recent systematic reviews point out that the technology readiness of most applications is rather low (Liu, Stroulia, Nikolaidis, Miguel-Cruz, & Rios Rincon, 2016) and that there are several barriers towards the acceptance of AAL (Peek et al., 2014).

For AAL technologies to be successful in the future, it is crucial to get a deeper theoretical understanding of how and why prospective users perceive AAL technologies in a certain way and identify the factors that drive or hinder the acceptance of AAL.

1 General Introduction

1.1 POPULATION AGING

Europe has one of the highest shares of elderly people in the world. In 2016, already 19% of the European population[1] was 65 years and over. Looking at the prognoses, this share will increase to 29% by 2070; meaning that more than 1 in 4 people in Europe will be 65 years or over. There is also an increase of the oldest-old (80 years and over) from 5% in 2016 to an estimated share of 13% in 2070 (European Commission, DG ECFIN, 2017).

As people grow older, it is expected that there will be more people with age-related chronic diseases and in need of long-term care (Colombo, Llena Noza, Mercier, & Tjadens, 2011). At the same time, there are less people in the working age population (15-64 years) providing the necessary funds. This is expressed in the old-age dependency ratio. In Europe, this ratio is projected to increase from 30% in 2016, to 51% by 2070. In other words, there will be only two working-age people as providers of healthcare and pension funds for each older person on the receiving end. This puts the financial sustainability of the European health- and long-term care systems at risk. In 2013, already 1.6% of the gross domestic product (GDP) in Europe was spent on long-term care. This share is projected to increase to 2.6% – 4.3% by 2060, depending on which projection scenario is applied (European Commission, DG ECFIN, 2015)

Another area of concern is the expected shortage of informal and formal caregivers. Colombo et al. predicted in 2011 that to maintain the current ratio of informal caregivers to care recipients, some countries would need a 20%-30% increase in informal caregivers. Informal caregivers are crucial to the functioning of the care system as they are unpaid, usually the preferred (Colombo et al., 2011; Eckert, Morgan, & Swamy, 2004), and often the primary (Henz, 2006) source of care. They are typically female and spouses, children, or children-in-law, with a majority in the 45-65 age group (Henz, 2006; Huber, Rodrigues, Hoffmann, & Marin, 2009).

[1] The data in this chapter is based on the demographic projections by Eurostat 2015, which were also used in the referenced source report. In this chapter, we considered the data of the EU-28 member countries including the UK to describe the European population.

Changing family structures and a growing participation of women in the labor market put the reliance on informal caregivers at risk (Colombo et al., 2011). In addition, providing care to a kin can be burdening and negatively affect the informal caregivers health and well- being (Schulz & Beach, 1999). Formal care organizations also suffer from a shrinking work force (Hussein & Manthorpe, 2005; Verbeek-Oudijk, Woittiez, Eggink, & Putman, 2014) and major budget cuts (Visser- Jansen & Knipscheer, 2004), thereby endangering the access and quality of care and putting even more pressure on the informal caregivers.

1.2 TOWARDS SUSTAINABLE LONG-TERM CARE IN EUROPE

To cope with the demographic pressure and the accompanying challenges, many European governments have reformed their long-term care policies over the last decades. According to the OECD, Long-term care (LTC) can be defined as (Colombo et al., 2011, p. 2):

> *"A range of services required by persons with a reduced degree of functional capacity, physical or cognitive, and who are dependent for an extended period of time on help with basic activities of daily living (ADL). This personal care component is frequently provided with basic medical services, nursing care, prevention, rehabilitation or palliative care. LTC services can also be combined with lower-level care related to help with so-called instrumental activities of daily living (IADL) (e.g., domestic help, help with administrative tasks, etc.)"*

Although long-term care reforms significantly differ across Europe, some overall trends can be observed (Colombo et al., 2011; Mosca, Van der Wees, Mot, Wammes, & Jeurissen, 2016; Pavolini & Ranci, 2008; Verbeek-Oudijk et al., 2014):

AGING IN PLACE

In many European countries there is a shift towards 'aging in place'. Aging in place encompasses two main transitions:
(1) the decentralization of the organization and regulation of care to regional and local levels and (2) a shift from intramural care to more care at home. The rationale behind these reforms is that care is organized more efficiently, and that local authorities can deliver more tailored care solutions with respect to the local context and individual care needs. Secondly, care at home is less expensive than institutional care and is also in the interest of older adults, who often prefer to stay in their trusted home environment for as long as possible. However, according to Peeters, Wiegers, Bie, and Friele (2013) this shift also puts more responsibility on care recipients and their family members regarding the monitoring of their health and the organization of their care.

MORE RELIANCE ON INFORMAL CARE

In countries with a high proportion of publicly funded care such as Sweden, Denmark or the Netherlands, there is a shift to more reliance on informal care. In countries that already heavily rely on informal care (e.g. Czech Republic, Poland, Italy, Spain), informal care remains important but efforts are made to improve the availability of publicly funded care. To increase the autonomy and capacity of informal caregivers, public resources are increasingly invested into supportive measures: cash benefits, tax benefits, paid and unpaid leave, flexible work arrangements, home-based professional support, respite care, and training and counseling for informal caregivers. However, Courtin, Jemiai, and Mossialos (2014) conclude that these support policies are still in an early stage and there are significant differences between countries regarding the availability, extent and quality of support.

Moreover, most countries do not have an adequate system in place to identify informal caregivers and their needs. Finally, according to Mosca et al. (2016) many countries already rely heavily on informal care, and it is uncertain how informal caregivers can cope with the increasing demand without negative consequences, such as reduction in labor-market participation as well as physical and mental health problems.

AUTONOMY AND FREEDOM OF CHOICE

Several European countries have implemented greater division between financing and provision of care. By introducing a competition mechanism into public sectors and providing incentives to develop private services, the range of home-care services has diversified over the last decades. This market mechanism has been further reinforced by giving care recipients more autonomy and freedom of choice. This freedom of choice allows care recipients to choose their preferred care provider and take control over the care they receive. The downside of this approach is that the competition has encouraged cost saving measures among private care providers, threatening the quality of both care and employment (Pavolini & Ranci, 2008)

ACTIVE AGING

Another response to the demographic shift is the promotion of the 'active aging' policy vision (also referred to as 'healthy aging' or 'successful aging'). According to the World Health Organization (WHO) (2002, p. 12) active aging can be described as:

> *"The process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age. Active ageing applies to both individuals and groups. It allows people to realize their potential for physical, social, and mental well-being throughout their lives and to participate in society according to their needs, desires and capacities, while providing them with adequate protection, security and care when they require assistance."*

In other words, active aging policies aim at promoting a healthy lifestyle, sustained employment, participation in the community, and overall quality of life, thereby reducing long-term care and pension expenditures (Foster & Walker, 2013). Active aging challenges the view of older adults as frail, passive and dependent but emphasizes autonomy and participation. It also emphasizes protection, dignity and care (Stenner & McFarquhar, 2010). However, critics have pointed out that the active aging vision is mostly framed by young and middle-aged policy makers and researchers whose vision might differ from the needs and wishes of older adults themselves (Clarke & Warren, 2007; Stenner & McFarquhar, 2010).

LONG-TERM CARE IN THE NETHERLANDS

The trends described above have also been leading the transformation of the Dutch long-term care system. In January 2015, the Netherlands introduced the new Long-term Care Act (Wet langdurige zorg) together with the revised Social Support Act (Wet maatschappelijke ondersteuning) and the Health Insurance Act (Zorgverzekeringswet), thereby replacing the former Dutch Exceptional Medical Expenses Act (Algemene Wet Bijzondere Ziektekosten). One of the key aspects of this transition is that municipalities have become primarily responsible for the long-term care of their residents. Centrally funded care is now limited to people with heavy care needs who require permanent supervision or residential care. The transition of the Dutch long-term care system also includes substantial saving targets. This entails a shift to more care at home, more reliance on informal care, and more self-management among care receivers. The responsibilities of formal caregivers have also changed. As gatekeepers between municipalities, health insurers, home care organizations, informal caregivers and care receivers, formal caregivers have an increased responsibility in coordinating and managing different levels of care and support. At the same time, they are dealing with budget cuts and imminent staff shortages (Kroneman et al., 2016). As Kroneman et al. (2016) point out:

> *"This reform has come with a great deal of social unrest, because the reform also includes substantial savings targets, and with greater pressure on long-term care seekers to first try to find a solution within their social network. It remains unclear how this will work in practice and whether the savings targets will be met."*
> (p. xxii)

It can be concluded that the trends and reforms described above entail several risks in terms of access and quality of care, the increasing workload for informal and formal caregivers, and the overreliance on the autonomy and self-management of care receivers.

1.3 TECHNOLOGIES FOR INDEPENDENT LIVING AND ACTIVE AGING

In order to facilitate the new care reforms and addressing the accompanying risks, Ambient Assisted Living (AAL) technologies have received increased attention from government, industry and research. AAL is the umbrella term for various ICT-based technologies (e.g., smart home technology, mobile and wearable technology, assistive robotics) that build on the principles of ambient intelligence to provide supportive environments to older adults and their caregivers. AAL is envisioned as a key solution to the challenges of the aging population, while maintaining a high quality of care. The promises of AAL include saving long-term care costs, improving the quality of care, unburdening family caregivers, and increasing the independence and overall quality of life of older adults. Over the last decade, the European Union (EU) has provided a substantial proportion of funding to stimulate research, development and market exploitation for AAL such as the 'Active and Assisted Living Program' (AAL JP) or the 'European Innovation Partnership on Active and Healthy Ageing' (EIP AHA) (Gehem & Sánchez Díaz, 2013, p. 40). The EU considers the older age group as an emerging market ('the silver economy') for innovative products and services that support independent living and active aging, with an estimated spending capacity of over €3000 billion (European Commission, DG CONNECT, 2013). Several major European companies have shown increasing interest in this market group, such as Philips with their HealthSuite (Philips, 2017) or Bosch with their Vivatar app (Bosch Healthcare Solutions, 2017). New companies have appeared on the European market such as Sensara (Sensara, 2017), Zora Robotics (Zora Robotics NV, 2017) and HomeTouch Care (HomeTouch Care Ltd, 2017).

The interaction between technologies and older adults is also a growing area of interest in the academic field. Vines, Pritchard, Wright, Olivier, and Brittain (2015) found 162 papers that had a primary focus on the relationship of older adults and technology and were published in human-computer interaction venues (ACM SIGCHI) by the end of 2012. Of these papers, 80% were published after 2006. Several interesting research projects have been launched such as the

Aging in Place project (Rantz et al., 2005), Aware Home (Abowd, Bobick, Essa, & Mynatt, 2002) including Digital Family Portrait (Rowan & Mynatt, 2005), and social service robot Care-o-bot (Kittmann, Fröhlich, Schäfer, Reiser, & Haug, 2015). Finally, new academic fields have emerged, such as gerontechnology, which focuses on interdisciplinary research at the crossroads of gerontology and technological innovations (Bouma, Fozard, Bouwhuis, & Taipale, 2007).

Although there is increasing interest in AAL among governments, industry and research, most technologies are still in a research and development stage and have not been widely diffused into the market (Liu et al., 2016; Queirós, Silva, Alvarelhão, Rocha, & Teixeira, 2015).

1.4 TO ACCEPT OR TO REJECT

For AAL technologies to be successful, it is crucial that the potential users have a positive attitude towards these technologies and are ready to embrace these solutions in their daily lives. In the context of AAL, potential users are primarily older adults. However, the care routine of formal and informal caregivers will be directly affected by the implementation of AAL technologies. Therefore, formal and informal caregivers can be considered as a secondary user group.

While the policy enthusiasm for AAL technology is high, the actual uptake among the potential users might be problematic. Different studies have shown that there are several barriers towards the acceptance of AAL (Cardinaux, Bhowmik, Abhayaratne, & Hawley, 2011; Hwang, Truong, & Mihailidis, 2012; Novek, Bettess, Burke, & Johnston, 2000; Peek et al., 2014; Rashidi & Mihailidis, 2013). It is therefore surprising, that the AAL field is still technology-driven rather than user-driven (Chan, Campo, Estève, & Fourniols, 2009; Queirós et al., 2015) and lacks a theoretically founded understanding of how and why users will accept or reject AAL technologies (Liu et al., 2016; Peek et al., 2014). Moreover, ageism, stereotyping and oversimplification of acceptance issues is still prevalent among developers of AAL technologies, leading to an improper assessment of the older adults' individual lifestyle, needs and expectations (Eisma et al., 2004; Östlund, 2005; Peine, Rollwagen, & Neven, 2014; Vines et al., 2015). This gap in a profound understanding of the user's perspective is likely to lead to poor implementations of AAL technologies that lack added value, usability, or simply do not fit the user's needs and are therefore prone to be rejected.

User acceptance is therefore an area that deserves more attention in AAL research to develop a comprehensive and theoretically grounded understanding of the user's acceptance process. These insights can be leveraged to guide the design, development and implementation of future AAL applications and increase the likelihood of future acceptance by the intended user groups.

1.5 SCOPE, RESEARCH QUESTIONS AND OUTLINE

To address the gaps outlined above, this dissertation aims to develop a comprehensive and theoretical grounded understanding of how and why the intended users will accept or reject AAL technologies and translate these findings into implications for the development, implementation and policy direction of these technologies. Hence, the research question central to this dissertation is:

> ***Which factors determine the acceptance of AAL technologies among older adults (primary focus) and their caregivers (secondary focus)?***

The overall aim is to foster a more user-driven approach to AAL technologies that prioritizes the wishes, concerns and needs of the prospective users.

1.5.1 PART I: DEFINING AAL

AAL is still a relatively new and emerging area that encompasses several types of technologies (e.g. smart homes, robotics, wearable sensors) as well as a broad range of application domains (e.g. health and rehabilitation, safety and social inclusion). Due to this broadness and its interdisciplinary nature there is no common understanding among researchers on how AAL should be defined.
Before studying the user acceptance of AAL, we first need to clearly define AAL and shed more light on its characteristics, application domains, tools and techniques. Therefore, the first research question central to this dissertation is:

> *RQ 1: How can Ambient Assisted Living (AAL) be defined?*

Chapter 2 will address this question and looks at different attempts in literature to conceptualize AAL and establishes some common ground resulting in a clear definition of AAL. The second part of the chapter provides a comprehensive overview of the intended application domains of AAL and commonly used technologies and techniques in the field. The chapter closes with a short outlook on current challenges and future directions of AAL research.

1.5.2 PART II: EXPLORING POTENTIAL ACCEPTANCE FACTORS

Technology acceptance is a complex phenomenon with many personal, social, technological and other contextual factors to consider. At the time this research started, AAL studies focusing on user acceptance were still scarce. Moreover, the field was dominated by studies focusing on specific AAL application and that included only a limited number of users. Consequently, there was no consensus about important drivers and barriers towards AAL acceptance from the perspective of the intended user groups. This lead to the second research question of this dissertation:

> *RQ 2: Which factors do older adults and their caregivers perceive as potential drivers and barriers towards AAL acceptance?*

Chapter 3 presents a literature review of 22 academic publications in the AAL field that were published between 2000 and 2014 and had a primary focus on user acceptance. This review accumulates and compares the findings from these studies to achieve some consensus about important drivers and barriers towards AAL acceptance. Moreover, this literature review provides an initial understanding of the underlying aspects, meanings and perceptions associated with these acceptance factors.

Chapter 4 strives to further define and validate these acceptance factors within the context of our own qualitative user studies. Three user studies are presented. The first study was conducted within the European research project SONOPA (SOcial Networks for Older adults to Promote an Active life). User groups included older adults from France and the UK and formal caregivers from Belgium. The second user study was conducted with informal caregivers from the Netherlands. Different examples of AAL technologies were used as stimulus material. The third user study was conducted with 'couples' of older adults and informal caregivers. A later iteration of the SONOPA prototype was evaluated within this third user study.

Both chapters contribute to the understanding of the underlying aspects, meanings and perceptions of potential acceptance factors. Hence, both chapters provide the groundwork for the development of a theoretical framework of AAL acceptance.

1.5.3 PART III: TOWARDS A MODEL OF AAL ACCEPTANCE

Recent systematic reviews in the field of AAL argue that most studies on AAL acceptance lack a theoretically grounded approach (Liu et al., 2016; Peek et al., 2014) This makes it difficult to accumulate and compare knowledge about the social, psychological, and behavioral mechanism behind the acceptance factors in order to build a strong theoretical foundation for the field. Furthermore, the majority of studies uses a qualitative approach and relatively small sample sizes (Liu et al., 2016; Peek et al., 2014). More large-scale quantitative approaches are needed to make statistically grounded and externally valid inferences about the relative importance of different drivers and barriers, their underlying relationships, and their explanatory power for the future acceptance of AAL technologies. Hence the third research question of this dissertation is:

> *RQ3: Which factors are the most important determinants for the acceptance of AAL technology among older adults in an early acceptance stage and how are these factors related?*

Chapter 5 argues that technology acceptance should be considered as a process over time and introduces the different stages of technology acceptance. The second part of the chapter takes a critical look at some of the popular theories and models of technology acceptance research, and discusses whether the theory forms a good theoretical foundation to understand and explain AAL acceptance in the current development and acceptance stage. The chapter closes with the introduction of the new conceptual model of AAL acceptance which integrates the established theoretical foundation with the qualitative insights from Chapter 3 and Chapter 4.

Chapter 6 presents the design and scope of the online AAL acceptance survey that was used to validate the conceptual model of AAL acceptance. The second part of the chapter describes the results of the first pilot study that was conducted with 320 Dutch older adults. In this pilot study, structural equation modeling is used to explore the psychometric properties of the measurements and to provide initial evidence for the proposed conceptual model of AAL acceptance. The pilot study results in refined measurements and an adapted conceptual model of AAL acceptance.

Chapter 7 describes the results of the main study with a new sample of 1296 Dutch older adults that were representative for the Dutch older adult population. Structural equation modeling is used to validate the adapted conceptual model of AAL acceptance. Based on these findings, statistically grounded and externally valid inferences about the current state of early acceptance of AAL technology are made, and the relative importance of different acceptance factors, their underlying relationships, and their explanatory power for the intention to use AAL are discussed.

1.5.4. PART IV: FROM SCIENCE TO PRACTICE

Will the policy vision of AAL as the solution to healthy and independent aging, active participation in society, a reduced workload for informal and formal caregivers, and savings on healthcare budget become reality from the perspective of the prospective users?

The last part of this dissertation is dedicated to highlight the main findings of and translate these into practical implication for the future development, implementation and policy direction of AAL. Hence, the last research question is:

> *RQ4: What are the implications for the design, implementation and policy direction of AAL technologies?*

Chapter 8 contains the general discussion of this dissertation. It summarizes the main findings, discusses the overall limitations, and suggests directions for future research. The chapter closes with several practical implications and recommendations for the future development, implementation and policy direction of AAL.

PART I

Defining AAL

2
Introducing Ambient Assisted Living

The definition of AAL has been previously published in:

Jaschinski, C., & Ben Allouch, S. (2018). Listening to the ones who care: exploring the perceptions of informal caregivers towards ambient assisted living applications. *Journal of Ambient Intelligence and Humanized Computing*, 1-18. https://doi.org/10.1007/s12652-018-0856-6a

Ambient Assisted Living research is still a relatively new and emerging field that encompasses several types of technology as well as a broad range of application domains. Overlapping and related fields include ambient intelligence, gerontechnology, assistive technology, telemonitoring, smart homes, human-robot interaction, and mobile and wearable technology. Due to this wide scope and its interdisciplinary nature, there is no common understanding among researchers on how AAL should be defined. Before studying the user acceptance of AAL, the aim of this chapter is to clearly define AAL and shed more light on its characteristics (2.1), application domains (2.2), tools and techniques (2.3) and describe current challenges in the field (2.4). Hence, the current chapter addresses the first research question (RQ 1):

> *How can Ambient Assisted Living (AAL) be defined?*

2.1 CHARACTERISTICS OF AAL

There is no precise, nor widely adopted definition for AAL among researchers across different fields. However, after looking at previous attempts for describing and defining AAL we found some common ground.

BUILDS ON THE PRINCIPLES OF AMBIENT INTELLIGENCE

Ambient Intelligence (AmI) is a research paradigm that brings intelligence to everyday environments through sensor networks, pervasive computing and artificial intelligence. This way, our environments become sensitive, adaptive and responsive to our presence and needs. (E. H. L. Aarts & Encarnação, 2006; E. H. L. Aarts & Marzano, 2003; Cook, Augusto, & Jakkula, 2009). AAL applies the classic principles of Ambient Intelligence to a new generation of assistive technologies for older adults, which are embedded (i.e., non-invasive and unobtrusively integrated into the environment); context-aware (i.e., recognize the user and the situational context); personalized (i.e., tailored to the specific needs of the individual user); adaptive (i.e., responsive to the user through learning); and anticipatory (i.e., anticipating the user's needs and desires without conscious mediation) (Acampora, Cook, Rashidi, & Vasilakos, 2013; Blackman et al., 2016; Van den Broek, Cavallo, & Wehrmann, 2010; Queirós et al., 2015; Rashidi & Mihailidis, 2013; Sun, De Florio, Gui, & Blondia, 2009). In AAL, ambient intelligence is used to create supportive environments that provide all-encompassing, non-invasive and pro-active assistance to the user. As Blackman et al. (2016, p. 57) state: "AAL is the result of a progression from individual devices assisting with one task or activity of daily living to ambient systems in which the assistance or support completely encompasses the living area and the person". For example, while traditional pendant alarms require the older adult to actively push a button to request assistance, AAL systems are envisioned to anticipate and prevent emergency situations before they actually occur, through multimodal sensing and continuous monitoring.

COMPRISES VARIOUS STATE-OF-THE-ART ICT-BASED TECHNOLOGIES AND ADVANCED COMPUTATIONAL TECHNIQUES

AAL includes a broad range of advanced technologies with a strong emphasis on smart home technology, mobile and wearable technology and assistive robotics (Rashidi & Mihailidis, 2013). These technologies are combined with advanced computational techniques including activity recognition, behavioral pattern discovery, anomaly detection, context modeling, planning and scheduling, and location and identity identification (Acampora et al., 2013; Rashidi & Mihailidis, 2013). All components of the AAL environment are interconnected and communicate with each other. The embedded sensors collect information about the environment and the user (sensing); computational techniques are used to aggregate, analyze and interpret this information and decide on the appropriate action (reasoning); and various types of actuators, intelligent interfaces and assistive devices facilitate action and interaction with the user (acting) (Van den Broek et al. 2010; Queirós et al. 2015).

AIMS TO MAINTAIN OLDER ADULTS' INDEPENDENCE AND TO ENHANCE THEIR GENERAL QUALITY OF LIFE WHILE ALSO SUPPORTING THEIR CAREGIVERS

The vision of AAL is to provide older adults with secure and supportive environments (Blackman et al., 2016; Cardinaux et al., 2011; Sun et al., 2009), to maintain and improve their physical, cognitive and psychological health (Blackman et al., 2016; Van den Broek et al., 2010; Peek et al., 2014; Rashidi & Mihailidis, 2013), and to foster social involvement and active participation in society (Blackman et al., 2016; Van den Broek et al., 2010; Queirós et al., 2015). The ultimate goal is to preserve the older adults' independence (Blackman et al., 2016; Van den Broek et al., 2010; Cardinaux et al., 2011; Peek et al., 2014; Rashidi & Mihailidis, 2013; Sun et al., 2009) and improve their overall quality of life (Blackman et al., 2016; Van den Broek et al., 2010; Cardinaux et al., 2011).
A secondary target group of AAL technologies are informal and formal caregivers (Van den Broek et al., 2010; Chan et al., 2009; Queirós et al., 2015; Rashidi & Mihailidis, 2013). AAL technologies aim to reduce the burden on caregivers (Pollack, 2005; Rashidi & Mihailidis, 2013), provide peace of mind (Mynatt & Rogers, 2001), help them to manage and coordinate care tasks (Bossen, Christensen, Groenvall, & Vestergaard, 2013; Van den Broek et al., 2010; Consolvo, Roessler, & Shelton, 2004) and facilitate remote communication and social connectedness between caregivers and older adults (Cornejo, Tentori, & Favela, 2013). This vision underlines the development towards assistive solutions that target more than one area of 'successful aging' and offer all-encompassing support.

Hence, we will define Ambient Assisted Living as:

> *State-of-the-art ICT-based solutions that build on the principles of ambient intelligence to create intelligent environments that provide all-encompassing, non-invasive, and pro-active support to older adults and have the ultimate goal to maintain their independence, enhance their overall quality of life, and support their caregivers.*

The terms 'Ambient Assisted Living (AAL)', 'AAL technologies', 'AAL solutions' and 'AAL applications' will be used interchangeably within this dissertation.

2.2 APPLICATION DOMAINS OF AAL

In line with the AAL vision of all-encompassing support, the application domains of AAL solutions are broad. Within the AAL roadmap, Van den Broek et al. (2010) distinguish three main application domains that will be discussed below.

AGEING WELL AT HOME

This first domain is described as "enjoying a healthier and higher quality of daily life for a longer time, assisted by technology, while maintaining a high degree of independence, autonomy and dignity" (p. 16). Many older adults prefer to stay in their own trusted home environment for as long as possible (Eckert et al., 2004). However, age-related physical and cognitive decline can make aging at home challenging. Even older adults who are still healthy and active might need some form of assistance in the near future. Creating a safe and supportive home environment is therefore an important focus area of AAL. Examples of applications in this domain include: in-home security systems, environmental control and home automation systems, health monitoring systems, medication management systems, systems for activity monitoring (e.g. sleep patterns, movement patterns including wandering behavior, diet), systems for emergency and fall detection, reminder and planning systems, social service robots, systems that assist with sensory deficits and daily-life tasks, serious games to stimulate cognitive and physical skills, and care-management systems to support informal and formal caregivers.

AGEING WELL IN THE COMMUNITY

The second domain is defined as "staying socially active and creative through ICT solutions that are geared toward social networking as well as good access to public and commercial services, so improving the quality of life and reducing social isolation" (p. 16). There are several factors that can contribute to social isolation and loneliness in later life, such as decline in physical and mental health, change of the social environment due to relocation, retirement or loss of a partner, the demand to care for a partner in poor health, a the lack of transportation options (Wherton & Prendergast, 2009). Staying socially connected and participating actively in the community is therefore an important part of the WHO's 'active aging' policy (WHO, 2002). Indeed, research shows that social relationships and active social participation are important for the perceived quality of life (Bowling, Gabriel, Dykes, & Dowding, 2003; Gabriel & Bowling, 2004). Social connectedness is associated with a good physical, cognitive and psychological health (Luanaigh & Lawlor, 2008; Shankar, McMunn, Banks, & Steptoe, 2011; Thurston & Kubzansky, 2009). Several AAL applications aim to reduce social isolation and to facilitate social relationships and active participation in the community. Examples of these applications include smart mobility and navigation aids, social companion robots, social network applications and other communication and service platforms, interactive games and storytelling, ambient awareness systems, and other systems that facilitate social interaction and recreational activities.

AGEING WELL AT WORK

The third and final domain is described as: "remaining active and productive for a longer time, with an improved quality of work and a better work-life balance via easy to access ICT, innovative practices for adaptable workplaces, ICT skills and competences and ICT enhanced learning (e.g. e-skills and e-learning)" (p. 16). As older adults are expected to participate in the labor market for longer, the third domain of AAL technologies aims to create safe and supportive working environments and to promote the equality, health and well-being of older adult employees. Examples of applications in this domain include smart and adaptive workstations, multimodal interfaces, environmental control, smart indoor mobility and navigation aids, assistive robots, and health monitoring at work.

Following the principles of ambient intelligence and all-encompassing support, AAL applications will become increasingly more connected and intertwined and traversing multiple environments. This implies that domains are not clearly separated from each other, but are closely connected and partially overlap. For now, this dissertation will focus on the first and second domain (home and community) and pay less attention to AAL applications for the work domain.

2.3 CURRENT AND FUTURE AAL TOOLS & TECHNIQUES

AAL leverages various state-of-the-art technologies with a strong emphasis on smart home technology (2.3.1), mobile and wearable technology (2.3.2), and assistive robotics (2.3.3) (Rashidi & Mihailidis, 2013). Other commonly used technologies include care management systems, reminder and planning systems, social network and communication applications, ambient awareness systems and serious games (2.3.4). To make sense of the rich data about the environment and the user and decide on the appropriate action, various advanced algorithms are used (2.3.5).

2.3.1 SMART HOME TECHNOLOGY

A smart home is a home which is equipped with a network of various types of sensors and actuators that collect continuous and rich contextual information about the environment and the resident. In the context of AAL, this information is aggregated and used to provide a safe and supportive home environment by the means of in-home security, automation, environmental control, cognitive and sensory assistance as well as health and activity monitoring (Demiris & Hensel, 2008; Liu et al., 2016; Rashidi & Mihailidis, 2013). Table 2.1 provides an overview of ambient sensors that are commonly used in AAL home environments.

Table 2.1 Ambient Sensors Commonly Used in AAL Home Environments (adapted from Cardinaux et al., 2011; Rashidi & Mihailidis, 2013)

SENSOR TYPE	COMMON APPLICATIONS
environmental sensors (e.g., light, humidity, ambient temperature, air quality)	comfort, healthy environment, activity monitoring
smoke and gas sensors	security
water sensors	activity monitoring, health monitoring
sensors in home appliances	comfort, security, daily life assistance, activity monitoring
motions sensors (e.g., active (AIR) and passive infrared (PIR), ultrasonic)	comfort, security, activity monitoring, fall and emergency detection
open/close sensors for doors and windows (e.g., magnetic switch)	security, activity monitoring
pressure sensors (embedded in the floor or furniture)	activity monitoring, fall and emergency detection
radiofrequency identification (RFID)	security, activity monitoring, cognitive assistance, medication intake
microphone	activity monitoring, fall and emergency detection
camera (low-resolution, infrared, visible light)	security, activity monitoring, fall and emergency detection, health monitoring

Over the last decades, several smart home projects have been implemented across the globe. The Aware Home in the US is a two story house with two identical living spaces, which are equipped with a variety of sensors (cameras, microphones, infrared, RFID, ultrasonic, pressure) (Abowd et al., 2002; Georgia Institute of Technology, 2018; Kidd et al., 1999; Mynatt & Rogers, 2001). These sensors unobtrusively monitor and support the residents. Example applications include a force-sensitive smart floor that can localize and identify residents, a memory aid based on RFID tags that helps residents to find lost objects, and the ambient awareness system Digital Family Portrait that provides distant family members with information about the residents' daily activities. In Asia, the Welfare Techno House project constructed 16 demonstration houses across Japan to test and develop new AAL concepts (Suzuki, Ogawa, Tobimatsu, & Iwaya, 2001; Tamura et al., 2007). For example, the Takaoka Techno House provides automatic control of lighting, curtains and windows, and a camera based security system for the front door. The house is also equipped with several ambient health monitoring systems, including conductive textiles in the bed, silver chloride electrodes in the bathtub for Electrocardiogram (ECG) measurement, and a toilet with a weight measuring platform and urinary volume measurement. The European ENABLE project developed and tested several smart home technologies to assist people with mild to moderate dementia in the UK, Ireland, Norway, Finland and Lithuania (Adlam et al., 2004; Cahill, Begley, Faulkner, & Hagen, 2007). Example technologies include a stove monitor that automatically shuts off gas stoves, and a night light that detects when a person gets up and provides ambient lightning to prevent falls.

Other well-known smart home initiatives include the Casas project (Cook, Crandall, Thomas, & Krishnan, 2013), the Tiger Place project (Rantz et al., 2013), the MavHome project (Das & Cook, 2004), the Ubiquitous Home project (Yamazaki, 2007), the Gloucester Smart House (Orpwood, Gibbs, Adlam, Faulkner, & Meegahawatte, 2004), and the Future Care Lab (Klack, Möllering, Ziefle, & Schmitz-Rode, 2011)

2.3.2 MOBILE AND WEARABLE TECHNOLOGY

As sensors become increasingly smaller, flexible and affordable, mobile and wearable technologies provide powerful tools for health monitoring and indoor and outdoor activity monitoring among older adults. By continuously monitoring physiological parameters, tracking location and movement, and detecting and analyzing activity patterns, these applications aim to support health management and rehabilitation from home, detection of physical and cognitive decline, prevention of accidents, and immediate response in case of emergencies.

SMARTPHONES AND SMARTWATCHES

Smartphones are equipped with various sensors, such as accelerometer, gyroscope, proximity sensors, global positioning system (GPS), Bluetooth, camera, microphone and environmental sensors that can be leveraged for indoor and outdoor activity monitoring (Incel, Kose, & Ersoy, 2013). Smartwatches and other wrist-worn devices have also been used for activity monitoring, as they are equipped with similar sensors (Chernbumroong, Atkins, & Hongnian Yu, 2011; Sen, Subbaraju, Misra, Balan, & Lee, 2015). In contrast to smartphones, wrist-worn devices are more reliable for recognizing activities that involve hand movement such as eating, drinking or smoking (Shoaib, Bosch, Incel, Scholten, & Havinga, 2016). They usually also provide more continuous data for indoor monitoring, as they can be worn comfortably 24h a day (Bieber, Haescher, & Vahl, 2013; Rawassizadeh, Price, & Petre, 2014). For other activities smartphones are preferred, because they are usually worn close to the hip and are suitable for recognizing activities such as cycling or walking stairs (Bieber et al., 2013; Shoaib et al., 2016). Recent studies have attempted to combine sensor data from both devices for advanced activity recognition (Casilari & Oviedo-Jiménez, 2015; Shoaib et al., 2016). Due to its placement and continuous skin contact, smartwatches and other wrist-worn devices or armbands are also suitable for monitoring physiological parameters, such as heart rate (Electro-cardiogram (ECG)), body temperature, perspiration (Galvanatic Skin Response (GSR)), and muscle activity (EMG) (Klonovs et al., 2016; Rawassizadeh et al., 2014).

Several researchers have used smartphones, smartwatches and other wrist-worn devices in the AAL field. Casilari and Oviedo-Jiménez (2015) combined of-the-shelf smartphones and smartwatches using their built-in accelerometer and gyroscope for fall-detection among older adults. Their system was able to decrease the number of false alarms, while maintaining the ability to detect actual falls. Lutze, Baldauf, and Waldhor (2015) applied smartwatches to prevent dehydration of older adults by monitoring arm movement. Kikhia et al. (2016) used sensors embedded in a wristband to determine stress levels among older adults with dementia by sensing their GSR.

SMART GARMENTS AND E-TEXTILES

Smart garments and e-textiles offer another tool for non-invasive health and activity monitoring. Sensors can be integrated into the garment, into the fabric or even into the fiber (Rashidi & Mihailidis, 2013). Examples include MagIC, a vest with knitted electrodes for ECG measurement, a textile based plethysmograph to monitor respiration rate, and a three-axis accelerometer attached to the vest. MagIC was applied for telemonitoring of cardiac patients (Di Rienzo et al., 2010). A similar garment was introduced by Pandian et al. (2008). Smart Vest is a t-shirt with sensors integrated into the fabric that monitor various physiological parameters including ECG, photoplethysmogram for blood flow (PPG), body temperature, blood pressure, GSR as well as geo- location (GPS). Cheng, Amft, Bahle, and Lukowicz (2013) tested textile capacitive sensor patches attached on different body parts for various physiological measurements and activity recognition scenarios including ECG and respiration rate, wrist and hand gestures, food and liquid intake and gait and ground information.

Other popular wearables for health and activity monitoring include sensors that are attached to or embedded in shoes, belts or jewelry (Brodie et al., 2016; Moufawad el Achkar et al., 2016; Sardini & Serpelloni, 2010; Sim et al., 2011).

EPIDERMAL ELECTRONIC SYSTEMS (EES)

Other on-body sensing tools for health monitoring are sensors embedded in pads that are attached to the skin. However, this solution has limited value for monitoring in everyday life settings, as they can be uncomfortable and easily detach from the skin (Yeo et al., 2013). More recently, flexible, skin-like sensing systems called epidermal electronic systems (EES) have been introduced (Yeo et al., 2013). Due to their flexibility and thinness, they naturally fuse with the human skin, thereby enabling close contact and robust physiological measurements (Imani et al., 2016). While most EES focus on physical or electrophysiological parameters, such as skin temperature or ECG (Bian et al., 2014; Webb et al., 2013; Yeo et al., 2013), Imani et al. (2016) introduce a hybrid sensing patch that monitors electro-physiological parameters (i.e., ECG) as well as biochemical parameters (i.e., sweat- lactate levels) for more comprehensive monitoring.

IN-VIVO SYSTEMS

A more invasive method for health monitoring are solutions which are inserted into the body (in-vivo monitoring). Examples include glucose sensors implanted under the skin for detecting hypoglycemia among diabetics (Juhl et al., 2010), and orally administered capsules for sensing temperature, pressure, images, and pH data as well as provide drug delivery (Mc Caffrey, Chevalerias, O'Mathuna, & Twomey, 2008).

2.3.3 ASSISTIVE ROBOTICS

Assistive robotics in AAL can be broadly categorized in rehabilitation robots, social service robots and social companion robots (Broekens, Heerink, & Rosendal, 2009; Robinson, MacDonald, & Broadbent, 2014). The first category can be described as “physically assistive devices that are not primarily communicative or perceived as social entities” (Robinson et al., 2014, p. 576). Rehabilitation robots help with physical training, compensate for physical deficits, and support older adults with daily life tasks. Examples include robotic mobility aids (Spenko, Yu, & Dubowsky, 2006), exoskeletons (O'Sullivan et al., 2015), and robots that help with physical training (Johnson, Wisneski, Anderson, Nathan, & Smith, 2006).

The second category are social service robots. They also assist with various daily life tasks, support mobility and can monitor the older adult's health and safety. These service robots are categorized as social because the older adult can actively interact with the robot (Robinson et al., 2014). Pearl is a mobile service robot that is approximately one meter tall, has a human-like appearance and interacts with the user through speech, visual displays, facial expressions and physical motion (Pineau, Montemerlo, Pollack, Roy, & Thrun, 2003; Pollack et al., 2002). Pearl was designed to assist older adults by reminding them of daily life tasks and activities such as drinking, meals, medicine intake, and guiding them through the environment. Care-o-bot is another mobile service robot (Hans, Graf, & Schraft, 2002; Kittmann et al., 2015; Reiser, Jacobs, Arbeiter, Parlitz, & Dautenhahn, 2013). The latest iteration, Care- o-bot 4, is about 1.5 meters tall and has an abstract human-like appearance. In contrast to earlier iterations, more attention was payed to embodiment and interaction modalities of the robot to improve its sociability. The user can interact with Care-o-bot through gestures, speech, touch screen or tablet. Care-o-bot 4 is able to react with facial expressions (eyes), head- and body movement, and via the built-in speakers. With its highly flexible arms and hands the robot is able to manipulate objects such as fetching, carrying or lifting objects (Kittmann et al., 2015). Other examples of service robots include RIBA (Mukai et al., 2010) or Kompaï (Kompaï Robotics, 2017).

The third category are social companion robots. The primary function of these robots is to enhance the emotional well-being and reduce loneliness by providing companionship and facilitating social interactions (Broekens et al., 2009). An example of a social companion robot is Paro, a robotic seal covered with soft fur. Paro reacts to basic speech, being stroked, and being held by moving his head and flippers, blinking with his eyes, and imitating the noise of a baby seal. Paro aims to evoke similar responses as a real pet animal such as reducing stress and anxiety, providing psychological comfort, and stimulating social interactions (Wada, Shibata, Saito, Sakamoto, & Tanie, 2005). Another social companion robot is AIBO, a mobile robotic dog with embedded sensors and a hard plastic exterior. AIBO can move his head, tale and legs. AIBO has been tested with older adults and has shown to decrease stress and loneliness while increasing social behavior (Kanamori, Suzuki, & Tanaka, 2002; Tamura et al., 2004). Zora is a humanoid care robot based on Softbank Robotics' Nao robot. Zora aims to activate and interact with older adults by singing, dancing or stimulating physical exercises (Kort & Huisman, 2017; Melkas, Hennala, Pekkarinen, & Kyrki, 2016; Parviainen et al., 2016).

During the last years, the separation between these robot categories has become more blurred, as developers of service robots have included more interaction modalities and social features to increase the user's acceptance (e.g., care robot-1 vs. care-robot-4). Hence, future assistive robots are likely to provide both enhanced functional support as well as social companionship.

2.3.4 OTHER TECHNOLOGIES

Other commonly used technologies in the AAL field include care management systems, reminder and planning systems, social network and communication applications, ambient awareness systems and serious games. For example, CareCoor is a care management system that facilitates coordination and planning of care tasks among informal and formal caregivers. It provides information about scheduling, completion of care tasks, swapping or cancellation of tasks, new tasks and a feature for exchanging messages (Bossen et al., 2013). Family Window is an always-on video communication and awareness tool that is intended to evoke feelings of connectedness between distant family members, for example, an older adult and his children or grandchildren (Judge, Neustaedter, & Kurtz, 2010). Tovertafel is a collection of interactive serious games with light projections for older adults with dementia to improve social interaction and reduce feelings of anger, fear and sadness (Anderiesen, 2017).

Together these various types of technologies are used to create smart and supportive environments for the older adult users and their caregivers.

2.3.5 ALGORITHMS AND COMPUTATIONAL TECHNIQUES

To provide the intelligence to the older adults' environments, advanced algorithms and computational techniques are used. These techniques make sense of the vast amount of data collected by the various AAL applications. In the following, we will summarize some of the commonly used techniques in AAL based on the accounts of Acampora et al. (2013) and Rashidi and Mihailidis (2013). For a more elaborate description, including a technical discussion, we refer to the work of these authors.

ACTIVITY RECOGNITION

To provide pro-active assistance, AAL technologies need to recognize what people are doing based on different types of low level data. Activities of interest include for example: sleeping, walking, exercising, toileting, drinking, eating or medication intake. The approach to activity recognition depends on the underlying sensors, the machine learning algorithm used to model the activity, and the complexity of the activity of interest.

BEHAVIORAL PATTERN DISCOVERY

A closely related approach is the detection of reoccurring patterns in the collected activity data, through unsupervised learning techniques. These patterns contribute to the interpretation of sensor data and can be used to construct new models to enable the recognition of the same patterns at future occurrence.

ANOMALY DETECTION

Anomaly detection refers to finding patters in the collected data that deviate from the expected behavior. This is crucial in AAL applications, e.g., to detect changes in daily routines, non-compliance with medication intake, wandering behavior and falls or other emergencies. Anomaly detection is most accurate for behaviors that are performed on a regular basis.

CONTEXT MODELING

AAL systems have to adapt to changing contextual information regarding the physical context, the user/task context and the computational context (Bettini, Brdiczka, Henricksen, Ranganathan, & Riboni, 2010). Therefore these systems need to represent many types of contextual information such as spatial information about the environment, medical history, user profiles and preferences, activity structures, and sensor information.

PLANNING AND SCHEDULING

Automatic planning and scheduling can be very valuable in various AAL scenarios. Examples include reminding older adults with cognitive impairments about tasks and activities and automating daily routines for users with physical impairments.

LOCATION AND IDENTITY IDENTIFICATION

To be able to monitor, track and provide proactive and location-based assistance, AAL systems must be able to identify the older adult and know where he or she is located, especially in case of multiple residents.

2.4 CURRENT CHALLENGES IN AAL

Despite these promising technical developments, there are several challenges in the AAL field that have yet to be resolved. These challenges concern the technical feasibility and overall implementation of AAL (2.4.1), the user acceptance (2.4.2), and the lack of large-scale quantitative and evidence-based research and a theoretical discourse (2.4.3).

2.4.1 TECHNICAL FEASIBILITY AND IMPLEMENTATION

Smart home and wearable sensors collect an abundance of data. While these data are the foundation of personalized, pro-active and all-encompassing assistance, they also entail serious security issues which need to be addressed with advanced data protection techniques and security protocols. This is especially important for sensitive data, such as health data or visual material. The combination of various interconnected sensors and devices further challenges the implementation of secure data analysis and storage (Acampora et al., 2013; Mukhopadhyay, 2015; Rashidi & Mihailidis, 2013). For these sensors and devices to able to communicate with each other, interoperability and standardization is an additional problem that researchers are currently trying to resolve (Memon, Wagner, Pedersen, Beevi, & Hansen, 2014; Queirós et al., 2015).

Another issue in AAL systems is reliability. Reliable recognition of activities and human behavior in uncertain and uncontrollable environments such as the home is challenging. Although sensors and algorithms are constantly evolving, many studies still report reliability issues such as false alarms, low prediction accuracy, or problems in dealing with multiple residents. Reliability issues do not only lead to distress and trust issues among users but can also have serious implication for their health and well-being. Improving the reliability of AAL systems therefore stays high on the research agenda (Cardinaux et al., 2011; Liu et al., 2016; Rashidi & Mihailidis, 2013).

In case of wearable devices, there is the additional challenge of designing comfortable, lightweight and safe devices with good aesthetics and low energy consumption that the older adult is able and willing to wear 24h a day. At the same time, developers still need to embed the necessary hardware and software for reliable, secure and continuous data collection (Mukhopadhyay, 2015).
For assistive robots, one of the biggest challenges is the facilitation of natural interaction and social engagement between older adults and robots. Researchers are still working towards an acceptable physical appearance, the design of human-like gestures, facial expression, and body movement, and the implementation of social intelligence and autonomous behavior (Matarić, 2017; Robinson et al., 2014). Furthermore, most robots are still limited in their functionality and are not yet able to assist with multiple and complex daily life tasks (Rashidi & Mihailidis, 2013). Another concern in assistive robotics is warranting safe movement and operations within the home environment (Salem & Dautenhahn, 2015).

Finally, as AAL systems need to facilitate natural interaction with the older adult users, the design of simple and intuitive interfaces is another issue that developers need to address (Queirós et al., 2015; Sun et al., 2009).

Although AAL applications are slowly starting to enter the market, a recent systematic review concluded that the overall technology readiness of AAL applications is still low and most applications remain in a (pre-)pilot stage (Liu et al., 2016). This is confirmed by another review study that concluded that, despite extensive research efforts in the AAL field, only a few applications have moved beyond the pilot stage (Memon et al., 2014). Some of the hurdles for the implementation and diffusion of AAL systems is the uncertainty of their costs and the lack of regulations regarding reimbursement models (Rashidi & Mihailidis, 2013; Reeder et al., 2013; Vimarlund & Wass, 2014). It should be noted, that recent research efforts have started to address these issues by analyzing the cost-effectiveness of AAL applications and by exploring means to embed these technologies into the healthcare system (Manetti, Orsini, & Turchetti, 2017).

2.4.2 USER ACCEPTANCE

The most important pre-condition for diffusion of AAL is user acceptance. Several recent systematic reviews point to user acceptance as one of the big hurdles to implementation and diffusion of AAL systems in real-life settings (Peek et al., 2014; Rashidi & Mihailidis, 2013; Robinson et al., 2014). Indeed, the nature and objectives of AAL solutions have severe implications for user acceptance. These devices occupy private environments or even the body, collect and store personal and health-related data, influence behavior and habits, ask people to socialize via or even with a machine, and take over tasks that are usually carried out by the older adults themselves or a human caregiver. However, while the number of user-acceptance studies has somewhat increased during the last years (Liu et al., 2016), the field is still technology-driven rather than user-driven and a true user-centered mindset has not yet been adopted by most AAL researchers and developers (Queirós et al., 2015). This often leads to stereotyping, oversimplification and inadequate understanding of user needs, and consequently to bad designs which are prone to be rejected by the intended users (Eisma et al., 2004; Östlund, 2005; Peine et al., 2014; Vines et al., 2015).

Hence, older adults and their caregivers should be involved throughout the conceptualization and development process to avoid a gap between user needs and expert beliefs (Piau, Campo, Rumeau, & Vellas, 2014; Queirós et al., 2015; Rashidi & Mihailidis, 2013). Moreover, the field needs to develop a comprehensive and theoretically grounded understanding of the factors that drive or hinder the acceptance of AAL and their underlying relationships. These insights can be leveraged to improve AAL conceptualization and development and increase the likelihood of future acceptance by the intended user groups.

2.4.3 LARGE-SCALE QUANTITATIVE AND EVIDENCE-BASED RESEARCH AND THEORETICAL DISCOURSE

Although many AAL studies claim that these technologies have a great potential for supporting older adults to age healthy and independently, the actual clinical evidence for this claims is relatively weak.

In 2008, Demiris and Hensel found no studies that presented positive evidence for the influence of AAL technologies on health outcomes, emergency care or in preventing nursing home placement. Liu et al. (2016) found a few studies with positive clinical evidence for monitoring ADL, cognitive decline, mental health, and heart conditions, and mixed evidence for COPD management. The researchers did not find any study with evidence for disability prediction, health-related quality of life, or fall prevention. Robinson et al. (2014) concluded that assistive robots need more trials in real-life home settings to prove that they fit in the daily life of older adults and offer effective support.

At the moment, the prominent methodological approach to measure user acceptance is qualitative rather than quantitative and sample sizes are usually small. To understand the relative importance of acceptance factors, identify their underlying relationships and make statistically grounded and externally valid inferences about their influence in the acceptance process, more large-scale quantitative research is needed (Liu et al., 2016; Peek et al., 2014). A related concern is that AAL research is rather rich in data but poor in theory (Blackman et al., 2016). This is confirmed by Liu et al. (2016), who found that none of the studies investigating user acceptance used a theoretical framework to explain and underpin their findings. Developing a theoretical discourse could help AAL researchers to understand the underlying social, psychological, and behavioral mechanisms of the acceptance process.

Overall, one can conclude that there is a lack of robust methodological approaches, such as randomized control trials, longitudinal designs, large-scale quantitative designs and theory-driven approaches, to provide profound understanding of the user acceptance and solid proof for the effectiveness of AAL (Martin, Kelly, Kernohan, McCreight, & Nugent, 2008; Morris et al., 2013; Peek et al., 2014).

This dissertation will address some of the challenges described above by (1) focusing on the user; (2) identifying potential drivers and barriers for AAL acceptance; (3) developing a theoretical understanding of the underlying social, psychological, and behavioral mechanisms in the acceptance process; (4) model the underlying relationships between acceptance factors and (5) deploying a large-scale quantitative survey to test and validate these factors and make statistically grounded inferences about their relative importance. In extension, these insights will contribute to the development of a theoretical discourse in the AAL field that provides guidance to developers and policy makers to improve AAL designs, recognize and address ethical dilemmas, and explore and establish structured regulations.

PART II

Exploring Potential Acceptance Factors

3
Exploring Potential Acceptance Factors of Ambient Assisted Living: A Literature Review

Parts of this chapter have been previously published in:

Jaschinski, C., & Ben Allouch, S. (2015).
An Extended View on Benefits and Barriers of Ambient Assisted Living Solutions.
International Journal on Advances in Life Sciences, 7(1&2), 40-53.

The previous chapter provided a definition of AAL, its various application domains as well as its key technologies and techniques. It also became clear that user acceptance is still a major challenge in AAL research and one of the big hurdles to the diffusion of AAL systems in real-life settings. In a first step to address this challenge, we conducted a literature review to get an understanding of the current knowledge regarding potential acceptance factors of AAL technologies. Together with Chapter 4, this chapter addresses the second research question of this dissertation (RQ 2):

> *Which factors do older adults and their caregivers perceive as drivers and barriers towards the acceptance of AAL technologies?*

3.1 BACKGROUND AND AIM

Technology acceptance is a complex phenomenon with many personal, social, technological and other contextual factors to consider. At the time this doctoral research started (June, 2013), AAL studies focusing on user acceptance were still scarce. Moreover, these studies were usually centered on specific AAL applications and involved a limited number of users. This literature review intends to accumulate and compare the results from these studies to achieve some consensus about important drivers and barriers towards AAL acceptance.

In this review, the focus is on older adults who still live independently. Besides merely identifying the factors which are important in the acceptance process, this literature review will also give a clearer understanding of the underlying aspects, meanings and perceptions associated with these factor. Thus, this study provides part of the groundwork for the development of a theoretical framework for explaining AAL acceptance (Chapter 5) as well as for the development of quantitative measurements (Chapter 6).

3.2 METHODOLOGICAL APPROACH

3.2.1 SEARCH STRATEGY

Based on the research question specified above, the databases Scopus and Google Scholar were searched. We used various combinations and variations of the following group of keywords:

- ‘older adult’, ‘senior’, ‘elderly’, ‘aging’,
- ‘independent’, ‘autonomous’, ‘aging in place’, ‘in-home’
- ‘assistive technology’, ‘assisted living’ ‘ambient assisted living’, ‘ambient intelligence’ ‘gerontechnology’, ‘smart home’, ‘robotics’, ‘monitoring’ ‘sensors’
- ‘acceptance’, ‘adoption’, ‘use’, ‘perception’, ‘experience’, ‘need’

Additional eligible studies were found by scanning through the references of the identified studies (snowballing). After the initial screening of titles and abstracts, we included (n = 22) papers applying the following inclusion criteria:

- peer-reviewed and English language
- published between 2000 - 2014
- qualitative approach, quantitative approach or mixed-method approach
- focus on factors that influence the acceptance of AAL technologies among older adults
- primary participants are older adults[2] who still live independently, including assisted living facilities[3]. Secondary participants can be informal or formal caregivers

Studies were excluded if they had a primary focus on describing and testing technical aspects of AAL rather than assessing user acceptance. Other studies were excluded because participants were living in nursing homes or because older adults were not included in the sample. In two manuscripts (Cornejo et al., 2013; Heerink, Kröse, Evers, & Wielinga, 2010), some of the reported sub-studies met the inclusion criteria, while other sub-studies did not (i.e. involving participants from nursing homes).
For these manuscripts, we only included the findings from the sub-studies that met the inclusion criteria.

[2] As we were also interested in the perceptions of the future generation of older adults, we did not apply a strict lower age limit, as long as the respective study also involved adults above the age of 60.

[3] It was decided to include the study of Demiris et al. (2004), although it was unclear in which part of the continuing care retirement facility (independent living, assisted living, skilled nursing facility) participants were residing. As most statements referred to the home environment, we inferred that participants were mainly residing in the independent living or assisted living part of the facility.

3.2.2 DATA EXTRACTION AND ANALYSIS

Data extraction focused on potential acceptance factors in terms of perceived drivers and barriers of AAL acceptance.
As qualitative data offer richer descriptions of acceptance factors, we first analyzed studies with qualitative and mixed-method approaches. Thematic synthesis was applied to group the extracted data and identify overarching themes of drivers and barriers (Thomas & Harden, 2008). The thematic synthesis approach of Thomas and Harden (2008) draws on the principles of traditional qualitative data analysis and involves three stages of coding: (1) free coding, (2) grouping into descriptive themes, and (3) development of analytical themes. During the data analysis, our approach was mainly inductive, meaning that the initial codes were data-driven. However, partial deduction occurred due to the research question (categorizing data in terms of drivers and barriers), the researcher's existing theoretical knowledge on technology acceptance, and inferences and interpretations by the authors of the reviewed studies, which could not be completely ignored.

In the quantitative studies, the statistical evidence for the factors identified from the qualitative studies was investigated. We also looked at the descriptions and definitions of the measurements and the wording and content of the items (if available).

To understand and compare the context of the studies included in the sample, we also extracted data about the studied AAL application, participants' characteristics (age, gender, health status, living situation, caregivers involved), sample size, test country and applied methodology (see Appendix 3A).

3.3 RESULTS

3.3.1 CHARACTERISTICS OF THE SELECTED STUDIES

The studies in the sample examined different AAL applications (or a combination of applications) such as smart home technology (in-home monitoring) (n = 13), mobile and wearable technology (n = 2), social service robot (n = 3), robotic mobility aid (n = 1), robotic mobile presence system (n = 1), social network and communication system (n = 4), ambient awareness system (n = 3) or the general concept of AAL (n = 3).
The sample size in these studies ranged from 1 – 1518 participants. Participants' health status varied across studies. Several studies (n = 9) also included the perspective of informal caregivers and formal caregivers. While some studies investigated the technology in a conceptual phase, some technologies (mostly prototypes) were tested in the field. The majority of studies applied a qualitative approach (n = 12), five studies had a mixed-method approach and another five studies had a quantitative approach.
The selected studies were conducted in the US (n = 10), Europe (n = 9), Australia (n = 1), Canada (n = 1) and Mexico (n = 1). For a detailed description of the characteristics of the selected studies see Appendix 3A.

3.3.2 PERCEIVED DRIVERS OF AAL ACCEPTANCE

The data analysis revealed eight themes that were categorized as potential benefits and thus as drivers of AAL acceptance. Table 3.1 shows an overview of these themes and the frequency of their occurrence in the reviewed studies (i.e., total number of studies in which the respective theme occurred).

HEALTH AND SAFETY

Health and safety were perceived as important benefits of AAL technologies in the reviewed studies. Immediate response to emergencies (e.g., Van Hoof, Kort, Rutten, & Duijnstee, 2011; Wild, Boise, Lundell, & Foucek, 2008), detecting and preventing falls or other emergencies (e.g., Mahmood, Yamamoto, Lee, & Steggell, 2008; Sixsmith, 2000), and monitoring physiological parameters (e.g., Demiris et al., 2004; Steele et al., 2009) were regarded as highly valuable features of AAL technologies. Other valued features included property security (e.g., Demiris et al., 2004) and detection of other safety hazards like gas leaks or fire (e.g., van Hoof et al., 2011). Participants reported that sensor-based AAL technologies have the advantage of automatically responding to emergencies.
In contrast, traditional push-alarms do not work if they are out of reach, if the person in need is unable to push the button, or if the person forgets to wear it (e.g., Steele et al., 2009; Van Hoof et al., 2011). Another reported advantage was the possibility of around-the-clock monitoring that cannot be achieved with the occasional check-ins by human caregivers (Steele et al., 2009). By continuously monitoring the older adult's activities, gradual changes in health status like cognitive decline can be detected early on (Wild et al., 2008). Another study mentioned the timely assessment of adverse drug events as perceived advantage of continuous monitoring (Demiris et al., 2004). Other valued features of AAL included health management tools such as fitness tracking, medication management, and easy communication with health-care providers (Joe, Chaudhuri, Chung, Thompson, & Demiris, 2014). Overall, participants from the reviewed studies perceived that AAL technology could benefit their health, and provide them with an increased feeling of

Table 3.1 Overview of the Themes Categorized as Drivers of AAL Acceptance

DRIVERS OF AAL ACCEPTANCE	OCCURRENCE IN SAMPLE (n = 22) n (%)	REFERENCES (SEE APPENDIX 3A)
health and safety	18 (82)	1, 2, 3, 4, 6, 7, 8, 9, 13, 14, 15, 16, 17, 19, 20, 22, 25, 26
support and unburden caregivers and provide peace of mind	8 (36)	4, 6, 7, 8, 11, 13, 19, 20
social connectedness	8 (36)	4, 8, 11, 12, 16, 19, 21, 26
independent living and aging in place	7 (32)	1, 4, 6, 7, 13, 17, 20
enjoyment and leisure	6 (27)	9, 11, 12, 19, 20, 26
support with daily activities	5 (23)	2, 9, 16, 20, 26
self-confidence and status	2 (9)	15, 19
education and information	2 (9)	11, 20

safety and assurance. The health and safety benefits often superseded concerns about privacy and intrusiveness (e.g., Steele et al., 2009; Van Hoof et al., 2011; Wild et al., 2008).

SUPPORT AND UNBURDEN CAREGIVERS AND PROVIDE PEACE OF MIND

Both older adults and caregivers themselves perceived AAL technologies as good tools for support and for reducing the overall burden on caregivers. It was mentioned that AAL technologies could take over some responsibilities that would be usually performed by a caregiver, such as providing reminders for medication intake (Joe et al., 2014). Besides the physical support, AAL technologies were also perceived as tools for emotional support by enabling caregivers to check on the older adult from distance, giving them the assurance that the older adult is continuously looked after, and knowing that emergency situations are immediately picked up (e.g., Rowan & Mynatt, 2005; Sixsmith, 2000). Older adults also appreciated that AAL technologies could reduce the concerns of their family members and provide them with peace of mind, especially family members who were living at distance (Rowan & Mynatt, 2005; Wild et al., 2008). One study also underlined that monitoring data could help formal and informal caregivers in gaining a timely, objective and more holistic understanding of the older adult's well-being, compared to self-reported accounts or occasional check-ups that might not accurately reflect the actual well-being of an older adult (Wild et al., 2008).

SOCIAL CONNECTEDNESS

Another benefit of AAL technologies that resulted from the literature review concerns the older adult's social connectedness. Social connectedness has been described as a key element of a good quality of life (Bowling et al., 2003; Gabriel & Bowling, 2004) and successful aging (Bouma et al., 2007). Several of the reviewed studies demonstrated that AAL technologies can help older adults to feel closer to family members and combat social isolation and loneliness (Cornejo et al., 2013; Lorenzen Huber et al., 2012; Rowan & Mynatt, 2005). The field trial of the Digital Family Portrait project revealed that the female participant felt less lonely, knowing a family member was watching over her (Rowan & Mynatt, 2005). Lorenzen Huber et al. (2012) explored a reciprocal monitoring system in which older adults are equal actors in the information exchange rather than just passive subjects to monitoring. Their results showed that the tested technology gave both older adults and their family members, "windows into each other's daily lives" (p. 450) and provided new topics of communication, while eliminating typical caregiving questions. Similar findings were reported by Cornejo et al. (2013). AAL technologies can also provide opportunities to connect with peers. In the Building Bridges project participants met fellow seniors via online calls and chat to discuss a broadcast they had listened to. Participants stated that they were very keen to arrange real-life meetings and get to know their conversations partners (Wherton & Prendergast, 2009).

In contrast, Steele et al. (2009) found that their older adult participants strongly rejected the suggestion to incorporate social features in an assisted living technology. Similarly, Van Hoof et al. (2011) found that the video telephony feature in the tested system was hardly used and did not improve participants' social contacts or feeling of loneliness. In the study of Joe et al. (2014), social technology features like 'communicate via social network' and 'communicate with family and friends' were ranked as uninteresting or unwanted by the majority of participants.

INDEPENDENCE AND AGING IN PLACE

Independence and aging in place were perceived as essential benefits of AAL technologies. Several studies found that independence and aging in place was of utmost importance to older adults, and technologies that can facilitate independent living were therefore perceived as beneficial (e.g., Beringer, Sixsmith, Campo, Brown, & McCloskey, 2011; Steele et al., 2009; Van Hoof et al., 2011; Wild et al., 2008). Many older adults are attached to their own homes because of their possessions, past memories and the familiar neighborhood (Van Hoof et al., 2011). Consequently, they often had a negative view on nursing homes and regarded them as a last resort (Steele et al., 2009; Van Hoof et al., 2011).

ENJOYMENT AND LEISURE

Enjoyment and leisure were also regarded as benefits of AAL technologies. Several older adults reported to have fun when interacting with the tested technologies (Lorenzen Huber et al., 2012; Wherton & Prendergast, 2009). Heerink et al. (2010) found older adults' perceived enjoyment to predict the intention to use a robot. Participants also recognized that AAL technologies could stimulate leisure activities. For example, in the study of Beer and Takayama (2011) older adults suggested to use the tested robotic mobile presence system to attend concerts or sport events from the comfort of their own home. Similarly, Joe et al. (2014) found that entertainment features such as 'watching classic movies' were appreciated by several participants.

SUPPORT WITH DAILY ACTIVITIES

With older age physical, cognitive and sensory impairments increase (Craik, 1994; Maki & McIlroy, 2006; Massion, 1994; Schieber, 2003). AAL technologies are envisioned to help older adults to compensate for these deficits and help them with their daily activities. Indeed, Smarr et al. (2014) found that older adults valued the assistance of a robot in helping them with chores such as cleaning, fetching objects and reminders. With these tasks robotic assistance was even preferred over human assistance. Similarly, Demiris et al. (2004) found that older adults viewed assistance with impairments and a reminder function as potential advantages of AAL technologies. This was also confirmed by Joe et al. (2014), who's participants were enthusiastic about support with various tasks and reminders.

SELF-CONFIDENCE AND STATUS

The literature review showed that AAL technology could increase older adults' self-confidence by providing a feeling of mastery (Bright & Coventry, 2013) and even serve as a status symbol (Lorenzen Huber et al., 2012). However, self-confidence and status were not very prominent benefits and only appeared as a theme in two of the reviewed studies.

EDUCATION AND INFORMATION

Opposed to common stereotypes, older adults are still capable of learning new things and are often still active and productive (Ory, Hoffman, Hawkins, Sanner, & Mockenhaupt, 2003). This was confirmed by the results of the literature review. In the Building Bridges Project participants were very excited about the educational element of the tested communication application (Wherton & Prendergast, 2009). Similarly, Joe et al. (2014) found that older adults wanted the tested AAL technology to include features like 'learning something new' and 'keeping up with the news'. However, 'education and information' was not a very prevalent theme and only emerged from two of the reviewed studies.

3.3.3 PERCEIVED BARRIERS OF AAL ACCEPTANCE

Besides benefits, the literature review revealed several barriers that could interfere with the successful adoption and use of AAL tech-nologies. Table 3.2 shows an overview of the nine themes that were categorized as barriers of AAL acceptance.

PRIVACY, INTRUSIVENESS AND CONTROL

Concerns about privacy, data security and possible intrusion were perceived as important barriers towards the acceptance of AAL technologies. Several older adults were reluctant to the monitoring aspect of AAL technologies as it felt like surveillance to them. They did not like the feeling of being watched and sharing their daily routine with others, including family members (Beringer et al., 2011; Kanis et al., 2011; Marquis-Faulkes & McKenna, 2003). Participants strongly rejected the use of cameras (e.g., Demiris et al., 2004; Marquis-Faulkes & McKenna, 2003). Indeed, in the survey of Beach et al. (2009), motion sensors were rated more acceptable than video recordings. Moreover, older adults worried that their personal information could get in the wrong hands and be misused, for example by health insurers (Boise et al., 2013; Joe et al., 2014). In contrast, some researchers found that privacy was just a minor concern to most of their older adult participants (e.g., Steele et al., 2009; Van Hoof et al., 2011;
Wild et al., 2008). These participants regarded some loss of their privacy as a valid trade-off for their safety, independence and health. Another reason could be the lack of awareness of potential security risks (Boise et al., 2013; Steele et al., 2009). Lorenzen Huber et al. (2012) and Boise et al. (2013) found that privacy concerns can change over time and might arise only after active exposure and interaction with the technology. Privacy concerns also depend on the recipient of the monitoring data and the types of data that are shared (Beach et al., 2009; Lorenzen Huber et al., 2012).

Table 3.2 Overview of the Themes Categorized as Barriers of AAL Acceptance

BARRIERS OF AAL ACCEPTANCE	OCCURRENCE IN SAMPLE (n = 22) n (%)	REFERENCES (SEE APPENDIX 3A)
privacy, intrusiveness and control	16 (73)	1, 2, 3, 6, 7, 8, 11, 13, 14, 17, 18, 19, 20, 22, 25, 26
loss of human touch	10 (45)	1, 2, 7, 9, 11, 13, 19, 20, 22, 26
self-efficacy, technology experience and usability	9 (41)	1, 2, 6, 11, 12, 13, 18, 20, 25
absence of perceived need and perceived value	8 (36)	1, 2, 7, 11, 12, 13, 15, 25
financial cost	6 (27)	1, 2, 6, 13, 25, 26
social stigma and pride	5 (23)	1, 2, 7, 15, 22
reliability and trust in technology	5 (23)	1, 2, 6, 13, 22
health concerns	2 (9)	1, 17
burden caregivers	2 (9)	4, 7

In addition, older adults felt that AAL could interfere with their normal routine and behavior (Beringer et al., 2011; Wherton & Prendergast, 2009). For example, participants in the study of Beringer et al. (2011) worried about having to dress up and keeping their house tidy for video calls. Another concern was that family caregivers could patronize them and interfere with decisions that should be theirs to make (Steele et al., 2009) Moreover, older adults were concerned that technologies would be too visible in their home environment and could cause clutter and disturbance (Van Hoof et al., 2011). Indeed, some participants in the study by Van Hoof et al. (2011) complained about visible cables, annoying sounds and interference with other devices, such as the TV. However, in other studies AAL technology was not perceived as disturbing or intrusive (Cesta et al., 2007; Sixsmith, 2000).

Most older adults wanted to have some level of control over the AAL technology, e.g., turn it off manually or control which data are shared (Steele et al., 2009; Ziefle & Röcker, 2010). On the other hand, some older adults argued that a monitoring system cannot assure safety, unless it is switched on all the time. Emergencies could happen while the system is switched off or after users forget to switch it back on (Steele et al., 2009). According to Demiris et al (2004) a low level of user-control and active user interaction would also be more suitable for people who are not very confident in their use of technologies.

LOSS OF HUMAN TOUCH

According to the literature review, the loss of human touch is also a matter of concern to the older adult target group (Beer & Takayama, 2011; Demiris et al., 2004; Marquis-Faulkes & McKenna, 2003; Sixsmith, 2000). Participants thought that AAL technologies cannot and should not replace human assistance and human interaction, but should be used as a supplement to human care (Demiris et al., 2004; Marquis-Faulkes & McKenna, 2003; Wherton & Prendergast, 2009). Indeed, Smarr et al. (2014) revealed that, although robot assistance is accepted for certain tasks, human assistance is preferred for personal care tasks (e.g., wash hair), leisure activities (e.g., entertaining guests) and most health-related tasks (decide which medication to take). Similarly, Joe et al. (2014) found that their participants preferred in-person communication with their physician over technology mediated contact. In contrast, the study of Lorenzen Huber et al. (2012) showed that, despite earlier concerns about monitoring technologies reducing the contact with family caregivers during pilot studies, the quality and quantity of communication actually improved during the field trial with the technology. However, this does not change the fact that older adults are concerned about technology replacing human care.

SELF-EFFICACY, TECHNOLOGY EXPERIENCE AND USABILITY

Several older adults were apprehensive towards technology and worried about their abilities concerning technology use.
They feared that AAL technologies would be

difficult to use and not be adapted to their specific needs (Demiris et al., 2004; Joe et al., 2014; Steele et al., 2009). Making mistakes when interacting with the technology was one of their concerns (Steele et al., 2009). This perception was often routed in earlier negative experiences with technology.
Three of the quantitative studies underlined the importance of ease of use regarding the acceptance of AAL (Beach et al., 2009; Heerink et al., 2010; Ziefle & Röcker, 2010). Moreover, several field studies encountered usability problems when participants interacted with the tested technology (e.g., Van Hoof et al., 2011; Wherton & Prendergast, 2009). Furthermore, Sixsmith (2000) and Steele et al. (2009) noticed that limited understanding of technologies can lead to unrealistic high expectations or misconception about AAL technologies. Therefore, several authors note that besides good usability, training and technical support are crucial for the acceptance and implementation of AAL technologies (Beer & Takayama, 2011; Demiris et al., 2004; Steele et al., 2009).

ABSENCE OF PERCEIVED NEED AND PERCEIVED VALUE

The literature review showed that the absence of subjective need and perceived value formed a major barrier towards AAL acceptance (e.g., Sixsmith, 2000; Steele et al., 2009; Wild et al., 2008). Several older adults in the reviewed studies did not feel the immediate need to use AAL technologies or did not see a lot of added value in AAL for themselves. The subjective need and perceived value of AAL technologies seem to be influenced by several contextual and personal factors, such as living situation, available care and social provision, and subjective health and well-being. Wild et al. (2008) concluded that many older adults seem to struggle to imagine future deterioration, when they might benefit from features such as monitoring. Others simply do not want to admit the need for assistive technology (Bright & Coventry, 2013). Furthermore, many older adults might not fully understand the additional benefits AAL can provide (Steele et al., 2009). Two of the quantitative studies confirmed that meeting the user's needs (Beach et al., 2009) and the perceived usefulness (Heerink et al., 2010) were important factors for the acceptance.

FINANCIAL COST

Another barrier concerns the cost of AAL technologies. In the reviewed studies, several older adults stated that, due to their limited income, such systems would not be affordable to them (Beer & Takayama, 2011; Demiris et al., 2004; Sixsmith, 2000; Steele et al., 2009). Even if they could afford them, some older adults were not willing to spend a lot of money on AAL technologies (Sixsmith, 2000; Steele et al., 2009). Participants also mentioned that AAL should be paid for by their children or subsidized by the government (Steele et al., 2009).

SOCIAL STIGMA AND PRIDE

The literature review revealed that the fear of social stigma and pride was also a potential barrier towards the acceptance of AAL technologies. Many older adults were hesitant to use technologies that draw attention to the fact that they are aging and need assistance, as these could stigmatize them as frail or dependent (Bright & Coventry, 2013; Demiris et al., 2004; Steele et al., 2009). Pride and embarrassment were often the reasons for being hesitant towards assistive devices (Bright & Coventry, 2013; Steele et al., 2009; Wild et al., 2008). Consequently, older adults wanted AAL technologies to be as discreet and unobtrusive as possible (Marquis-Faulkes & McKenna, 2003; Steele et al., 2009).

RELIABILITY AND TRUST IN TECHNOLOGY

Many older adults worried about the reliability of AAL technologies and questioned their ability to ensure the health and safety of the user (Marquis-Faulkes & McKenna, 2003; Steele et al., 2009). Participants worried about interruptions in energy supply (Steele et al., 2009), the occurrence of false alarms, or that the system would overlook emergency situations (Marquis-Faulkes & McKenna, 2003; Sixsmith, 2000) Indeed, several studies reported false emergency alarms during the field trials of their monitoring systems (Sixsmith, 2000; Van Hoof et al., 2011). While some participants were annoyed by these false alarms, other participants perceived false alarms as a reassurance that the systems is running and functioning (Rowan & Mynatt, 2005; Van Hoof et al., 2011).

HEALTH CONCERNS

While health and safety were perceived as major benefits of AAL, a few participants in the study of Steele et al. (2009) also had health-related concerns. They worried that the electromagnetic radiation of ambient sensors could cause cancer or that an implanted sensor could evoke allergic reactions. Some participants in the study of Beringer et al. (2011) noted that vital sign monitoring could cause the user additional stress.

BURDEN CAREGIVERS

The study of Wild et al. (2008) showed that, although support for caregivers was identified as a potential benefit of AAL technologies by some older adults, others worried that sharing health-related data with family members could cause them additional concern. Participants from the study of Mahmood et al. (2008) therefore preferred to share monitoring data with formal caregivers, instead of burdening family members.

3.3.4 CONTEXTUAL AND PERSONAL FACTORS

The results of the literature review suggest that contextual and personal factors such as age, gender, social-economic status, culture, living situation, available care and social provision, objective health and subjective health as well as health expectations might play a role in the acceptance process. However, the findings concerning the influence of these factors are somewhat inconsistent. For example, the qualitative findings of Wild et al. (2008) suggested that the perceived need and value of AAL might be influenced by the older adult's subjective health. However, Ziefle and Röcker (2010) statistical analysis revealed that subjective health did not influence the willingness to use AAL across different applications. There was some consistency with regard to health status and privacy concerns. Both Beach et al. (2009) and Boise et al. (2013) found that people with better health conditions had more concerns about their privacy. Mahmood et al. (2008) suggested a conceptual model with age as an influencing factor. However, again age showed no significant influence in the study of Ziefle and Röcker (2010) except regarding the importance of ease of use. Due to these inconsistencies, at this stage we cannot make any explicit predictions regarding the role of personal and contextual factors in the acceptance process.

3.3.5 OTHER FINDINGS

Many of the reviewed studies reported that, in general, older adults were receptive to the idea of AAL technologies and had a positive overall attitude towards them (e.g. Beer & Takayama, 2011; Demiris et al., 2004; Smarr et al., 2014; Steele et al., 2009; Wild et al., 2008). Moreover, the fact that several studies involved caregivers, even when they were not the primary users, suggests that caregivers might influence the acceptance process.

Finally, the composition of the literature sample confirms that there is still a lack of large-scale, quantitative approaches with representative samples that investigate AAL acceptance.

3.4 CONCLUSION

In the search of potential acceptance factors of AAL technologies, this literature review identified eight drivers and nine barriers towards AAL acceptance. The most prevalent drivers are health and safety; support and unburden caregivers and provide peace of mind; social connectedness; and independent living and aging in place. The most prevalent barriers include privacy, intrusiveness and control; loss of human touch; self-efficacy, technology experience and usability; and absence of perceived need and perceived value. A schematic overview of our results can be found in figure 3.1.

During our work on the current literature review, we came across a systematic review with a similar research focus (Peek et al., 2014). Most of the identified drivers and barriers, i.e., safety; independent living; support and unburden caregivers; privacy, intrusiveness and control; absence of perceived need; education and information usability; technology experience; social stigma; reliability and trust in technology; financial cost; burden caregivers and health concerns were confirmed by the work of these authors. This further validates our own findings. Similar to our study, several personal and contextual factors were identified such as subjective health, social provision and culture. Peek et al. (2014) also suggest that caregivers have an important influence in the acceptance process.

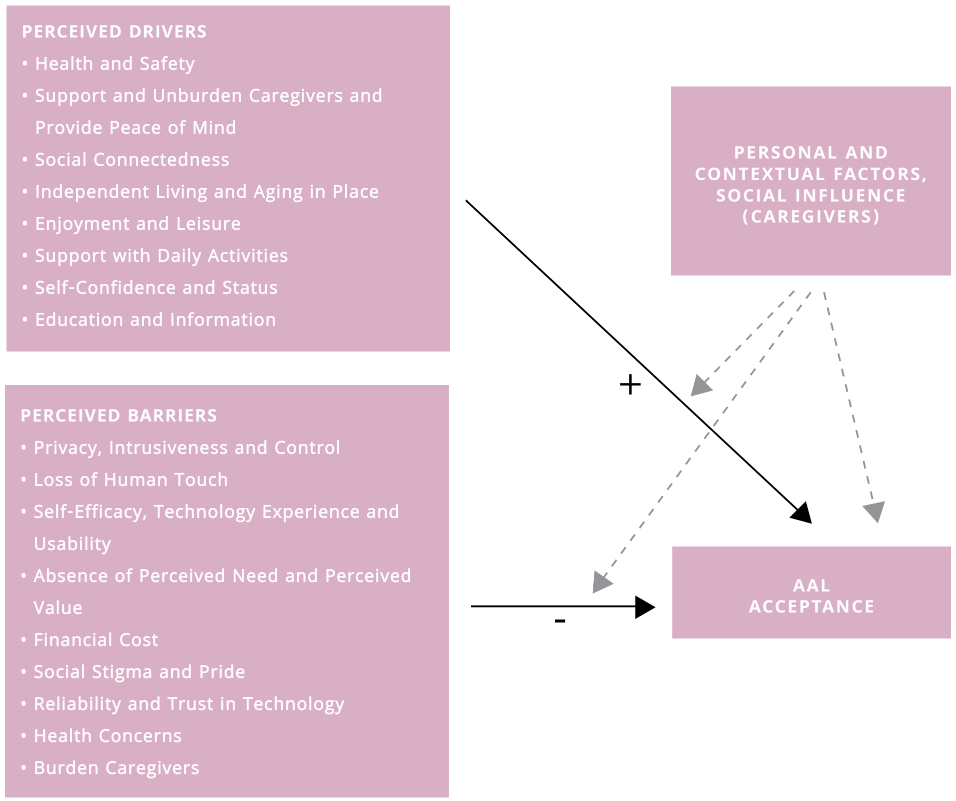

Figure 3.1. Schematic overview of the results of the literature review

3.5 SHORT DISCUSSION

This literature review is not without weaknesses. Due to practical limitations, we did not follow a strictly systematic approach. Therefore, no formal quality assessment of the reviewed literature was performed, except for only accepting peer-reviewed studies. Moreover, by limiting the search to two databases, relevant studies might have been missed. Furthermore, the selection and analysis of the literature was performed by a single researcher. Therefore, parts of the selection process and data analysis might have been susceptible to bias due to the researcher's personal judgment and views (Grant & Booth, 2009). Finally, as with most reviews, we did not have access to the original data and reported results have already been subject to a filtering and judgment process of the original authors. This could have influenced our own interpretations, especially with regard to the qualitative studies. Therefore, the next chapter will attempt to further validate the identified factors within our own user studies.

Despite these limitations, we believe that this review identifies relevant drivers and barriers for the acceptance of AAL technologies. The current findings have been reinforced by a systematic review with a similar research focus that has been published while we were working on our own review.

Appendix 3A Sample Characteristics

REFERENCE NUMBER AND AUTHORS	AAL CATEGORY	PARTICIPANT CHARACTERISTICS						TEST COUNTRY	APPLIED METHOD
		NUMBER	AGE	GENDER	HEALTH STATUS	LIVING SITUATION	CAREGIVERS INVOLVED		
1 (Steele et al., 2009)	smart home technology (in-home monitoring) wearable and in-vivo technology	*n* = 13	65+	6 males 7 females	n/a	independently	no	AUS	**qualitative:** focus groups
2 (Demiris et al., 2004)	general concept of AAL	*n* = 15	65+	7 males 8 females	n/a	independently and assisted living	no	US	**qualitative:** focus groups
3 (Boise et al., 2013)	smart home technology (in-home monitoring)	*n* = 119	80+ *M* = 83	22% males 78% females	average or better health *n* = 92 with normal cognitive function *n* = 27 with mild cognitive impairment	independently	no	US	**quantitative:** survey
4 (Mahmood et al., 2008)	smart home technology (in-home monitoring) and communication application	*n* = 9	70+	2 males 7 females	normal cognitive function	assisted living	no	US	**qualitative:** focus group

REFERENCE NUMBER AND AUTHORS	AAL CATEGORY	PARTICIPANT CHARACTERISTICS						TEST COUNTRY	APPLIED METHOD
		NUMBER	AGE	GENDER	HEALTH STATUS	LIVING SITUATION	CAREGIVERS INVOLVED		
6 (Van Hoof et al., 2011)	smart home technology (in-home monitoring)	*n* = 18	63+	4 males 14 females	*n* = 7 cope with mild to moderate psychogeriatric health problems (incl. dementia) other respondents have (severe) somatic health problems	independently and assisted living	informal caregivers	NL	**qualitative:** field trial with observations and interviews
7 (Wild et al., 2008)	smart home technology (in-home monitoring)	*n* = 23	66-91 *M* = 80.6	n/a	stable health, no signs of dementia	independently	*n* = 16 informal caregivers	US	**mixed-method:** focus groups and card sorting
8 (Rowan & Mynatt, 2005)	smart home technology (in-home monitoring) and ambient awareness	*n* = 1	76	1 female	good health	independently	*n* = 1 informal caregivers	US	**qualitative:** field trial with interviews, diaries
9 (Smarr et al., 2014)	social service robot	*n* = 21	65 - 93 *M* = 80.25	6 males 15 females	*M* = 3.09, where 1 = poor 3 = good 5 = excellent	independently	no	US	**mixed-method:** focus group and questionnaires

REFERENCE NUMBER AND AUTHORS	AAL CATEGORY	PARTICIPANT CHARACTERISTICS						TEST COUNTRY	APPLIED METHOD
		NUMBER	AGE	GENDER	HEALTH STATUS	LIVING SITUATION	CAREGIVERS INVOLVED		
11 (Wherton & Prendergast, 2009)	social network / communication application	focus groups: n/a think aloud: n/a field trial: *n* = 15	focus groups: n/a think aloud: n/a field trial: 60+	n/a	**n/a**	n/a	n/a	IE	**qualitative:** focus groups think aloud field trials with interviews
12[4] (Heerink et al., 2010)	social service robot	exp. 1: *n* = 40 exp. 2: *n* = 88 exp. 4: *n* = 30	exp. 1: 65-89 exp. 2: n/a exp. 4: 65-89	exp. 1: 18 males 22 females exp. 2: 28 males 60 females exp. 4: 16 males 14 females	n/a	n/a	n/a	NL	**quantitative:** 3 experiments with questionnaires
13 (Sixsmith, 2000)	smart home technology (in-home monitoring)	focus groups: *n* = 28 (incl. caregivers) field trial: *n* = 22 (older adults)	60-85+	equal gender distribution (field trial)	*n* = 8 significant health problems *n* = 9 minor health problems (field trial)	assisted living	informal caregivers formal caregivers	UK	**mixed-method:** focus groups and field trial with interviews and questionnaires
14 (Kanis et al., 2011)	smart home technology (in-home monitoring)	*n* = 6	n/a	n/a	some participants had partial physical or cognitive impairments	assisted living	no	NL	**mixed-method:** participatory design activities, interviews, questionnaires

[4] One of the experiments was not included for further analysis as it did not meet the inclusion criteria.

REFERENCE NUMBER AND AUTHORS	AAL CATEGORY	PARTICIPANT CHARACTERISTICS						TEST COUNTRY	APPLIED METHOD
		NUMBER	AGE	GENDER	HEALTH STATUS	LIVING SITUATION	CAREGIVERS INVOLVED		
15 (Bright & Coventry, 2013)	robotic mobility aid	focus groups: *n* = 19 observation & interviews *n* = 6	focus groups: 67 - 86 observation & interviews 71 - 86	n/a	focus groups: 2/3 mobility problems observation & interviews: ranging from completely mobile, to using a rollator or needing personal assistance	n/a	n/a focus groups: *n* = 7 informal caregivers	UK	**qualitative:** focus groups, observation and interviews
16 (Cesta et al., 2007)	smart home technology (in-home monitoring) and social service robot	*n* = 40	56 - 88 *M* = 70.3	13 males 27 females	n/a	n/a	no	IT	**quantitative:** experiment with questionnaire
17 (Beringer et al., 2011)	smart home technology (in-home monitoring)	*n* = 12	61 - 95 *M* = 75.6	3 males 9 females	excellent: 3 very good: 3 good: 2 fair: 4 poor: 0	n/a	no	CA	**qualitative:** interviews
18 (Ziefle & Röcker, 2010)	smart home technology (in-home monitoring) and mobile/wearable technology	group 1: *n* = 7 group 2: *n* = 35 group 3: *n* = 40	group 1: 40 - 50, *M* = 45.5 group 2: 51 - 65, *M* = 58.6 group 3: 66 - 92, *M* = 74.1	group 1: 45% males 55% females group 2: 43% males 57% females group 3: 45% males 55% females	*n* = 39 suffer chronic diseases	n/a	no	DE	**quantitative:** questionnaire

REFERENCE NUMBER AND AUTHORS	AAL CATEGORY	PARTICIPANT CHARACTERISTICS						TEST COUNTRY	APPLIED METHOD
		NUMBER	AGE	GENDER	HEALTH STATUS	LIVING SITUATION	CAREGIVERS INVOLVED		
19 (Lorenzen Huber et al., 2012)	smart home technology (in-home monitoring (reciprocal)) and ambient awareness	*n* = 6	73-86 M = 82.17	6 females	good to excellent	assisted living	*n* = 4 informal caregivers	US	**mixed-method:** field trial with data logs and interviews
20 (Joe et al., 2014)	general concept of AAL (multifunctional wellness tool)	*n* = 14	62	6 males 8 females	n/a	assisted living	no	US	**mixed-method:** focus groups and questionnaire
21[5] (Cornejo et al., 2013)	social network application and ambient awareness	*n* = 1	88+	1 female	n/a	indepen-dently with daughter	*n* = 8 informal caregivers	MX	**qualitative:** field trial with interviews
22 (Marquis- Faulkes & McKenna, 2003)	smart home technology (in-home monitoring)	3 groups with *n* = 7-15	n/a	n/a	some studies included healthy older adults, while others included participants with neurological deficits	n/a	*n* = formal caregivers	UK	**qualitative:** focus groups with scenario based drama
25 (Beach et al., 2009)	general concept of AAL	group 1: *n* = 762 group 2: *n* = 756	group 1: 45-64 group 2: 65+	499 males 1019 females	both disabled and non-disabled	n/a	no	US	**quantitative:** survey
26 (Beer & Takayama, 2011)	robotic mobile presence system	*n* = 12	63-88	5 males 7 females	excellent:17% very good: 33% good: 42% fair: 8% poor: 0%	indepen-dently	no	US	**qualitative:** experiment with interviews

[5] The pilot study was not included for analysis as it did not meet the inclusion criteria.

4 Why Should I Use This?

PERCEPTIONS OF OLDER ADULTS AND THEIR CAREGIVERS TOWARDS AMBIENT ASSISTED LIVING TECHNOLOGIES

Parts of this chapter have been previously published in:

Jaschinski, C., & Ben Allouch, S. (2014). Ambient Assisted Living: Benefits and Barriers From a User- Centered Perspective. In *AMBIENT 2014, The Fourth International Conference on Ambient Computing, Applications, Services and Technologies* (pp. 56–64).

Jaschinski, C., & Ben Allouch, S. (2015). An Extended View on Benefits and Barriers of Ambient Assisted Living Solutions. *International Journal on Advances in Life Sciences, 7*(1&2), 40-53.

Jaschinski, C., & Ben Allouch, S. (2017). Voices and Views of Informal Caregivers: Investigating Ambient Assisted Living Technologies. In A. Braun, R. Wichert, & A. Maña (Eds.), *Ambient Intelligence. AmI 2017, LNCS* (Vol. 10217, pp. 110–123). Malaga, Spain: Springer International Publishing. http://doi.org/10.1007/978-3-319-56997-0_8

Jaschinski, C., & Ben Allouch, S. (2018). Listening to the ones who care: exploring the perceptions of informal caregivers towards ambient assisted living applications. *Journal of Ambient Intelligence and Humanized Computing,* 1-18. https://doi.org/10.1007/s12652-018-0856-6a

The previous chapter presented a literature review of potential drivers and barriers towards the acceptance of AAL technologies. The current chapter tries to further define and validate these factors within our own user studies. Hence, together with Chapter 3, this chapter further addresses the second research question (RQ 2):

> *Which factors do older adults and their caregivers perceive as drivers and barriers towards the acceptance of AAL technologies?*

The first study (4.1) was conducted within the European research project SONOPA (SOcial Networks for Older adults to Promote and Active life). User groups included older adults from France and the UK and older adults and formal caregivers from Belgium. The second user study (4.2) was conducted with informal caregivers from the Netherlands. Different examples of AAL technologies were used as stimulus material. Finally, the third user study (4.3) was conducted with couples of older adults and informal caregivers. A later iteration of the SONOPA prototype was evaluated within this third user study.
These user studies will contribute to the understanding of the underlying aspects, meanings and perceptions of the potential acceptance factors. Hence, this chapter further contributes to the development of a theoretical framework and the development of quantitative measurements for the different acceptance factors (Chapter 5 and Chapter 6).

4.1 USER STUDY 1

4.1.1 BACKGROUND AND AIM

The first user study was part of the research project SONOPA (http://www.smartsigns.nl/en/sonopa/), which was carried out in the framework of the European AAL Joint Program together with a consortium of research partners, SMEs and end-user organizations.
The aim of the SONOPA project was to empower older adults to age in their own home environment while staying active, safe and socially connected. The envisioned SONOPA system consisted of four major components (see Figure 4.1):

1. A **sensing infrastructur**e with low resolution visual sensors (30 x 30 pixels) (Camilli & Kleihorst, 2011) and passive infrared sensors (PIR) to detect the older adult's location and monitor his/her activities.

2. A simplified **social network environment** that offers different social interaction components like message system, activities and interest groups, video calls and real-time chat.

3. The **controller** that receives and analyses the sensor data and social network data with advanced activity recognition and match-making algorithms.

4. An **intelligent user-interface** that is linked to a web application and offers information and recommendations to the older adult using input from the older adult's activity data, social network activity and an online calendar. Informal caregivers can also push information to the user-interface.
The intelligent user interface is set up as a cloud-based solution that runs on a tablet or a smart TV.

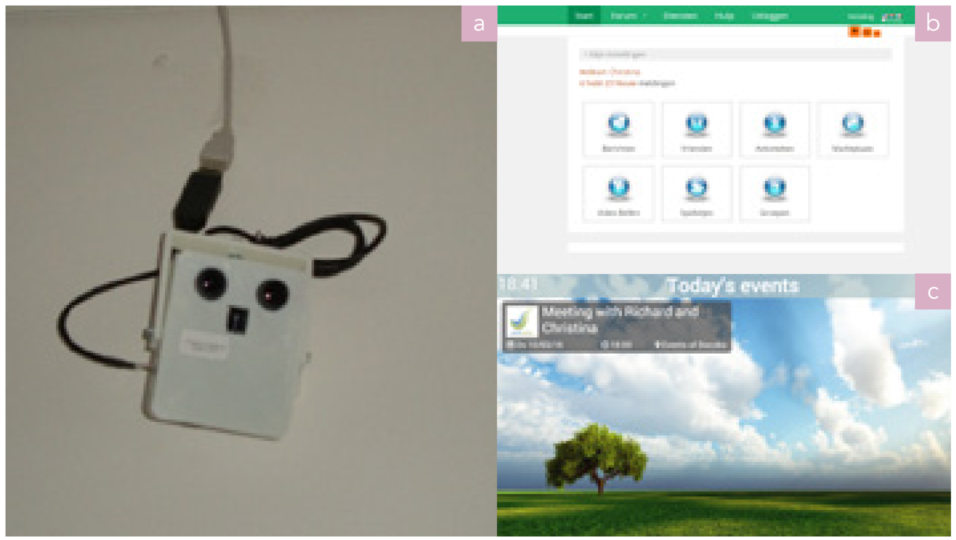

Figure 4.1. Components of the SONOPA system: a) visual sensor, b) social network environment c) intelligent user-interface with calendar information

The first user study aims to explore and specify the user requirements for the envisioned SONOPA technology. Furthermore, this study aims to validate the acceptance factors that were identified from the literature review (Chapter 3) in the context of the envisioned SONOPA system.

4.1.2 METHOD

To elicit user requirements and validate the acceptance factors from the literature review, a qualitative user study with older adults and formal caregivers (i.e., elder care professionals) was conducted. Three focus groups and 21 semi-structured interviews were conducted in the UK, France and Belgium. Participants were sampled within the network of the project's end-user organizations Docobo (UK), E- seniors (France), and Christelijke Mutualiteit (Belgium).

The interviews and the focus groups in the UK and France were conducted with older adults as the intended primary user group. Six older adults participated in the focus-groups as well as in the in-depth interviews. The focus group in Belgium was conducted with formal caregivers as a potential secondary user group. Moreover, formal caregivers' expertise was based on the interaction with a diverse population of older adults and therefore offered additional insights on the acceptance factors.

Table 4.1 illustrates the distribution of participants in the interviews and focus groups per country.

4.1.3 PROCEDURE AND MATERIALS

The focus groups and interviews targeted the following topics: (1) problem experience related to daily activities and the level of social connectedness; (2) evaluation of the conceptual SONOPA system; (3) design requirements.

An animated video with drawings was used to demonstrate and visualize two potential user scenarios of the future SONOPA technology (see Figure 4.2). The first scenario focused on the SONOPA activity monitoring feature and making new friends via the social network environment. The second scenario focused on getting assistance with daily activities via the social network environment (see Appendix 4a for the full script of the user scenarios).

Furthermore, participants had to perform a short sorting task, in which ten potential features of the SONOPA solution had to be ranked in order of importance.
These features included: (1) reminders (e.g. for medicine), (2) calendar, (3) fall detection, (4) getting to know people from the neighborhood, (5) keeping in touch with family and friends (e.g., through video calls), (6) getting personalized activity recommendations, (7) detecting health problems, (8) easy access to all rooms in the house, (9) information about events in the neighborhood, (10) assistance with cooking.

Table 4.1 Distribution of Interviews and Focus Groups per Country in User Study 1

COUNTRY	FOCUS GROUPS	INTERVIEWS	NUMBER OF UNIQUE PARTICIPANTS
UK	8 older adults	8 older adults (3 couples)	11 older adults
France	5 older adults	4 older adults	8 older adults
Belgium	9 formal caregivers	9 older adults (1 couple)	9 older adults and 9 formal caregivers

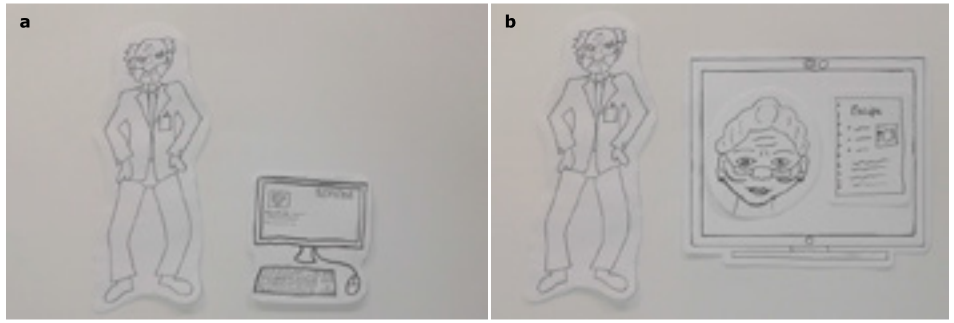

Figure 4.2. Screenshots from the SONOPA user scenarios: a) Mr. Smith creates a profile in the SONOPA social network. b) Mr. Smith tries a new recipe and gets help form Mrs. Wilson via the SONOPA social network.

Focus groups and interviews lasted between 1-1.5h and were video and/or audio recorded and transcribed verbatim for subsequent analysis. Thematic analysis was used to analyze the data (Braun & Clarke, 2006). During data analysis and coding, we tried to validate the acceptance factors from the literature review. Hence our approach was mainly deductive. However, we also allowed for new data-driven themes based on the participants' narratives (inductive approach). Several rounds of analysis were performed comparing new codes to previously assigned codes before deriving at the final set of themes.

4.1.4 PARTICIPANTS

In total, 28 older adults aged between 55 and 86 years (M = 71.36, SD = 9.45) participated in the user study. The sample consisted of 12 male and 16 female participants. Nine participants lived alone, while the other participants lived with a partner, family members or a friend. Most of the participants were retired (n = 24).

PARTICIPANTS FROM THE UK

The participants from the UK (n = 11) were sampled by project partner Docobo in the Bookham area, Surrey, UK. Bookham is located in Surrey, England about 20 miles southwest of London. The Bookham area has about 10500 inhabitants. Participants from the UK group were aged between 69 and 86 years (M = 78.36, SD = 4.97). The gender distribution in the UK sample was three male and eight female participants.

PARTICIPANTS FROM BELGIUM

The participants from Belgium (n = 9) were sampled by project partner Christelijke Mutualiteit in the Dendermonde area. Dendermonde is located about 25 miles southwest of Antwerp in the Flemish province of East Flanders and has approximately 44.500 inhabitants. Participants from Belgium were aged between 55 and 80 years (M = 64.78, SD = 10.35). Seven male and two female older adults participated in the study.

PARTICIPANTS FROM FRANCE

The participant from France (*n* = 8) were sampled by project partner E-seniors in the Paris area. Paris has about 2.2 million inhabitants. Participants from France were aged between 60 and 81 years (*M* = 69.13, *SD* = 6.96). Two male and six female older adults participated in the study. It should be noted that E-seniors focuses on teaching ICT skills to older adults. Hence, participants from their network were relatively tech-savvy.

PARTICIPANTS' ACTIVITY LEVEL, SOCIAL CONNECTEDNESS AND TECHNOLOGY EXPERIENCE

The 21 participants who participated in an in-depth interview were also asked in more detail about their general level of activity, social connectedness, technology experience and experience with assistive technologies.

Overall, participants felt fairly active, ranking their own activity level at an average of 7.06 (*SD* = 2.07) on a 10-point scale. Moreover, the majority of the older adults felt fairly socially connected, ranking their own level of social connectedness at an average of 7.32 (*SD* = 1.59) on a 10-point scale.

Seven participants had rather poor technology skills, three participants had basic technology skills, five participants were fairly competent users and six participants could be described as experienced technology users. Approximately half of the participants would buy technological devices themselves, and the other half would rely on family or friends for support.
Most participants did not use social media and social networks. The reasons for non-use were negative associations or experiences, lack of interest, no time or considered as "waste of time", or a busy social life as it is. Only five participants reported to use social media and social networks on a regular basis.

Six participants used assistive technologies, including a panic button, a stair lift, a home security system, sensors for automatic lighting, a robot vacuum cleaner and health monitoring apps. Moreover, five participants mentioned that they had experience with assistive technologies through a relative, who used such devices. The mother of one participant was even involved in a trial of a sensor-based, in-home monitoring system.

FORMAL CAREGIVER PARTICIPANTS

The focus group in Belgium was conducted with four male and five female formal caregivers from Christelijke Mutualiteit. The formal caregivers were aged between 36 and 61 years (*M* = 46.50, *SD* = 9.89) and had an average of 14.4 years of years of work experience in the care sector (*SD* = 6.32).

4.1.5 RESULTS

The first set of questions aimed to get a better understanding of the problem areas older adults experience with regard to leading an active and social lifestyle.

PROBLEM EXPERIENCE

Health problems were perceived as the most prevalent barrier to an active and social lifestyle and were mentioned in all three focus group discussions as well as in the in-depth interviews. Examples for health conditions included incontinence, arthritis, osteoporosis, stiffness or weakness in joints and muscles (e.g. hip), vertigo, high blood pressure and high cholesterol, hearing impairments and general tiredness. For one female participant the latter was the most predominant barrier to being more active: *"Tiredness is the biggest thing really. I get angry that I can't do, what I used to do"*. Another participants stated that her medical condition had severely influenced her social life: *"They all stayed away. When you stay at home there are not many friends left"*. Health problems could be accompanied by a feeling of embarrassment: *"I did start with bowls, but I had to give that up, because [...] I had a medical condition, I had a tendency [that] the ball would go into the next line [...] it embarrassed me a lot"*. In some cases the problem was not about the older adults' own medical condition but their partner's condition which stopped them from being more active or participate in social activities.

Mobility problems were a recurring theme during focus groups and interviews. Participants complained about insufficient public transport options, the involved costs, and limited accessibility: *"My main problem is that I live far away from Paris [center] and I cannot easily get into Paris as much as I would like because the transport is too expensive"*. Some of the participants depended on their children for transport.

Financial cost was not just perceived as problem in regard to transport but also to being active in general. Being member of a social club or participating in other activities was often involved with extra costs, which some participants could not afford. Moreover, adapting the living environment in a way that it gives consideration to their physical restrictions was not affordable to most of the older adults.

Social isolation and loneliness were identified as both causes and consequences of inactiveness and a lack of social connectedness. Sometimes older adults can get isolated because their family and friends live far away or their loved ones die. As a consequence, older adults can get depressed, are less motivated to be active, and often isolate themselves even more: *"Sometimes I lack the motivation to do activities because I often feel very lonely"*. Another participant had observed this type of behavior in his own environment: *"People seem to withdraw into their own shell. And so it becomes much more difficult for them to actually have relationships with other people"*. According to the formal caregivers social isolation can also lead to fear of other people: *"People who are isolated often become a bit suspicious, which in turn makes them less receptive to people in their environment"*.

A changing environment can also lead to less social connectedness and inactiveness. Sometimes older adults move to live in assisted housing facilities or to be closer to their children. This often means that they leave old friends and their well-known neighborhood behind. It requires an extra effort to make new friends, and not everybody is motivated to do so: *"I have only lived here for two years, so really, I needed to go out of my way to make friends to do things with, and I haven't bothered, naughty I know, but I haven't bothered"*. One male participant in France moved away from his home country Italy to live in France. He felt, although he made an effort, that it was hard to make friends because he was a foreigner and people had an existing social network: *"I find the French people to be relatively suspicious of foreigners. I try to make an effort to approach people and create friendships, but it is not easy because most people already have a network of family members and existing friends, and it is hard to be added to the network when you become old"*.

Low self-confidence also surfaced as a barrier for an active and social lifestyle. Participants reported that older adults sometimes lose self-confidence and do not like to step out of their comfort zone anymore: *"I have a neighbor who never goes out. That is because she is comfortable in the group within the building, but she is not comfortable going out. She doesn't know what to say"*.

Character, habit and motivation were also perceived as barriers for an active and social lifestyle. Some people are naturally shy and find it difficult to approach people and to make friends. One of the formal caregivers stated that habit can influence social behavior: *"The housewife, who always stood at the stove, always looked after the children, never came outside the house, suddenly is supposed to engage into social life. It doesn't work like that".* Personal motivation was also perceived as an important factor of a social and active lifestyle.

Finally, other barriers included **safety concerns** and **awareness**. Some older adults regarded themselves as an easy target for mugging or were afraid to fall. Therefore, they rather stayed inside. Some people were also unaware of social and leisure facilities in their neighborhood.

OVERALL EVALUATION OF SONOPA

After getting an overview of the older adults' problem experience, the conceptual SONOPA system was evaluated with the animated video scenarios (see Appendix 4a and Figure 4.2).

Most of the older adults and formal caregivers in this study had an overall positive opinion about the conceptual SONOPA technology. However, many older adults felt no need for the use of SONOPA in their current situation. They perceived the concept of SONOPA as more suitable for people who are less independent, healthy, active and socially connected, as becomes clear in this statement from an older couple: *"I mean we're not in the position at the moment to need any of those things. But thinking of other people, I think it is marvelous".* Some of the UK focus group participants regarded SONOPA as particular suitable for single men because *"they don't do so well on their own".* However, five older adults were willing to use SONOPA in their own home environment. Eleven participants could imagine to use SONOPA in the future, when they felt less healthy and active, or in case they would lose their partner.
One participant was only interested in the sensors for fall-detection, and one participant was especially interested in the social network part. Eight participants had no intention to use SONOPA in their own home. Two participants did not give a clear answer regarding their intention to use SONOPA.

Four older adult participants had a particular negative opinion towards the overall concept of SONOPA. One of these four participants stated that she was already independent and socially connected: *"I'm independent, these four things in the room say blablabla go meet somebody... I have so many friends I wouldn't want it".* Another participant doubted that SONOPA could be a solution to the problem. He also thought that SONOPA would be too difficult to use for older adults. Yet another participant stated that he simply lacks experience and interest in technology.
The fourth participants with a negative opinion regarded SONOPA as a last resort: *"for the hopeless cases".* He wanted to avoid external help for as long as possible. If really necessary, he would prefer a human caregiver.

PERCEIVED DRIVERS TOWARDS THE ACCEPTANCE OF SONOPA

When asked about the positive aspects of the conceptual SONOPA technology, several of perceived drivers from the literature review could be validated in the context of the current study.

Safety. Safety was considered as an important advantage of the future SONOPA technology. Older adults and formal caregivers both felt that the sensor infrastructure could provide added safety and security by detecting falls or other emergencies and immediately contacting help. Thus, paralleling the findings from the literature review, fall-detection and immediate emergency response were identified as key benefits of SONOPA.
Another feature that was suggested to be incorporated into the SONOPA system was a reminder for turning off the stove. Similar to the literature review, automatic and around-the-clock monitoring was viewed as a major advantage of the SONOPA system, as becomes clear in this statement from a female older adult participant: *"I have a panic button on my mobile [...]. But as far as I'm concerned it is practically useless. Because if something serious happens it is either going to be on the other side of the room or in your handbag or you're not capable to press the button. So really what you are talking about is a lot more helpful".*
Another participant complaint that his mother would not use the current alarm system because she was worried to impose on someone, and therefore, automatic detection of emergencies would be a major advantage. Overall, participants thought that SONOPA could provide older adults with an increased feeling of safety and assurance.

Following earlier research (Steele et al., 2009; Van Hoof et al., 2011; Wild et al., 2008), the majority of older adults in the current study thought that safety benefits superseded concerns of privacy and intrusiveness.
They accepted the idea of sensors because they perceived them to benefit their personal well-being and safety at home: *"When I know that the sensors are installed in my home for my well- being, I don't have any problems with them being in my home".* Furthermore, most of the participants who were comfortable with sensors, were comfortable to have them in every room of the house as falls could happen everywhere. They were also willing to share the sensor data with an informal or formal caregiver. However, a few older adults would not like to have sensors in the toilet, bathroom and bedroom.

Support and Unburden Caregivers and Provide Peace of Mind. Similar to the literature review, the older adults stated that SONOPA could be very valuable for supporting and unburdening caregivers and providing peace of mind for the relatives. One male older adult participant regretted that a similar technology was not available when he was an informal caregiver:
"When my mother was older, I looked after her to be sure she is well. And I think this kind of solution would have been very valuable in that situation".

Social Connectedness. Social connectedness was perceived as a prominent advantage of SONOPA. The participating older adults and formal caregivers liked that the social network feature of the technology would allow older adults to make new friends and strengthen the neighborhood network. As stated by one male older adult: *"It's like a social club".* Participants also valued that one could stay in touch with family members and other existing contacts. They appreciated that contact would be one-on-one and could lead to meetings in real life. They concluded that SONOPA could prevent social isolation by getting people outside the house, motivating them to participate in social life, and therefore give them back a sense in life. By aiding social connectedness, SONOPA could simultaneously stimulate the older adult's activity level. As stated by one female older adult participant: *"If you meet someone, you get ready, you clean the house and you get busy with other daily chores. And this way this kind of technology could contribute to staying active".* While this is in line with some studies from the literature review, it contradicts findings from Steele et al. (2009) who found that their older adult participants strongly rejected the suggestion to incorporate social features in an AAL technology. However, one female formal caregiver from the Belgian focus group argued that particularly these social aspects could be the reason that more healthy and active older adults would be interested in SONOPA: *"For some people safety would not be such a big problem at first, and if that is all there is, they probably would not get it [the technology] installed. But it also includes some social elements which could maybe convince people to get it installed anyway. This way they get familiar with it [the technology] [...]. And by the time it is needed for safety purposes than there is already a good profile of this people, and this I consider a strength"*.

Enjoyment and Leisure. When discussing the conceptual SONOPA technology, several participants imagined that using SONOPA would be fun and enjoyable and could facilitate leisure activities. Several older adults also viewed the SONOPA social network feature as an opportunity to share common interests. As one female older adult participant stated: *"I do watercolor painting. I might find somebody who wants to come in with me once a week and sit"*.

Support with Daily Activities. In line with the findings from the literature review, support with daily activities such as assistance with chores and reminders (e.g., medicine, important appointments) was an appreciated feature among older adults and formal caregivers in the SONOPA user study. Some older adults liked the possibility to get personal advice from peers or family members via video-chat. One female older adult participant even suggested to use SONOPA to recruit help for chores through the social network feature: *"But imagine if you want to decorate your kitchen and you put it on there. You could have five people come around, and you could go shopping and come back and it would all be done"*.

Education and Information. A few participants requested informational and educational features for the future SONOPA technology. For instance, one participant suggested to incorporate online classes or educational videos in the SONOPA system. However, similar to the literature review, 'education and information' was not a very prevalent theme in the current study and was only mentioned by a few participants.

Surprisingly, independent living and aging in place were not explicitly mentioned as benefits with regard to the future SONOPA technology, although it was a prevalent theme in the literature review. A possible explanation for this is that SONOPA was already presented as a conceptual technology for independent aging at home. Consequently, participants might have felt that this was an obvious advantage and therefore unnecessary to recall. In addition, various statements made clear that independence is very important to the participants. Moreover, except for medicine reminders, health benefits such as detecting changes in one's health status or cognitive decline were not mentioned in the current user study. Self-confidence and status benefits were also not mentioned in the present study.

At the end of the interviews and focus groups, the older adults and formal caregivers were asked to sort ten potential features of SONOPA in order of importance, from 1 = very important to 10 = not important. Table 4.2 shows the median ranking of all potential features.

As shown in Table 4.2 fall detection (*Mdn* = 1) and reminders (*Mdn* = 2) had the highest overall median ranking. When asked to clarify why ranking fall detection as most important, one participant said: *"Well, I think that this is one of the things that is essential actually. If something happens to you like that. Then I just feel, for the sake of our daughter as well as for our sake, it is an important sort of thing"*. Reminders were also regarded as important: *"Because it is very important to take one's medicine at the right time [...] Otherwise I cannot function"*.

Table 4.2 Relative Importance of the Potential Features of the SONOPA Technology

BENEFIT	HIGHEST RANKING	LOWEST RANKING	MEDIAN RANKING	MEDIAN RANKING OLDER ADULTS	MEDIAN RANKING FORMAL CAREGIVERS
fall detection	1	8	1	1	1
reminders (e.g. for medicine)	1	8	2	2	2
keeping in touch with family and friends (e.g. through video calls)	1	10	3	3	3
detect health problems	1	10	4	5	4
easy access to all rooms in the house	1	10	5	8	5
calendar	2	10	5	4	5
getting to know people from the neighbourhood	2	10	6.5	6	7
information about events in the neighbourhood	1	10	6.5	7	6
getting personalize activity recommendation	3	10	7	6.5	7
assistance with cooking	1	10	9	10	8

In contrast, assistance with cooking (*Mdn* = 9) was perceived as least important. All of our older adult participants were still preparing their meals themselves, and some felt almost insulted by the idea of needing assistance.
It is surprising to see that social benefits such as getting to know new people from the neighborhood (*Mdn* = 6.5) and information about events in the neighborhood' (*Mdn* = 6.5) were not ranked higher, considering that social connectedness was perceived as a major positive aspect of the conceptual SONOPA technology. However, this can be explained by the fact that most of our participants had a stable existing social network and did not feel very lonely at the time this study was conducted.

PERCEIVED BARRIERS TOWARDS THE ACCEPTANCE OF SONOPA

Privacy, Intrusiveness and Control.
Although the majority of older adults found it acceptable to have sensors in their home due to the perceived benefits, loss of privacy was considered as an important disadvantage of the future SONOPA technology. Moreover, some of SONOPA's potential functionalities were regarded as intrusive (e.g. activity recommendations, monitoring). Several older adults felt that the SONOPA technology would invade their personal space and felt uneasy about being monitored: *"I think it is Big Brother, being watched all the time"*.
They worried that SONOPA could interfere with their natural behavior, as argued by a female older adult: *"But I don't know whether you would creep around the house, thinking: oh dear, they can see me [...]. That would be horrible, sort of spy on the wall"*. Some of the older adults were concerned that the data could get in the wrong hands. In line with

these concerns, most older adults wanted to be able to switch the SONOPA system off and be in control over which data they share and with whom: *"You wouldn't want it all the time, because it would distract you wouldn't it [...] You sit down for a read, you wouldn't want to get kicked like you should be doing something else"*. On the contrary, several other participants argued that the system would only work to its full potential, when it could not be switched off. With regard to the social network, some older adults were sceptic about having an online profile and sharing data such as zip code, name and personal interests with others. Some were concerned that data would be misused or would give neighbors a reason to gossip about them: *"I only want my neighbors to know, what I want them to know"*. Similar concerns about loss of privacy, intrusiveness and control were identified in the literature review.

Loss of Human Touch. In line with the findings from the literature review, older adults and formal caregivers in the current user study worried about the loss of human touch. They stated that SONOPA could not and should not replace human care and human interaction, as becomes clear in this statement from a male older adult: *"For me human contact is still most important [...]. Thus, I prefer no computer"*. A female older adult participant pointed out: *"The negative point is that this person's family and the environment cannot fully rely on this application. Because the application cannot replace the human"*. However, loss of human touch was a less prevalent theme in the current user study, possibly due to SONOPA's social features.

Self-Efficacy, Technology Experience and Usability. Similar too many previous studies from the literature review, older adults in the SONOPA user study were worried about the potential complexity of the future SONOPA system. It was repeatedly emphasized that they did not grew up with technology and therefore might lack the necessary skills, technology experience and confidence to interact with SONOPA: *"I think a lot of our generation are computer shy"*. It was therefore suggested that, the developers should pay attention to the usability of the SONOPA system: *"But if you got to go to an iPod thing and should do tutututututu [push buttons] before you find out what you are supposed to do, that is not helpful"*. Some participants had a general negative perception of new technologies. Indeed, those participants also had a negative opinion of the potential SONOPA technology.

Absence of Perceived Need and Perceived Value. As mentioned earlier in this paragraph, many older adults felt no need for the use of SONOPA in their current situation. Similar to Wild et al. (2008), our participants found it hard to imagine a future need for assistance. Mirroring observations of Peek et al. (2014), it was observed that many older adults talked about a hypothetical older person who could benefit from SONOPA, rather than themselves. Some older adults also thought that the future SONOPA technology would not offer a lot of added benefits. For example, older adults reported to already use a paper calendar for overlooking their appointments or a pill-box to remember to take their medications. However, it also became clear that the concept of SONOPA was still quite abstract, and therefore some participants did not fully understand potential benefits SONOPA could offer to them. Indeed, one of the formal caregivers argued that for older adults the benefits of a new technology are often too abstract and not immediately tangible, so they often stick to what they know.

Social Stigma and Pride. The literature review showed that the fear of social stigma and older adults' pride were potential barriers to the acceptance of AAL technologies. Similar findings resulted from the SONOPA user study. While assistance with chores was well perceived by a few older adults, others felt no need for assistance and almost felt insulted by the idea: *"I don't need anybody to tell me how to make a stew"*. We observed that some older adults were very proud of their independence and therefore rejected anything that would imply otherwise. Indeed, one older adult pointed out that older adults might be resistant to accepting assistance and therefore would not want to use technology that stigmatizes them as frail and dependent.

Reliability and Trust in Technology. Older adults in the current user study were concerned about the reliability of the future SONOPA technology, especially the sensors. They worried that the system could give false alarms: *"It might just go off with your natural things"*.

Financial Cost. Although financial cost came not up as top-of-the-mind concern among the older adults in the present study, it became clear that the SONOPA technology has to be affordable for a person living on a pension. When asked about what they would be willing to pay for SONOPA, the majority of participants preferred a monthly payment scheme, and answers ranged from €15 a month to €100 a month. Participants also stated that it was hard to answer this question without knowing more details about the future SONOPA technology and the services included. Several French and Belgian participants demanded that the government would cover parts of the cost.

Health Concerns. Although our participants did not share the health concerns about electromagnetic radiation or additional stress from previous research, one older adult stated that SONOPA could make people less active and healthy because they do not have leave the house to have social contact: *"It could be possible that you shackle them behind the computer"*.

The literature review showed that some older adults perceived AAL technologies to put an additional burden on family caregivers. This concern was not mentioned in the context of the SONOPA user study. However a new barrier theme surfaced from the data that was labeled **contextual limitations.** Older adults worried that SONOPA would not work in all domestic environments, as becomes clear in this statement from a female participant: *"I can't honestly visualize it to be a possibility. Not in an old house"*.

4.1.6. SHORT CONCLUSION AND REQUIREMENTS FOR THE FURTHER SONOPA DEVELOPMENT

In conclusion, the results show that, overall, participants were fairly positive towards the conceptual SONOPA system and identified many benefits including safety; support and unburden caregivers and provide peace of mind; social connectedness; support with daily activities; enjoyment and leisure; and information and education. These benefits were very similar to the acceptance drivers that were identified from the literature review. However, participants also voices several concerns including privacy, intrusiveness and control; loss of human touch; self-efficacy, technology experience and usability; absence of perceived need and perceived value; social stigma and pride; reliability and trust in technology; financial cost; health concerns; and contextual limitations. Again these concerns were very similar to the acceptance barriers that were identified from the literature study. It can therefore be concluded, that almost all acceptance factors from the literature review could be validated in the context of SONOPA.

Based on these results, there are several implications for the further development of SONOPA:

1. To stimulate older adults and their caregivers to use SONOPA, its benefits have to be clear, specific and profound. As the SONOPA system was still experienced as abstract, for the pilot phase two demo sites should be equipped with the SONOPA prototype, so a large number of potential users can experience the system and get a better understanding of its benefits.
To appeal to the needs of different user groups, it is recommended to offer the system in a modular way. One mode should be tailored to the active and healthy older adults, with an emphasis on the social and leisure features and only a few sensors. The other mode should target the older adults who experience physical and cognitive problems and put more emphasis on support and safety features with a denser sensor installation.

2. To target concerns about privacy, intrusiveness and control, it is important to take all necessary measures to ensure safe data storage. Moreover, the number of sensors should be reduced and feedback on the design should be collected to make the system less obtrusive. Within the social network environment, the users should have control over which data they want to share and with whom.

3. SONOPA should promote and not replace social interaction. It is expected that the SONOPA social network and local event recommendations will improve the contact with family members and peers and stimulate the creation of new social connections online and offline.

4. Many features of the SONOPA prototype are automated and require little user interaction. During the pilot phase the participants will receive a short training for using the more interactive features, such as the social network environment. Moreover, it is important to improve the usability of these features with the help of the users' feedback.

5. By offering different modes of the SONOPA system and keeping the hardware requirements to a minimum, it should be possible to minimize the cost of the SONOPA system. A monthly payment scheme for the different modes of the SONOPA system is recommended.

4.2 USER STUDY 2

4.2.1 BACKGROUND AND AIM

The second user study seeks to explore the perceptions and needs regarding AAL among informal caregivers as an important secondary user group. By exploring the perceptions of informal caregivers, this study contributes to the understanding and further validation of the acceptance factors identified in Chapter 3.

The burden on informal family caregivers of older adults is ever increasing. With the recent reform of long term care policies towards more 'aging in place', informal caregivers are expected to take up more care tasks in the near future (Pavolini & Ranci, 2008). In the Netherlands, informal care is defined as:

> *"Long-term care that is provided beyond a caregiving profession to a person with care needs by one or more members from the close social environment, as such that care provision directly results from the social relationship"* (House of Representatives of the Netherlands, 2001, p.7).

Tasks performed by informal caregivers include domestic support (e.g., groceries, prepare meals, cleaning); psychosocial support (e.g., administration, doctor visits, social activities, emotional support) and, usually to a lesser degree, personal care (e.g., bathing, dressing, feeding) and basic medical care (e.g., monitor medication intake, surgical dressing) (Timmermans, 2003). This might change in the near future and formal care tasks are likely to shift more and more towards informal caregivers. While older adults are likely to embrace the idea of aging in their trusted home environment and receiving care by one of their kin (Eckert et al. 2004), it is unsure how informal caregivers will cope with the increased workload. Caring for a frail older adult can have negative consequences for the caregiver's physical health and mental well-being (Pinquart & Sörensen, 2003;
Schulz & Beach, 1999). Other undesirable consequences include a reduced participation in the labor market and an increased risk for financial dependence (Colombo et al., 2011; Mosca et al., 2016). Moreover, a recent study showed that people might not be willing to take on more care tasks, especially with regard to personal and medical care (Hoefman, Meulenkamp, & De Jong, 2017). It is therefore questionable whether continuous and high quality care can be provided under the demographic transition and the new care reforms.

AAL technologies are considered as a solution to reducing the burden on informal caregivers. However, so far, informal caregivers have not receive enough attention in AAL research. Informal caregivers are either underrepresented or not included in most AAL studies, except if they are considered as the primary user (Bossen et al., 2013; Consolvo et al., 2004; Rowan & Mynatt, 2005). Another exception includes AAL applications designed for people with dementia. In these studies informal caregivers are considered as the main decision maker and natural spokesperson for the care receiver (e.g., Hwang, Truong, & Mihailidis, 2012; Rialle, Ollivet, Guigui, & Hervé, 2008).

This lack of caregiver involvement in user studies is surprising, as informal caregivers play a vital role in the care of older adults and are therefore directly affected by the use of assistive technologies such as AAL. While AAL applications could relieve some of the informal caregivers' task pressure and provide them with peace of mind, informal caregivers might also feel threatened by these technologies, as they could take over some of their tasks and make them feel less needed. It is also unclear whether informal caregivers will entrust a technology with the care of their loved ones.

We argue that informal caregivers should be involved in acceptance studies, even when they are not the primary users, and even when applications do not specifically target people with dementia. These informal caregivers will still be affected by the use of AAL technology. Furthermore, informal caregivers usually have an important influence on care-related decisions (Bass & Noelker, 1987; Byrne, Goeree, Hiedemann, & Stern, 2009) and the selection and appropriation of assistive devices (Greenhalgh et al., 2013). Furthermore, AAL studies with older adults suggest that older adults take their family's needs and opinions into account when making care-related decisions (Courtney et al., 2008; Lorenzen-Huber, Boutain, Camp, Shankar, & Connelly, 2011). Luijkx, Peek, & Wouters (2015) investigated the influence of family members on the acceptance of different technologies such as computers, laptops, tablets, mobile phones, electric bikes and personal alarms. They conclude that:

> *"the acceptance of technology by older adults, in the sense of purchasing and using devices, is not an individual matter; it is influenced by spouses, children and grandchildren"* (p. 15479).

For the future success of AAL technologies, it is therefore crucial to consider the perceptions and needs of the informal caregivers.

4.2.2 METHOD

With the objective to explore the informal caregivers' attitudes, concerns and needs regarding AAL, semi- structured interviews with 20 Dutch informal caregivers were conducted. This qualitative approach allowed us to get an in-depth understanding of the informal caregivers' perception of AAL technologies.

The objective of this study was not to evaluate a specific AAL application but rather to explore the general perception of AAL among informal caregivers. Therefore, we used several different AAL applications that could aid the care receiver's mobility and safety as examples in this study. Mobility and safety are important aspects for shaping the older adults' level of independence and overall quality of life (Gabriel & Bowling, 2004; Rubenstein, 2006). With older age, problems in these areas increase. Common restrictions which affect the mobility include balance control, reduced perception of touch and vibration, reduced walking speed, gait disorders, strengths deficits, and lower reaction time (M. E. Rogers, Rogers, Takeshima, & Islam, 2003). Those restrictions also increase the likelihood of falls, which is one of the most prevalent safety risks for older adults. Falls can lead to anxiety, inactivity, further mobility restrictions, premature nursing home placement, or even death (Rubenstein, 2006).

For the field of safety different types of sensors were shown to the participants. Each example contained a short textual description and a visual. Visual sensors (cameras) and ambient sensors were used as the first two examples. It was explained that these sensors can monitor the older adults' activities and detect falls or unusual behavior such as abnormal sleep behavior. As a third example we used wearable sensors. It was explained that these sensors could be implanted, body-worn or be integrated into a garment to continuously measure the older adult's vital signs. The accompanied visual depicted ultrathin sensor technology that is directly applied on the skin, similar to Webb et al. (2013). For the mobility field we showed a smart wheelchair with an autonomous break system, wayfinding support and speech recognition (Lankenau, 2001). Moreover, a smart wheeled walker with an autonomous break system and wayfinding support, and an adaptive kitchen with moveable cupboards and countertops was displayed. As a fourth example we used an assistive robot. It was explained that the robot could help with different (instrumental) activities of daily living ((I)ADL). The accompanied picture showed TU Eindhoven's robot AMIGO fetching an object from a drawer. To provide additional context on how these AAL tools could aid the care receiver in real life, two user scenarios, one focusing on safety and the other focusing on mobility, were created.

The interviews were conducted by two trained research assistants in the participants' own home environment to create a comfortable interview situation. Each session started with some general information about the purpose of the study, the interview procedure and the consent for recording. The interview started with several questions about the context of informal care such as daily care routine, workload and motivation to provide informal care. We also included some question about the care receiver's mobility and safety issues. After that, the participant viewed the AAL examples together with the scenarios and were probed to reflect upon their perceptions and attitudes regarding AAL.

Each session lasted about 60–90 min and was audio recorded and transcribed verbatim for subsequent analysis. Thematic analysis was used to identify common themes (Braun & Clarke, 2006). Similar to the first user study, the approach was mainly deductive as we used the identified acceptance factors from the literature review and the first user study as a pre-existing framework for coding. However, as this study was conducted with informal caregivers as a new user group, we also allowed for new themes to be discovered directly from the participants' narratives (inductive approach). Several rounds of coding were performed to compare new codes to previous assigned codes, to make sure the identified themes remained valid and to derive the final set of themes. A random sample of two interviews (10%) was coded by a second researcher to evaluate the reliability of the identified themes. The interrater agreement between both researchers was 79%.

4.2.3 PARTICIPANTS

The participants were conveniently sampled in the rural Eastern part of the Netherlands within the network of the research assistants. To be included in the sample, informal caregivers had to provide informal care for at least 3 months, and caregiving had to directly result from a close social relationship (House of Representatives of the Netherlands, 2001; Timmermans, 2003).

The final sample had a large proportion of female participants (n = 18) with almost all (n = 19) participants from the 45–65 age group (M = 53.3, SD = 6.91). This is similar to the typical informal caregiver population (Henz, 2006; Huber et al., 2009). Most of the participants were working part-time (n = 14) or full-time (n = 3), next to their caregiving responsibilities. The large majority provided care to one or two family members, either parents (n = 17), in-laws (n = 1) or siblings (n = 1). Only two participants cared for a person outside their family circle (i.e., friend, neighbor). More than half of the participants (n = 11) had been an informal caregiver for at least 10 years. When asked about their time investment, nine participants reported to spend less than 3h a week on caregiving tasks, five participants spent 3–7h a week, and only three participants spent 8h or more a week on informal caregiving. All caregivers reported to provide some form of psychosocial support (e.g., administration, doctor visits, social activities, emotional support), and most of them (n = 19) also helped with domestic tasks (e.g., groceries, prepare meals, cleaning). Only three respondents were involved with personal care (e.g., bathing, dressing, feeding) and basic medical care (e.g., monitor medication intake). When asked about their overall ICT experience, all participants had experience with mainstream ICT such as pc, laptop, smart phone or tablet, and most of them (n = 14) used these tools on a daily basis.

4.2.4 RESULTS

CONTEXT INFORMAL CARE

When asked about their motivation of providing care 12 informal caregivers reported it to be pleasant and rewarding: *"It's a wonderful job [...]. I really enjoy it. But I have a darling mother-in law, so that makes it easy"* (participant 4, in-law, female). Nine participants perceived care as a 'matter of course': *"This is what you do, you don't think about it"* (participant 2, daughter). This was often connected to a feeling of reciprocity: *"I think it is normal, being a daughter. In the past, my mother cared for me, now I care for my mother"* (participant 5, daughter). Four informal caregivers also felt some degree of obligation to provide support: *"It's what you supposed to do. It's your mother and you care for her"* (participant 13, daughter). This obligation was sometimes routed in the care-receivers' wish to age in their own home environment. Finally, less frequently mentioned drivers were the caregiver's own peace of mind (n = 2) and altruism (n = 1).

The most common problem the participants experienced as informal caregivers was workload. More than half (n = 11) of the participants reported to sometimes feel overburdened, especially in combination with their other responsibilities: *"If you work four days a week and you have one day off, it is quite stressful"* (participant 17, daughter). Five participants also felt emotionally challenged: *"At the moment it is really hard. It's not so much the time you invest but the psychological burden to see your father further deteriorate"* (participant 19, daughter). Three participants mentioned that they encounter resistance on the part of the care receiver in accepting their support: *"I sometimes do things for her with good intentions, but she perceives it as taking away her agency"* (participant 2, daughter). Other problems, which were revealed by individual caregivers, included lack of support (participant 19, daughter), communication between caregivers and bureaucracy (participant 9, daughter), physical burden and financial burden (participant 7, daughter), and confidence in one's own abilities (participant 10, daughter). Five participants reported to experience no problems with regard to providing care: *"No not really, because we are several people, and tasks are divided. One person does this, and the other does that"* (participant 13, daughter).

In accordance with our expectations, almost all informal caregivers (n = 18) were closely involved in care-related decision making. According to their comments, informal caregivers regularly checked on potential safety risks and new care needs: *"Once in a while, I want to sit with her in the car to see if it is still safe. And if I feel it isn't safe anymore, then I will discuss this with her"* (participant 8, daughter). Subsequently, they are often the ones who initiate the appropriate measures to address these issues. However, the degree of social influence differed. Some informal caregivers pointed out to provide carefully phrased suggestions, while others had a strong advisory role. A few informal caregivers even made decisions without consulting the care receiver first: *"As soon as needed, we bought a wheeled walker [...], although she did not want one in the beginning. You just buy the thing and put it there"* (participant 1, son).

CURRENT STRATEGIES TO COPE WITH SAFETY AND MOBILITY ISSUES

The safety and accessibility of the care receiver's home environment were important topics for informal caregivers (n = 17). Reasons for concern included potential falls or accidents (n = 14), burglary (n = 12) and other home safety issues like gas leaks or fire (n = 3). To address these safety issues, informal caregivers reported about several adaptations and assistive technologies in the care receiver's home. Those adaptions included grab bars, threshold ramps, a shower seat, a hoist and an adapted bed. Some of the more technological solutions included a hospital bed, a stair lift, a key lock box, and a doorbell signaler. Although most of the solutions were rather low-tech, two participants had experience with more advanced solutions in the care receiver's home, such as temperature sensors and stove sensors (participant 19, daughter) and even cameras for monitoring (participant 6, friend, female). In case of an emergency, it was important to the participants that the care receiver could immediately reach out for help. Therefore, thirteen care receivers had a personal alarm system: *"Now I know [...], if something is wrong, she can push the button and one of us will be alarmed"* (participant 5, daughter). Two informal caregivers even reported that the care receivers had a tablet for check-ins with the formal care service (participant 1, son and participant 14, neighbor, female).

The care receiver's mobility and transport options were also important to the caregiver. Informal caregivers (n = 12) emphasized that they want the care receiver to go outdoors, engage in activities, and stay in touch with social contacts to avoid social isolation: *"I think it's important that she gets outside now and then and that she has her social contacts"* (participant 3, daughter and sister). The majority of informal caregivers (n = 18) stated that the care receiver uses walking aids such as cane, wheeled walker, wheelchair or mobility scooter to support their mobility. In addition, many informal caregivers assisted with transport. This was contributed by the fact that accessibility and transport options were often limited, or that participants worried about traffic accidents: *"Then I sit here with an anxious feeling while she is away with the car. Well, then I rather drive her myself"* (participant 4, in-law, female).

Although informal caregivers provided assistance on many levels, they tried to preserve the care receiver's independence and autonomy (n = 12): *"I think it's important that she can do her own thing for as long as possible"* (participant 2, daughter).

GENERAL EVALUATION OF AAL

The majority of participants (n = 13) had a positive overall attitude towards AAL. They appreciated the different possibilities for support and thought of AAL technologies as a positive development for the future of caregiving: *"Well, I think first of all, it is fantastic that a lot stuff is being developed"* (participant 3, daughter and sister). In contrast, four of the interviewed participants were rather skeptical towards AAL: *"I think it's a scary idea"* (participant 6, friend, female) or *"I can't really picture it to be honest"* (participant 12, daughter). In their view, AAL technologies were a last resort and they would rather try to manage the necessary care by themselves: *"I don't hope it will come to this [...], and then I still think that we as her children would manage most of it"* (participant 17, daughter). The remaining three caregivers had a mixed view of AAL technologies with some positive and some negative perceptions. Although most informal caregivers had a strong influence on care decisions, the majority (n = 15) emphasized that using an AAL technology would strongly depend on the wishes of the care receiver, and they would not use these tools without their consent: *"You have to honor their wishes. Do they want this or not"* (participant 10, daughter). Comparing the different applications that were used as an example in this study, the smart wheeled walker was positively perceived by most participants (n = 17), followed by the ambient sensors (n = 13) and the adaptive kitchen (n = 12). The participants especially liked that these tools could support the care receiver's mobility, prevent and signalize accidents and therefore provide some peace of mind to them as caregivers. In contrast, most participants had a negative attitude towards the assistive robot (n = 16), followed by the wearable and visual sensors (n = 8). The participants complained that these tools lack the human touch and invade the care receiver's privacy. It should be noted that only seven participants commented specifically on the smart wheelchair, making it difficult to compare these evaluations. Table 4.3 provides an overview of these overall evaluation. The next section discusses the specific drivers and barriers of AAL acceptance in more detail.

PERCEIVED DRIVERS OF AAL ACCEPTANCE

Safety. Safety was identified as a strong driver of AAL technology acceptance. Almost all participants (n = 19) perceived that AAL technologies could contribute to the safety of the care receiver. They appreciated that the various sensors could immediately trigger an

Table 4.3 Overview of the General Evaluation of AAL Applications among Informal Caregivers in User Study 2

PARTICIPANT	OVERALL ATTITUDE	AMBIENT SENSORS	VISUAL SENSORS	WEARABLE SENSORS	SMART WHEELCHAIR	SMART WALKER	ADAPTED KITCHEN	ASSISTIVE ROBOT
1	+/-	+	+	+	n/a	+	+/-	-
2	+	+	-	-	+/-	+	n/a	+
3	+	+	+	+	+	+	+	-
4	+	+	+	+	n/a	+	+	-
5	+	+	+	-	n/a	+	+	-
6	-	+/-	+	-	n/a	-	+	-
7	+	+	+	-	+/-	+	n/a	-
8	+	-	-	-	+	+	+	-
9	+	-	+	+	-	+	+	-
10	+/-	+	-	+	n/a	+	+	-
11	+	+	+	+	-	+	+	-
12	-	+	-	+	n/a	-	n/a	-
13	-	-	-	n/a	n/a	+	+	-
14	+	+	+	n/a	n/a	+	n/a	n/a
15	+	-	-	+	-	+	n/a	-
16	+/-	+	-	-	n/a	+	+	-
17	-	n/a	-	-	n/a	+	+	-
18	+	+	+	+	n/a	+	n/a	-
19	+	n/a	+/-	n/a	n/a	+	n/a	n/a
20	+	+	+/-	-	n/a	n/a	+	+

Notes: + = positive evaluation; +/- = mixed evaluation; - = negative evaluation; n/a = no answer

alarm in case of emergency, and falls or other accidents would not remain unnoticed by the caregiver: *"Essentially, you minimize the chance that somebody lies on the floor for one or two hours, or maybe days"* (participant 1, son). Informal caregivers liked that they could keep an eye on the care receiver's safety from distance and provide immediate help when needed: *"You can see that the person is safe and doesn't do anything stupid"* (participant 2, daughter).

With regard to the adaptive kitchen, participants pointed out that hazardous situations could be prevented, e.g. climbing on a chair to reach the upper cupboard. The smart wheeled walker and the smart wheelchair were regarded as a good tool to prevent dangerous situations and accidents outside the home, as becomes clear in this statement: *"Particularly the wheelchair and I-walker could prevent a lot of accidents [...] simply, because it is hard for older people to react quickly"* (participant 3, daughter and sister).

Peace of mind. Another strong driver that is closely related to safety was peace of mind. The majority of the participants (*n* = 15) emphasized that AAL technologies could increase their own peace of mind as well as the care receiver's peace of mind: *"Yes, I think it can contribute to peace of mind for all parties"* (participant 3, daughter and sister). The caregivers pointed out that the presence of sensors could help them to worry less about the care receiver's well-being: *"You know that if they fall, you get an alarm. That's very comforting"* (participant 9, daughter). Moreover, it would relieve them of some responsibility *"That you don't have to feel guilty if something should happen"* (participant 10, daughter). Interestingly, several participants (*n* = 7) were concerned that having all the sensor data could also have the opposite effect and cause more worries. As one participant stated: *"Sometimes, I think it is better that I don't know how she gets through the day. Because some stuff I don't want to see. Stuff that would scare me"* (participant 8, daughter). In line with this concern, the majority of participants (*n* = 14) preferred to have the sensor data managed by a professional care center and only be alarmed in case of emergency.

Support with Daily Activities. An additional 15 participants acknowledged that the presented AAL tools could increase the care receivers' mobility and support them with their daily activities. They pointed out that tools like the smart wheeled walker could encourage the care receiver to go more outdoors, walk small distances, and increase the overall mobility radius: *"And you help her with long distances. Now she is still able to do this, but when she can't anymore in the future this is very useful"* (participant 5, daughter). Participants also acknowledged that the adaptive kitchen and the assistive robot could compensate for the care receiver's physical limitations, e.g. getting dizzy when bending down to reach for objects as well as help the care receiver with housework and personal care.

Independence and Aging in Place. More than half of the participants (*n* = 11) mentioned the care receiver's independence as an important benefit of AAL, as becomes clear in this statement: *"I am an advocate of staying independent for as long as possible. And if you use these technologies then you stay independent"* (participant 20, son). According to the informal caregivers, staying independent would preserve the care receiver's sense of freedom and self-worth. They also acknowledged that AAL technologies could enable the care receiver to stay in the familiar home environment for as long as possible: *"Staying in her own environment is very important to my mother"* (participant 18, daughter). However, there were some critical voices towards keeping the care receiver home at all costs: *"Just let this guy go to a nursing home, please"* (comment on the user scenario, participant 17, daughter). Three informal caregivers preferred a nursing home over AAL technologies when the health condition of the care receiver would change.

Support and Unburden Caregivers. Support with caregiving tasks was recognized as another driver of AAL technologies. Several participants (*n* = 8) pointed out that AAL technologies could support them in some of their usual caregiving task. For example, one participant stated with regard to the smart wheeled walker: *"I would not have to drive her to the hair dresser anymore because she could do it herself"* (participant 2, daughter). Participants recognized that AAL tools would enable them to provide more care from distance, perform tasks more efficiently and ultimately relieve some of their workload, meaning that they have more personal time: *"You have a little bit more freedom. You don't have to stay at home or find somebody else, when you are away for the weekend"* (participant 5, daughter).

Finally, a few caregivers mentioned **social connectedness** (*n* = 4) and **health benefits** (*n*=3) as other advantages of AAL technologies.

PERCEIVED BARRIERS OF AAL ACCEPTANCE

Privacy, Intrusiveness and Control. Privacy and intrusiveness formed strong barriers towards AAL technology acceptance.

Almost all participants (*n* = 18) were concerned that AAL technologies could invade the care receiver's privacy. This was especially true for the visual sensors but also for the wearable and ambient sensors. Some informal caregivers stated that they would feel like a spy, and that they would not want to have all kinds of information about the care receiver: *"A bit like Big Brother is watching you. That's the feeling I get"* (participant 8, daughter). Also, some participants thought that the care receivers themselves would not appreciate it to be monitored by them as caregivers. They also feared that care receivers might not always be fully aware that they are being monitored. While some participants regarded the care receiver's privacy as a priority, others believed the safety benefits to outweigh the privacy concerns (*n* = 6): *"In this phase safety is more important"* (participant 13, daughter). Some caregivers stated that, instead of feeling safe, the care receiver might feel uneasy about the sensors: *"Sensors under the skin measuring heartbeat and respiration – well that would get my heart rate up if everything is being monitored"* (participant 20, son). Other critical comments about the intrusiveness of the wearable sensors included: *"a bit like an alien"* (participant 8, daughter), *"I would feel like a robot myself"* (participant 2, daughter) and *"animals are also tagged"* (participant 6, friend, female).

Loss of Human Touch. Another strong barrier towards AAL technology acceptance was the loss of human touch. The great majority of participants (*n* = 17) had some concerns that AAL technologies could reduce the human touch in care. The participants stated that contact, warmth and empathy are crucial to the care receivers and that technology could not offer these qualities. Participants were especially critical towards the assistive robot in that regard: *"You want someone with you to hold your hand and hug you from time to time. Well, good luck with this robot"* (participant 4, in-law, female). Another concern was that technologies might create more distance between care givers and care receivers and therefore increase social isolation: *"Knowing they have those things at home, you might visit your mother or father less often to check on them"* (participant 4, in-law, female). The majority of caregivers emphasized that technology could not and should not replace human care: *"You can have the greatest devices. But people will rather be bathed one time less and have a chat, than being in a lonely home with all these technologies"* (participant 5, daughter). Or as participant 19 stated: *"I think technology can be a supporting tool, but the humans should stay in control"*. Interestingly, one of the few male informal caregivers (participant 20) actually preferred an assistive robot over a human caregiver for his father and for himself in the future. He argued that often female formal caregivers carry out intimate tasks such as bathing. The same participant stated that the formal caregivers should not be hold responsible for the care receiver's social involvement: *"People always emphasize the human touch [...], but I think, go visit clubs to get in touch with others. This should not depend on the caregivers"*.

Absence of Perceived Need and Perceived Value. The unfelt need for support was another significant barrier towards AAL technology acceptance. Before even exposing participants to the AAL technology examples, they were asked if they would like any support in their caregiving tasks. The majority (*n* = 17) stated that they would not need any support in their current situation. This can be explained by the fact that most of the participants shared their responsibilities with other family members, and some already received support from formal care services. This unfelt need also surfaced by most participants (*n* = 17) when evaluating the presented AAL technology examples. Several participants (*n* = 9) stated that the care receiver was still independent and healthy enough and would not need a specific AAL tool at the moment. Then again, other participants (*n* = 4) pointed out that the care receiver would be too restricted to benefit from a specific AAL tool, as becomes clear in this statement about the smart wheeled walker: *"This would not be suitable for my mother because she rarely moves outside the house anymore"* (participant 16, daughter). Some informal caregivers (*n* = 5) felt there was no need for a specific AAL tool because they lived nearby and could provide the necessary care themselves or with the support from a formal caregiver. They regarded AAL solutions as more suitable for older adults without a social support system or with family members living at some distance. Others (*n* = 6) stated to be satisfied with their current assistive tool, e.g., personal alarm system.

Self-Efficacy, Technology Experience and Usability. Another barrier towards AAL technology acceptance was technology experience. More than half of the caregivers (*n* = 11) were worried that the care receiver might lack the necessary experience and skills to be comfortable using AAL technologies. The participants emphasized that the care receivers have not grown up with technology and therefore might not be open towards AAL technologies: *"She would not want that. Because she is from another generation and is not at all used to technology"* (participant 2, daughter). The care receivers might even be scared of tools like an assistive robot: *"A robot is scary to people"* (participant 1, son). Also, care receivers might have difficulties handling AAL tools: *"If my mother gets a kitchen like that, all the buttons would drive her crazy"* (participant 17, daughter). A few caregivers (*n* = 2) were also worried about their own technology skills. However, most participants were convinced that technology experience would not be a barrier for them as the next generation of care receivers. Nevertheless, it was emphasized that usability is an important requirement for AAL technologies (*n* = 4).

Reliability and Trust in Technology. Reliability formed another barrier towards AAL technology acceptance. Half of the informal caregivers (*n* = 10) had doubts about the reliability of AAL technologies. Several participants stated that one could not completely trust AAL technologies because they might not work all the time: *"It's technology so it can break down, you can't completely trust these"* (participant 5, daughter). For example, one participant worried about potential accidents when the electronic breaks of the smart wheeled walker would malfunction. This lack of trust was often grounded in previous negative experience with care-related ICT tools. Therefore, several caregivers (*n* = 5) emphasized that they would like to be able to test and experience an AAL tool before using it.

Resistance to Change. Resistance to change was a new barrier mentioned by the informal caregivers. Several participants pointed out (*n* = 7) that the care receivers are not comfortable with new and unfamiliar situations and therefore might be apprehensive towards AAL technologies: *"I doubt that people that age can handle such major changes"* (participant 3, daughter and sister). Participants pointed out that AAL technologies which are based on familiar tools, e.g., adaptive kitchen, will be more acceptable than the unfamiliar tools, e.g., assistive robot.

Contextual Limitations. Additional barriers towards AAL technology acceptance were contextual limitations. Some informal caregivers (*n* = 7) stated that the care receiver's living environment could be problematic for some AAL tools. As one participants pointed out: *"It is all very narrow, so if a robot would need to get through, I see a problem"* (participant 20, son). Another caregiver also found the smart wheeled walker and the intelligent wheelchair less appealing for the care receiver because she lives further outside the city center with everything far away.

Financial Cost. Financial cost was also a barrier of AAL technologies. A few informal caregivers ($n = 5$) were concerned about the potential cost of AAL technologies: *"I think immediately: gosh this costs a lot of money. This is not affordable for the average older adult [...]"* (participant 9, daughter). Therefore, some participants demanded AAL technologies to be affordable enough for the less well-off older adults.

Social Stigma and Pride. Finally, pride was another barrier towards AAL technology acceptance that was mentioned by a few informal caregivers ($n = 2$). These participants stated that the care receiver had already trouble to accept support and therefore would be hesitant towards supporting tools such as AAL technologies.

4.2.5 SHORT CONCLUSION

In accordance with our expectations, almost all informal caregivers in our sample were closely involved in care-related decisions. They were often the ones initiating discussions about care-related issues, and their influence varied from careful phrased suggestion, to a strong advisory role, to making decisions for the care receiver.

The majority of informal caregivers in this second user study had a positive overall opinion about AAL and only four participants were highly critical towards AAL. However, most of them also voiced several concerns and there were some differences in opinion between AAL applications. While the smart wheeled walker was perceived as most acceptable, informal caregivers were most skeptical about the assistive robot. This could be explained by the fact that a traditional wheeled walker is a familiar assistive tool, which was already used by most care receivers. The robot instead, is much more unfamiliar. The statements from the informal caregivers also revealed that the assistive robot is viewed as a replacement of their own human care, while the wheeled walker is regarded as a supplement for support.

Safety; peace of mind; support with daily activities; independence and aging in place; support and unburden caregivers; social connectedness; and health benefits were perceived as drivers towards AAL technology acceptance. In contrast, privacy, intrusiveness and control; loss of human touch; absence of perceived need and perceived value; self-efficacy, technology experience and usability; reliability and trust in technology; resistance to change; contextual limitations; financial cost; and social stigma and pride were considered as barriers towards acceptance. When comparing these findings to the results from the literature review and user study 1, there are many similarities meaning that the acceptance factors could be further validated. This is not surprising, as the informal caregivers in this study did not just consider their own needs, but also spoke as advocates of the care receiver's needs.

Overall, our findings show that, although informal caregivers recognize the potential of AAL technologies, they also have various concerns when it comes to AAL technologies. Considering, that informal caregivers seem to have a strong social influence on the care receivers' opinions and subsequently, could have a positive influence on the decision to adopt AAL technologies, their attitudes, concerns and needs deserve more attention in the AAL community.

4.3 USER STUDY 3

4.3.1 BACKGROUND

User study 2 explored the perceptions and needs of informal caregivers towards various AAL applications. At first glance, most of the acceptance factors were similar to the acceptance factors perceived by older adult participants in user study 1. The aim of this third user study is to include couples of informal caregivers and older adults within the same study, to be able to compare both groups and discover potential subtle differences in their perceptions. The second goal is to gain more insights into the decision dynamics and the social influence of informal caregivers in the process of care-related decision making. Third, similar to the previous user studies, this study contributes to the further validation of the acceptance factors.

4.3.2 PARTICIPANTS

In total, nine Dutch informal caregivers and eight care receivers participated in the second study ($n = 17$). Participants were conveniently sampled in the research assistant's network in the rural Eastern part of the Netherlands. To be included in the sample, informal caregivers had to provide informal care for at least 3 months, and caregiving had to directly result from a close social relationship. Care receivers had to live independently, and receive informal care for at least 3 months, to be considered for inclusion. Snowballing was used to find additional eligible participants. Table 4.4 gives a detailed overview of the background information of the sampled participants.

4.3.3 METHOD

We conducted semi-structured interviews with seven couples of Dutch informal caregivers and older adults. One of these couples included two informal caregivers (IC 3a and 3b) providing joint care for their neighbor as the care receiver (OA 3). In addition, one informal caregiver (IC 8) and one older adults (OA 9) were interviewed without also interviewing their respective care receiver and informal caregiver. During this study, a later iteration of the SONOPA prototype was presented as an example of AAL. The interviews were conducted by a research assistant in the participants' own home environment to create an open and comfortable interview situation. Informal caregivers and older adults were interviewed apart from each other with the exception of two older adults (OA 7 and 5), who preferred to be interviewed together with their caregiver. This already gives an indication of the important role of informal caregivers with regard to care-related topics. In addition, IC 3a and 3b were interviewed together, as they were taking care of the same care receiver.

Each session started with some general information about the purpose of the study, the interview procedure, the consent for recording, and a short demographic questionnaire. After the introduction, the interview started with some general questions regarding the older adult's current and preferred living situation for the future, the current care context, and the experience with (care-related) ICT technologies. In the second part of the interview, participants were introduced to the SONOPA system via different visuals and a detailed verbal description of all subcomponents and their main functionality. In addition, participants viewed a short demo video showing a potential user scenario for SONOPA (https://www.youtube.com/watch?v=WIOZ_Nh6_To).

Table 4.4 Participants' Background in User Study 3

INFORMAL CAREGIVER (IC)*	GENDER	AGE	RELATIONSHIP WITH CR	WORKING SITUATION	IC TASKS **	IC FREQUENCY	ICT EXPERIENCE
1	female	47	daughter	part-time	ds, ps	several times a week	high
2	female	50	daughter	housewife	ds, ps	several times a week	medium
3a	male	61	neighbor	full-time	ds, ps	several times a week	high
3b	female	61	neighbor	housewife	ds, ps	several times a week	medium
4	female	52	in-law	entrepreneur	ds, ps, mc,	several times a day	high
5	female	72	spouse	retired	ds, ps, pc, mc	full-time	low
6	female	46	daughter	part-time	ds, ps,	several times a week	high
7	female	46	daughter	housewife	ds, ps, pc	once a day	high
8	female	42	in-law	part-time	ds, ps	several times a week	high

OLDER ADULT (OA)*	GENDER	AGE	DISTANCE IC	LIVING SITUATION ***	FORMAL CARE**	ICT EXPERIENCE	CARE ICT USE
1	female	82	same town	alone, fh	no	medium	personal alarm
2	female	84	neighboring town	alone, fh	no	low	no
3	female	81	neighbors	alone, fh	no	high	several aids for visual impairment
4	female	80	same premises	alone, fh	yes: pc, dc,	high	no
5	male	71	live together	with spouse, fh	yes: pc, mc	low	personal alarm
6	female	79	same town	alone, fh	yes: dc	low	no
7	female	86	same neighborhood	alone, fh	yes	low	personal alarm
9	female	84	same town & neighboring town	alone, sf	yes, pc, dc	low	personal alarm

Notes: * equal participant numbers refer to the respective informal caregiver/care receiver ** ds = domestic support; ps = psychosocial support; pc = personal care, mc = medical care *** fh = family house, sf = senior flat

Following the demo video, participants were probed to reflect upon their perceptions and attitudes regarding SONOPA and AAL in general.

The sessions lasted about 60–90 min and were recorded and transcribed verbatim for subsequent analysis. Again, thematic analysis was used to analyze the data (Braun & Clarke, 2006). Our approach to data analysis was mainly deductive, using the themes from the literature review and the first two user studies as a pre-defined framework for coding. Similar to the previous user studies, we also looked for new data-driven themes in addition to validating pre-defined themes (inductive approach). A random sample of two interviews (14%) was coded by a second researcher to evaluate the reliability of the identified themes. The interrater agreement between both researchers was 90%.

4.3.4 RESULTS

INFORMAL CAREGIVERS' PERCEPTION

Informal caregivers in the current study were a bit more skeptical than in the first study. Only four informal caregivers (IC 3a, 3b, 7, 8) had an overall positive attitude towards SONOPA and AAL in general. Three of them wanted to use these technologies in their current care situation. The other informal caregivers had mixed attitudes towards SONOPA. Nevertheless, all but one participant could imagine to use some form of AAL in the future when the health of their care receiver would deteriorate. Similar to user study 2, ambient movement sensors were perceived as more acceptable than the visual sensors.

Most of the drivers of AAL acceptance that were discovered in the literature review and user study 2 were also mentioned by the informal caregivers in the current study: **safety** ($n = 7$), **peace of mind** ($n = 7$), **support and unburden caregivers** ($n = 6$), **social connectedness** ($n = 4$), **support with daily activities** ($n = 2$), and **independence and aging in place** ($n = 2$). Similar to user study 2, enhancing the care receiver's safety and providing peace of mind to themselves as well as the care receivers were perceived as the main advantages of SONOPA.
However, there was again some ambiguity in the perception of peace of mind, meaning that SONOPA was also viewed as a potential trigger for concern ($n = 5$): *"On the one hand, it can be less pressure. That you know it is safe. You know if she goes out and goes astray, then we will know. But if you get an overkill of information… this can also cause a lot of pressure I think"* (IC 1). Supporting caregivers was also recognized as an important advantage of SONOPA. This included the coordination between members of the (informal) care network, less face-to-face visits, saving time, relieving the workload and the possibility for agenda management: *"I think something like this may be able to relieve the workload of the informal caregiver. The caregiver doesn't have to visit to check-in. He can check on him or her [the care receiver] in a different way"* (IC 4). Social connectedness was a more prevalent driver than in user study 2. Almost half of the participants appreciated that AAL technologies like SONOPA could stimulate the social connectedness of their care receiver: *"She certainly misses the contact with friends. Maybe this [SONOPA] can support her with this"* (IC 8). Finally, support with daily activities and independence and aging in place were less prevalent drivers, in comparison with user study 2.

With regard to the barriers towards acceptance, most of the barriers from the literature review and user study 2 were also identified by the informal caregivers in the current user study: **absence of perceived need**

and perceived value (*n = 7*), **privacy, intrusiveness and control** (*n = 6*), **self-efficacy, technology experience and usability** (*n = 6*), **reliability and trust in technology** (*n = 3*), **financial cost** *(n = 2*), **loss of human touch** (*n = 1*), and **social stigma and pride** (*n = 1*). Similar to user study 2, the absence of perceived need and perceived value were important barriers towards the acceptance of SONOPA. Most informal caregivers stated that in their current situation, they would not need to use a technology like SONOPA: *"Considering my mother's state at the moment, I think, I don't need this yet"* (IC 1). Privacy, intrusiveness and control were also perceived as important barriers towards the acceptance of SONOPA. Caregivers were concerned about intruding upon the lives of their care receiver: *"I think, as an informal caregiver, I would still feel awkward if I saw this and would interfere with it. Because who am I to tell her that she must move around"* (IC 2). Furthermore, informal caregivers were worried about the technology experience of their care receiver: *"That is a technology that she cannot master"* (IC 6). Another barrier concerned the reliability of the technology. One-third of the informal caregivers had doubts about the reliable functioning of AAL technologies: *"technology can break"* (IC 6). Similar to user study 2, pride and financial cost were less prevalent barriers. Surprisingly, only one informal caregiver had concerns about the loss of human touch. In contrast, informal caregivers from user study 2 regarded loss of human touch as one of the most important barriers. This could be explained by the fact that SONOPA encompasses several features for social connectedness and mutual social awareness.

OLDER ADULTS' PERCEPTION

Only two older adults had an overall positive attitude towards SONOPA and AAL in general (OA 2, 3). One of these older adults (OA 3) already had lots of experience with technological aids due to her visual impairment. However, both participant did not feel the need to use a system like SONOPA at the moment but rather in the future, when their need for support would increase. Three older adults had mixed attitudes towards the presented system (OA 5, 6, 9). These three participants could not imagine to use SONOPA at the moment but might be willing to use it sometime in the future. The other three older adults were rather negative towards SONOPA and AAL in general and could not imagine to use these technologies (OA 1, 4, 7). Similar to the caregivers, **peace of mind** (*n* = 4) and **safety** (*n* = 3) were the most prevalent benefits of SONOPA among the older adults. Older adults felt that the system could give them and their family members peace of mind and make them feel safer in their home: *"A feeling that someone is looking after me"* (OA 2). Another benefit mentioned by OA 2 and OA 3 was that a system like SONOPA could help them to **age independently in their home environment**. OA 3 liked SONOPA's features for **social connectedness**. The same participant also thought that SONOPA could help to detect changes in someone's **health** status early on. Support and unburden caregivers and support with daily activities were not mentioned as benefits by the older adults.

The most prevalent barrier among older adults was the **absence of perceived need and perceived value** (*n* = 8). Even the participants who had a positive attitude towards AAL, felt no need to use the system in their current situation. The second most prevalent barrier towards acceptance was **privacy, intrusiveness and control** (*n* = 7). Participants felt uneasy about constantly being monitored and were afraid that informal caregivers would take too much control over their personal life: *"If you have a sweet tooth, which I have… That they know: oh, my mother has eaten candy again. That's nobody's business"* (OA 3). Five older adults were worried about their **technology experience** and wondered if they would be able to interact with SONOPA: *"Because my cognition keeps deteriorating, and I will get less and less access to this"* (OA 1). **Social stigma and pride** and **financial cost** were also barriers that became apparent among two older adults. Reliability and trust in technology and loss of human touch were not mentioned by the older adults in the current study.

MAIN SIMILARITIES AND DIFFERENCES BETWEEN INFORMAL CAREGIVERS AND OLDER ADULTS

Comparing the results of the two participant groups, informal caregivers were more positive towards SONOPA than the older adults. Almost half of the informal caregivers (*n* = 4) had a positive attitude towards the system, and almost all of them could imagine to use the system in their current situation (*n* = 3) or in the future (*n* = 5). In contrast, older adults were more skeptical towards SONOPA, and only two of them had a positive attitude. Nobody could imagine to use the system in their current situation, and three older adults did not want to use the system at all. Nevertheless, informal caregivers were still very critical towards the presented system, and absence of perceived need and perceived value; privacy, intrusiveness and control; and the care receiver's technology experience were the most prevalent barriers towards acceptance. Older adult's perceived the same barriers, although the unfelt need for support was even more prevalent among the older adults. Overall, informal caregivers mentioned some barriers that were not mentioned by the older adults, such as reliability and trust in technology and loss of human touch. Safety, peace of mind, and support with caregiving tasks were perceived as the most important benefits of SONOPA by the informal caregivers. While safety and peace of mind were also recognized as a benefits by half of the older adults, support for caregiving tasks was not mentioned by this participant group. Overall, it can be concluded that the majority of the older adults did not see much value in a system like SONOPA.

INFORMAL CAREGIVERS' INFLUENCE ON DECISION MAKING

During the interviews, we also wanted to learn more about the informal caregivers' influence on care-related decision making. Similar to the first study, it became clear that the informal caregivers play an important role in care-related decision making. Informal caregivers are often the ones initiating the discussion about care measurements and also have a strong advisory role. Some informal caregivers might even take the decision for the care receiver: *"They can be so stubborn at this age. Then I say well, mom, you cannot do these things anymore, so you have to"* (IC 2). However, most couples of informal caregivers and older adults reported to take care-related decisions together: *"I think I would make an overview of the advantages and disadvantages and then together with my mother-in-law decide what do with it"* (IC 4). Often more than one informal caregivers is involved in this decision making process: *"It is not a decision made by me or my mother alone, this sort of things we decide together"* (IC 7). Several older adults stated they would consider to use SONOPA, if their informal caregivers would ask them to: *"Then we would discuss this, and if they really think that this is also easier for them, then I would agree"* (OA 4).

4.3.5 SHORT CONCLUSION

In line with the findings from user study 2, informal caregivers had an important influence on care-related decisions and several older adults in the current study would consider to use SONOPA, if their family members would advise them to do so.

The informal caregivers in the current study were a bit more skeptical than in user study 2. Only half of them had an overall positive attitude towards SONOPA and only three of them wanted to use a technology like this in their current care situation. This could be explained by the fact that the SONOPA system includes visuals sensors, which were also negatively perceived in user study 2. For the future of AAL technologies, ambient sensors such as PIR sensors seem more promising as they are more likely to be accepted. The older adults in the current study were even more skeptical towards SONOPA. Only two of them had an overall positive attitude. Most of them did not see much value in a system like SONOPA, as they were satisfied with their current care provision.

Safety, peace of mind, and support with caregiving tasks were perceived as the most important benefits of SONOPA by the informal caregivers. While safety and peace of mind were also recognized as benefits by half of the older adults, support and unburden caregivers was not mentioned by this user group. Absence of perceived need and perceived value; privacy, intrusiveness and control; and the care receiver's technology experience were the most prevalent barriers towards acceptance among informal caregivers. Older adults perceived similar barriers, although absence of perceived need and perceived value was even more prevalent among the older adults. Informal caregivers also mentioned some barriers that were not mentioned by the older adults including reliability and trust in technology and loss of human touch.

4.4 OVERALL DISCUSSION

The presented user studies are not without limitations. First, all user studies used visuals, user scenarios or videos to present the different AAL examples to the user groups. Using these materials might provide a somewhat limited view on the advantages and disadvantages of AAL technologies. However, the focus of this study was to assess drivers and barriers in an early acceptance and development phase, rather than investigating actual use experience. Second, as participants were aware of the interviewer's involvement in the SONOPA project, participants might have been hesitant to voice all their concerns and negative perceptions towards the SONOPA technology (user study 1 and 3). We tried to compensate for this potential bias by encouraging participants to voice their honest opinion and by emphasizing that critical comments would help us to improve the SONOPA system. Third, participants in the user studies were sampled in a convenient manner which affects the generalizability of our results. However, overall the same drivers and barriers towards AAL acceptance resurfaced across the three user studies. Moreover, similar drivers and barriers were identified from the literature review, which strengthens our confidence that these acceptance factors are meaningful across a broader population of older adults and caregivers.

4.5 OVERALL CONCLUSION

The aim of these studies was to validate the acceptance factors from the literature within our own user studies and to further explore the underlying aspects, meanings and perceptions of the potential acceptance factors. Table 4.5 shows an overview of the identified acceptance factors.

The remaining chapters will aim to integrate these factors into a theoretical framework (Chapter 5) and validate this framework with a large-scale quantitative survey among a representative sample of the Dutch older adult population (Chapter 6 and 7).

Table 4.5 Overview of the Identified Acceptance Factors from the Literature Review and the Qualitative User Studies

ACCEPTANCE FACTOR	MENTIONED ASPECTS	LITERA-TURE REVIEW	USER STUDY 1	USER STUDY 2	USER STUDY 3
Health (+)	monitoring physiological parameters, detect gradual changes in health status, timely assessment of adverse drug events, fitness tracking, medication management, easy communication with health care providers	X	(X) only medicine and 'detect health problems' was ranked high in sorting tasks	X	(X) only older adults
Safety (+)	detecting and preventing falls or other emergencies, automatic and immediate response, around-the-clock monitoring and monitoring from distance, property security, detection of other safety hazards like gas leaks or fire, overall feeling of safety	X	X	X	X
Support and Unburden Caregivers (+)	physical support: take over caregiver tasks, reduce workload, help caregivers in gaining a holistic understanding of older adult's well-being	X	X	X	(X) only informal caregivers
Peace of Mind (+)	emotional support: providing assurance and peace of mind, reduce concerns (both older adults and caregiver)	X	X	X	X
Social Connectedness (+)	feeling closer to family members, combat social isolation and loneliness, facilitate communication, connect with peers	X	X	X	X
Independence and Aging in Place (+)	age in own home environment, preserve independence	X		X	X
Enjoyment and Leisure (+)	having fun when interacting with AAL, stimulate and facilitate leisure activities	X	X		
Support with Daily Activities (+)	compensate for impairments, support with daily life tasks, reminders	X	X	X	(X) only informal caregivers
Education and Information (+)	acquiring new skills and knowledge, receiving information	X	X		
Self-confidence and Status (+)	feeling of being capable, technology as a status symbol	X			
Privacy, Intrusiveness and Control (-)	loss of privacy, being constantly monitored, data security, interference with normal routine, being patronized, invasion of personal space, no control over technology	X	X	X	X

ACCEPTANCE FACTOR	MENTIONED ASPECTS	LITERA-TURE REVIEW	USER STUDY 1	USER STUDY 2	USER STUDY 3
Loss of Human Touch (-)	fear of technology replacing human care, less face-to-face interaction, create distance between older adult and caregiver, preference to interact with humans over technology	X	X	X	(X) only informal caregivers
Self-Efficacy, Technology Experience and Usability (-)	lack of confidence in technological skills, lack of technology experience, general negative overall attitude/ disinterest in technology, perception that technology is difficult to use	X	X	X	X
Absence of Perceived Need and Perceived Value (-)	unfelt need to use AAL, not a lot of added value, useful for others not for themselves, useful for some distance future no need in current situation	X	X	X	X
Financial Cost (-)	AAL is associated with high financial cost, cannot afford AAL, not willing to spend a lot of money on AAL	X	X	X	X
Social Stigma and Pride (-)	fear of being stigmatized as old, frail and dependent, not wanting to admit the need for support, pride and embarrassment	X	X	X	X
Reliability and Trust in Technology (-)	perception that AAL is unreliable, no trust in technology, concerns about false alarms	X	X	X	(X) only informal caregivers
Health Concerns (-)	electromagnetic radiation, allergic reactions (wearable), additional stress, decrease activity	X	X		
Burden Caregivers (-)	put additional burden and responsibility on caregivers, more emotional stress	X		X	(X) only informal caregivers
Contextual Limitations (-)	technology might not work in all domestic environments		X	X	
Resistance to Change (-)	being uncomfortable with new and unfamiliar situations			X	

APPENDIX 4A: SONOPA USER SCENARIOS OF USER STUDY 1

SCENARIO 1

Mr. Smith is 71 years old and is quite comfortable living alone at his home, but recently, he is prone to feeling a little depressed. His friends live some distance away, and he rarely gets to see them because of his increasing mobility problems.

Fortunately, his family told him about SONOPA with its cleverly designed social networking technology developed for people just like him. It will help Mr. Smith continue to enjoy living in his home, by promoting suitable activities and keeping him in contact with his friends. Furniture sensors, a smart screen, automatic door openers, movement detectors and an optional camera are installed in Mr. Smith's home. These will help provide a quick response in case of a fall or other accident. In this way the SONOPA system provides the peace of mind that Mr. Smith, and especially his family, really appreciate.

Mr. Smith creates a profile on SONOPA by providing a few personal details and a list of personal activity interests. SONOPA uses these to introduce him to other elderly people with similar interests who live close by. The sensors in his house create an activity profile for Mr. Smith and SONOPA monitors when his activity level falls below his normal level. Perhaps Mr. Smith has spent a lot of time watching television and may be feeling a little low. SONOPA identifies this as a good time to introduce Mr. Smith to Mrs. Wilson through the smart screen in his home. Mrs. Wilson used her SONOPA profile to indicate that she, like Mr. Smith, enjoys watching TV documentaries and playing stimulating games like chess. They agree to meet for a game of online chess and SONOPA updates their contact lists with each other's details.

By meeting each other through SONOPA Mr. Smith and Mrs. Wilson become better acquainted and share more activities, both through SONOPA and by meeting together. Mr. Smith also keeps in touch with his family and his distant old friends using SONOPA's video conferencing feature. Mr. Smith finds that with the help of SONOPA he has rekindled old interests and is enjoying them with new friends and simply doesn't have time to feel depressed or lonely anymore.

SCENARIO 2

When it comes to mealtimes Mr. Smith doesn't enjoy cooking as much as he used to, it has become more of a burden than a joy and he has slowly lost interest in this routine task. Because of this his skills in the kitchen have diminished.

Fortunately, SONOPA has a shared cooking application. As soon as Mr. Smith enters the kitchen to prepare lunch, the smart sign in the kitchen switches on and the application recommends some basic recipes and provides him with a step-by-step guide for cooking.

The social network infrastructure also displays a list of his friends in the neighborhood who are also in the kitchen at that moment. Mr. Smith notices that his new friend Mrs. Wilson, who is an excellent cook, is also busy preparing a meal.

Through the video conferencing unit he asks her for some advice for preparing a stew, as a result they discover that they both enjoy cooking together and decide to meet for lunch in Mrs. Wilson's home to enjoy the stew together.

But before he leaves his house SONOPA reminds Mr. Smith which medication he has to take with his lunch. Mr. Smith & Mrs. Wilson discuss further recipes that they could try together while they enjoy the stew that Mr. Smith has prepared for lunch. Mr. Smith enjoys preparing food again, thanks to SONOPA providing the missing ingredient.

PART III

Towards a Model of AAL Acceptance

5
Introducing the Model of AAL Acceptance

Parts of this chapter have been presented at:

Van Dijk, J. A. G. M., Ben Allouch, S., De Graaf, M. M. A., & **Jaschinski, C.** (2018). Toward a Process Model for Selection of Theories of Technology Acceptance. Paper presented at the *2018 Annual International Communication Association Conference.* Prague, Czech Republic.

In Chapter 3 and 4, a literature review and several qualitative studies were presented that explored the attitudes and perceptions of older adults and their caregivers towards AAL technologies. Based on these findings, different factors that drive or hinder the acceptance of AAL applications could be identified. At this point however, these results are an accumulation of potential acceptance factors, without a deeper theoretical understanding of the underlying psychological and behavioral mechanisms that cause these factors to be meaningful.

Hence, this chapter will look at relevant theories regarding technology acceptance behavior with the aim to develop a well-grounded understanding of the user's acceptance process. Together with the results from the qualitative studies, these insights will be translated into a theoretical framework for the acceptance of AAL technologies that concludes with the introduction of the conceptual model of AAL acceptance (RQ 3).

5.1 TECHNOLOGY ACCEPTANCE AS A MULTI-STAGE PROCESS

With the digitalization of all areas of our society and the rapid pace technology is evolving, technology acceptance is a topic of interest for many academic disciplines ranging from social sciences (e.g. sociology, psychology), to formal sciences (e.g., information systems, human-computer interaction), to applied sciences (e.g., communication sciences, media studies, educational technology, health sciences). Research on technology acceptance leads to important implications for the development, implementation, regulation and use of technology across various contexts. Due to the interest from many academic fields, there are different views on how technology acceptance should be understood. This is also reflected in the various models that have been proposed to explain technology acceptance.

We argue that technology acceptance should be considered as a process over time that consists of several stages of acceptance. Karahanna, Straub, and Chervany (1999) point out that the majority of acceptance research ignores the temporal dimension of the acceptance process, although acceptance factors might change over time. Indeed, the results of their study indicate that the meaningfulness of acceptance factors might differ before and after using a technology. Similar findings where obtained by P. J. H. Hu, Clark, & Ma (2003) who found that a richer set of factors is considered for the initial adoption decision, and only some factors remain meaningful for continuous use. In the following we will propose five stages of acceptance that are visualized in Figure 5.1. This model is based on earlier work on the multiple stages of acceptance by (Ben Allouch, 2016; De Graaf, Ben Allouch, & Van Dijk, 2016; Van Dijk, Ben Allouch, De Graaf, & Jaschinski, 2018; Karapanos, Zimmerman, Forlizzi, & Martens, 2009). The model is also based on the work of E. M. Rogers (2003) (Diffusion of Innovations Theory), Hirsch and Silverstone (2003), and Silverstone and Haddon (1996) (Domestication Theory) who also emphasized the temporal dimension of technology acceptance. Moreover, Hirsch and Silverstone (2003) and Silverstone and Haddon (1996) emphasize the role of the user in shaping the technology (Hynes & Richardson, 2009).

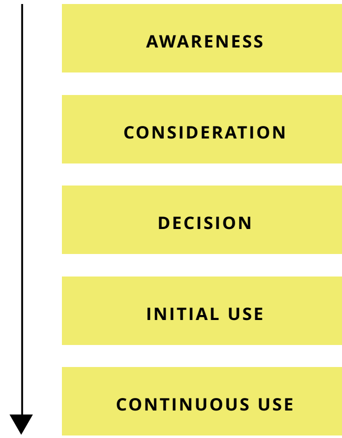

Figure 5.1. Multi-stage Process of Technology Acceptance

AWARENESS

The first step towards technology acceptance is the potential user becoming aware of a technology. This first exposure to a new technology can occur through media, the social environment or direct exposure. For example, a person might read about a new technology on the internet or being introduced by friends or other members from the social circle to a new technology.

CONSIDERATION

After being aware of a technology, the potential user might start the consideration phase in which the user assesses his/her need for a technology and weighs potential positive outcomes of using a technology against potential negative outcomes. These outcomes can be instrumental as well as affective in nature *(Do I need this? Will I enjoy using this? What will happen when I use this? What are the benefits/risk of using this?)*. Using a technology might also be reflected against personal norms and values and social expectations *(Is this something that I would use? What will other people think? Do other people use this?)*. Other considerations include potential personal and practical constrains *(Will I be able to use this? Can I afford this? Will this work in my home?)*. To aid this deliberation process and reduce uncertainty, the potential user is likely to gather information about the technology and consult members from his/her social environment for their opinion. The potential user might also actively seek initial use experience either by trying himself/herself or by observing others. At the end of this stage, the potential user has formed expectations and attitudes towards using the technology which is eventually translated into the explicit intention to use or reject a technology.

DECISION

At this stage the intention is transformed into the explicit action of acquiring the technology. This stage also includes actions required in preparation of this decision, such as planning when, where and how to obtain a technology as well as getting the necessary financial resources or infrastructure in place to use the technology. The decision to use a technology might not always be made by the user alone. In the context of AAL, caregivers could be involved in the decision making process. Indeed, our qualitative studies revealed that informal family caregivers were closely involved in care-related decision making. This involvement ranged from carefully phrased suggestions to taking a decision for the older adults. The risk of deciding for the older adult and without involving him or her in the consideration and decision making process is that the technology will be rejected. In our qualitative studies we heard several stories of mobile phones or tablets that were given as a present by well-meaning family members but eventually ended up in a drawer.

INITIAL USE

After acquiring a technology, the user might start using the technology in his/her own environment. At this stage the technology is still new and exciting and the user has to familiarize with the technology and learn how to use it. At this stage the user explores if the technology meets his prior expectations and starts adapting the technology to his/her personal needs and wishes. If the technology does not fit prior expectations, e.g., does not bring the expected benefits, is too complicated to use or has unexpected negative effects, it's likely that the user will reject the technology after all and will stop using it. Another potential reaction to unmet expectations and needs is modification. E. M. Rogers (2003, p.180) describes this as reinvention *"the degree to which an innovation is changed or modified by a user in the process of its adoption"*. Indeed, Greenhalgh et al. (2013) found that successful technology arrangements in the homes of older adults were often subject to *"bricolage"* (p.92): the pragmatic customization, adaption and integration of new devices or components with the existing infrastructure in the home. If, after initial use and potential modifications, the technology is perceived to have additional value and positively contributes to the user's daily life, it's likely that initial use is transformed into continuous use.

CONTINUOUS USE

At this stage the technology is used on a regular basis and over a longer period of time. Users have developed a use routine and the technology is integrated into their everyday life. Further shaping, adaptions and modifications might occur for optimal fit with the personal needs and daily practices. In some cases users become emotionally attached to a technology or even use the technology as an expression of their personal identity. At this stage, the long-term effects of using and interacting with a technology become visible, such as changes in behavior routines, communication patterns and social interactions. Rejection or discontinuance can still occur, for example if an improved version of the technology enters the market, if unforeseen long-term effects occur, or if the technology does not longer fulfill the user's needs. In case of AAL, older adult's support needs might change over time, and if a technology is not able to adapt to these changes, discontinuance is likely to occur.

It should be noted that the stages described above are neither clear-cut nor strictly linear. For example, a first consideration cycle can initially lead to rejection, but a second exposure can trigger a new consideration process. Furthermore in case of low technology readiness, a first consideration cycle might be based on abstract ideas and limited experience with the technology. As the technology matures, expectations become more salient and it's likely that a second or third consideration cycle occurs before a decision is made to use or reject a technology. Hence, the process of full acceptance and integration of a technology into everyday life can take months or even years (Van Dijk et al., 2018).

The current research focuses on the early stages of the acceptance process, specifically the consideration stage. Due to its novelty and the overall low technology readiness (mostly pilot stage) (Liu et al., 2016), we suspect that most users have limited knowledge and experience with AAL technologies. Nevertheless, we argue that for AAL technologies to be embraced in the future, it is crucial to get an early insight into the users' expectations towards AAL. More specific, we are interested in how these expectations inform the users' beliefs, attitudes and initial use intentions *(consideration stage)*. These insights into early acceptance can shape the further development, implementation and regulation of AAL technologies. As Van Dijk et al. (2018) underline, without exploring these early stages of acceptance we cannot know if a technology falls on fertile ground and is actually needed and asked for. Indeed, Vines, Pritchard, Wright, Olivier, and Brittain (2015) call for more human-computer interaction research to engage and understand older adults prior to design and development of technologies.

With this focus in mind, we will review popular theories and models of technology acceptance research and explore their adequateness for understanding early acceptance of AAL. Van Dijk et al. (2018) argue that the well-known theories of technology acceptance are not fully appropriate to cover the complete process of technology acceptance, but each theory is most appropriate for particular stages. While some theories are more appropriate for the early acceptance stages that lead up to the decision to use a technology, other theories are more appropriate to explain initial and sustained use. The choice of the theory also depends on the maturity the technology that is the subject of research. For example, although use experience with prototype technologies can be simulated in laboratory settings and in-home field trials, the ecological validity of this use experience is still low. Hence, theories that focus on initial and especially sustained use are more valid for mature technologies that users have already acquired and have used on a regular basis.

5.2 REVIEW OF EXISTING THEORIES AND MODELS OF TECHNOLOGY ACCEPTANCE AND HUMAN BEHAVIOR

Various theories and models have been proposed to understand and explain technology acceptance. In this section, we take a critical look at some of the popular theories and models from technology acceptance and behavioral research and discuss whether the theory forms a good theoretical foundation to understand and explain why user might accept or reject AAL technologies in an early acceptance stage.

5.2.1 DIFFUSION OF INNOVATIONS (DOI)

The 'Diffusion of Innovations' (DoI) theory is usually attributed to the American sociologist Everett M. Rogers who made the theory popular in 1962, by publishing a book with the same title (E. M. Rogers, 1962). DoI seek to explain how and why an innovation spreads and is adopted among members of a social system. Rogers defines diffusion as *"the process through which an innovation is communicated through certain channels over time among the members of a social system"* (E. M. Rogers, 2003, p.5). Thus, diffusion centers around four main elements: (1) *the innovation*; (2) *communication channels*; (3) *time* and (4) *the social system*. An *innovation* can concern an idea, an object or a practice that is perceived as new including technological innovations. *Communication channels* are the means by which the innovation is diffused. *Time* is reflected in the innovation decision process, the innovativeness of an individual (or other decision making units) and the innovation's rate of adoption within a social system. A *social system* can consist of individuals, informal groups, organizations or subsystems (E. M. Rogers, 2003).

Unlike other technology acceptance theories, DOI considers the decision about an innovation as a process over time. Rogers describes different phases in the decision making process towards adopting an innovation. Adoption is here defined as *"a decision to make full use of an innovation as the best course of action available"* (E. M. Rogers, 2003, p.177). The process starts with *knowledge* of the innovation's existence. In the *persuasion* phase the individual forms a favorable or unfavorable attitude towards the innovation which leads to the *decision* to adopt or reject the innovation.
The *implementation* phase is concerned with the actual application or use of the innovation. Here, *reinvention* can occur, meaning that the user might change or modify the innovation to some degree in the process of its adoption and implementation. Finally in the *confirmation* phase the individual seeks information that supports the adoption decision. At this point the decision to adopt or reject might also be reversed. Rogers describes this whole process and information-seeking and information–processing activity with the aim to gradually reduce uncertainty about an innovation (see Figure 5.2) (E. M. Rogers, 2003).

Individuals and other decision making units differ in their level of *innovativeness* or the relative earliness in adopting an innovation. Rogers distinguishes between five *adopter* types according to their levels of innovativeness: *innovators, early adopters, early majority, late majority, and laggards.* While innovators actively search for new ideas and are the first who adopt an innovation within a social system, laggards are usually conservative and suspicious towards innovations and are the last ones to adopt an innovation (E. M. Rogers, 2003).

According to DOI, the likelihood and speed at which an innovation is adopted also depends on several perceived attributes of the innovation: (1) *Relative advantage:* the extent to which an innovation is considered superior to an existing idea, product or practice; (2) *Compatibility:* the extent to which an innovation fits the personal values, experiences and needs of the potential user; (3) *Complexity:* the extent to which the innovations is considered to be difficult to understand or complicated in use; (4) *Trialability:* the extent to which an innovation can be experimented with; (5) *Observability:* the extent to which the effects of an innovation are visible to others (E. M. Rogers, 2003).

An Innovation diffuses through different communication channels such as mass media, interpersonal communication or interactive communication. Diffusion research shows that most people rely on the subjective evaluation of near-peers in adopting an innovation making diffusion a social process (E. M. Rogers, 2003)

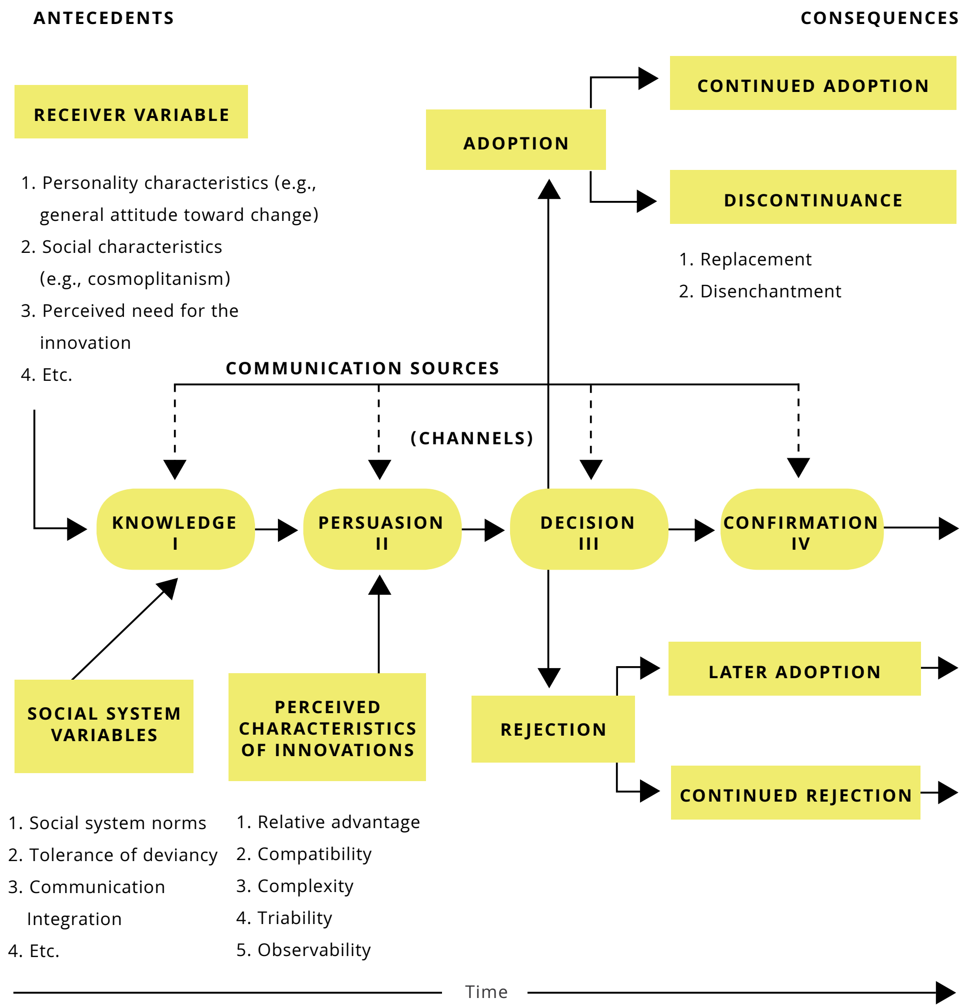

Figure 5.2. Diffusion of Innovations (reproduced from E. M. Rogers, 1995, p.165)

RELEVANCE OF DOI

With regard to the relevance for understanding the acceptance of AAL technologies, DOI has been a prominent theory in related fields, such as health promotion and health-related interventions. It has been used as a theoretical basis to study different health-based (technological) innovations at an individual (e.g. Chew, Grant, & Tote, 2004; Emani et al., 2012; Lee, 2004), organizational (Castle, 2001), or broader societal level (e.g. Helitzer, Heath, Maltrud, Sullivan, & Alverson, 2003). The ADOPT (Accelerating Diffusion Of Proven Technologies) model has used a diffusion of innovations perspective to develop a framework for technology diffusion of home and community-based health technologies for older adults. Technologies included remote patient monitoring, medication optimization and electronic health records (Wang, Redington, Steinmetz, & Lindeman, 2011). Moreover, DOI provides a comprehensive approach to technology acceptance by acknowledging the temporal dimension and including individual, social and technological factors. This is in line with our findings from the literature and our own qualitative studies that identified various individual, social and technological variables that are meaningful for AAL acceptance. Finally, according to Van Dijk et al. (2018), DOI is appropriate to study the stages of early acceptance that lead up to the decision to use a technology.

LIMITATIONS OF DOI

Despite its popularity in various academic fields, DOI has also been criticized.
One weakness of DOI is labeled pro-innovation bias and is also acknowledge by Rogers himself (2003). The pro-innovation bias entails that all innovations are regarded as positive and should be diffused and adopted by all members of society. This leads to a blind spot among researchers to look deeper into reasons for rejection and discontinuance of innovations (MacVaugh & Schiavone, 2010). Indeed, Greenhalgh, Robert, Macfarlane, Bate, and Kyriakidou (2004) found that from their 200 reviewed empirical studies only one explicitly studied discontinuance. Another point of criticism is that DOI lacks a strong theoretical understanding of human behavior that fully captures the psychological and behavioral mechanisms which lead to the adoption decision (Greenhalgh et al., 2004; LaRose, Gregg, Strover, Straubhaar, & Carpenter, 2007). According to Greenhalgh et al. (2004), DOI research often reduces individual factors to the popular adopter categories, which are

> *"stereo-typical and value-laden terms, which fail to acknowledge the adopter as an actor who interacts purposefully and creatively with a complex innovation"* (p. 598).

Third, several researchers argue that Roger's innovation characteristics might not be inclusive, meaningful and applicable across all innovations, contexts and users (Greenhalgh et al., 2004; Lyytinen & Damsgaard, 2001).

Despite its strong research tradition and comprehensiveness, it was decided to reject DOI as a theoretical starting point for the following reasons: (1) We agree with Greenhalgh et al. (2004) and LaRose et al. (2007) that as a sociological theory, DOI lacks deeper theoretical insights on the individual underlying psychological and behavioral mechanisms of acceptance behavior. These insights are crucial to fully understand why an individual might or might not accept AAL technologies and, in turn, translate these findings into meaningful recommendations for the development, implementation and regulation of AAL. (2) Following Greenhalgh et al. (2004), we perceive the categorization of adopters type as stereotypical and value-laden. DOI researchers would most likely categorize older adults as late majority or laggards. Earlier research has shown that such stereotypical perceptions do not adequately reflect the older adults' individual lifestyle, needs and expectations (Eisma et al., 2004; Östlund, 2005; Peine et al., 2014; Vines et al., 2015). (3) We share the view of Greenhalgh et al. (2004) and Lyytinen and Damsgaard (2001) that the DOI's innovation characteristics are not universally applicable and inclusive enough to understand the complex and dynamic context of AAL acceptance. (4) Finally, DOI is relatively complex and difficult to operationalize in comparison with other technology acceptance approaches.
In consequence, earlier research has often applied and validated specific elements of DOI instead of applying a comprehensive and time-sensitive approach, thereby neglecting some of the crucial characteristics of the theory in the validation process and providing only partial evidence for its validity.

5.2.2 TECHNOLOGY ACCEPTANCE MODEL (TAM)

One of the most influential models in technology acceptance research is the Technology Acceptance Model (TAM). TAM was first introduced by Davis in 1986 and further popularized through the well-cited publication of Davis, Bagozzi, and Warshaw (1989). TAM originates from information systems (IS) research and was originally developed to explain user acceptance of information technology (IT) in an organizational context. The theoretical foundation of TAM originates in the Theory of Action (TRA) (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). According to TRA, a person's salient beliefs about the consequences of a certain behavior determine the attitude towards the behavior, which in turn (together with subjective norm) influences the intentions to perform the behavior. Intention then predicts actual behavior. TAM has adopted this belief-attitude-intention-behavior relationship from TRA but proposes only two key beliefs that are relevant for IT acceptance across different IT applications, user populations and organizational contexts: perceived usefulness (PU) and perceived ease of use (PEOU).
PU is defined as the *"the degree to which a person believes that using a particular system would enhance his or her job performance"* (Davis, 1989, p.320) and PEOU is defines as *"the degree to which a person believes that using a particular system would be free of effort"* (Davis, 1989, p.320). Thus, in TAM attitude originates in two key beliefs, perceived usefulness (PU) and perceived ease of use (PEOU).

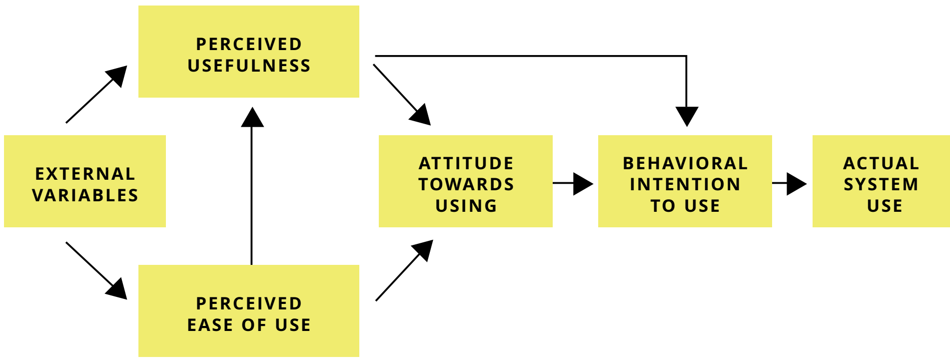

Figure 5.3. Technology Acceptance Model (TAM) (reproduced from Davis et al., 1989, p. 985)

TAM also posits that PEOU influences PU and that PU has a direct influence on the intention to use IT (see Figure 5.3). Later TAM 2 (Venkatesh & Davis, 2000) and TAM 3 (Venkatesh & Bala, 2008) have been introduced.

Since its introduction, TAM or extensions of TAM have been applied across different academic disciplines and contexts, extending well beyond its initial scope of acceptance of IT systems in an organizational setting. Applications and services which were subject of research included among others, personal computing (Igbaria, Zinatelli, Cragg, & Cavaye, 1997); e-mail (Karahanna & Straub, 1999); internet (Moon & Kim, 2001); e-commerce (Pavlou, 2003); wireless internet via mobile devices (Lu, Yu, Liu, & Yao, 2003); social media (Rupak, Rawski, Yang, & Johnson, 2014) and virtual reality (Bertrand & Bouchard, 2008). While the focus was initially on an organizational context, later studies applied TAM in a personal use context (e.g., Lu et al., 2003; Moon & Kim, 2001; Pavlou, 2003; Rupak et al., 2014).

RELEVANCE OF TAM

Concerning its applicability for the AAL domain, TAM has been used with older adult users (e.g., Conci, Pianesi, & Zancanaro, 2009; McCloskey, 2006; Nayak, Priest, & White, 2010) and to study the acceptance of healthcare technologies among professionals (see Holden & Karsh, 2010 for an overview). Although less frequently, TAM has also been used to investigate acceptance of healthcare technologies among patients (e.g. Wilson & Lankton, 2004). Moreover, TAM is parsimonious, has robust measurements and consistently shows good explanatory power for technology acceptance behavior (Holden & Karsh, 2010; Venkatesh, 2000; Venkatesh, Davis, & Morris, 2007). Finally, according to Van Dijk et al. (2018), TAM is appropriate to study the stages of early acceptance that deal with an individual's expectations, feelings, perceptions and attitudes and that lead up to forming a use intention.

LIMITATIONS OF TAM

Despite its major influence on technology acceptance research, several shortcomings have been identified. TAM has been criticized for its overreliance on PU and PEOU that has led to the neglect of other important factors such as potential antecedents of PU and PEOU. These antecedents could provide a deeper theoretical understanding of what causes a technology to be perceived as useful or easy to use (Benbasat & Barki, 2007; Y. Lee, Kozar, & Larsen, 2003). Following this line of argumentation, TAM provides little valuable and insightful information for developers and facilitators of technology beyond the fact that what is developed has to be useful and easy to use (Benbasat & Barki, 2007; Y. Lee et al., 2003; Mathieson, 1991). Other factors which have been overlooked by TAM include the social and cultural aspects of decision making (Bagozzi, 2007; Y. Lee et al., 2003). According to Bagozzi (2007), technology acceptance decisions are often performed collaboratively or are influenced by social and group norms. Moreover, TAM does not pay attention to what happens once the technology is in use such as learning, reinvention and integration into daily life (Benbasat & Barki, 2007). Indeed, several researchers have suggested that acceptance factors might change over time (De Graaf et al., 2016; P. J. H. Hu et al., 2003; Karahanna et al., 1999; Karapanos et al., 2009). Finally, originating in an organizational context, TAMs core factor PU mainly emphasize the extrinsic utilitarian value of technologies but intrinsic values (e.g. enjoyment) and emotions (e.g. technology anxiety) were neglected in the original TAM model (Bagozzi, 2007; Venkatesh, 2000). Although later versions of TAM (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000) and the numerous extensions try to address these issues, critics pertain that TAM has been broadened rather than deepened, and extensions have not been grounded in theory (Bagozzi, 2007). As Benbasat and Barki conclude (2007, p. 212):

> *"efforts to 'patch-up' TAM in evolving IT contexts have not been based on solid and commonly accepted foundations, resulting in a state of theoretical confusion and chaos".*

Despite several advantages, TAM was not chosen as a theoretical foundation for several reasons: (1) We agree with TAM critics that its predominant focus on PU and PEOU and the utilitarian value of technology provides little room for other salient beliefs that we identified in our own qualitative user studies and other AAL research. (2) TAMs provides little direction for the design and practice of AAL, which is one of the goals of this dissertation (3) TAM neglects the social context of technology acceptance decisions, although our own qualitative studies and previous work in the AAL field showed that caregivers play a crucial role in decision making. These studies also discovered that older adults might be concerned about the opinion of the social environment when using assistive technologies.

5.2.3 UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) was introduced by Venkatesh, Morris, Davis, and Davis in 2003. The goal of UTAUT is to synthesize acceptance factors from eight prominent acceptance models in IT acceptance research including Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975); Motivational Model (MM) (Davis, Bagozzi, & Warshaw, 1992); Technology Acceptance Model (TAM) (Davis, 1986; Davis et al., 1989); Theory of Planned Behavior (TPB) (Ajzen, 1991); Combined model of TAM and TPB (Taylor & Todd, 1995a); Model of PC Utilization (MPCU) (Thompson, Higgins, & Howell, 1991); constructs inspired by the innovation characteristics from diffusion of innovations theory (Moore & Benbasat, 1991) and a model based on Social Cognitive Theory (SCT) (Compeau & Higgins, 1995). According to UTAUT, the four core determinants in the acceptance of IT are: performance expectancy, effort expectancy, social influence and facilitating conditions. Definitions for performance expectancy and effort expectancy are similar to TAM's perceived usefulness and perceived ease of use respectively. The definition of social influence is similar to the construct subjective norm from TPB (see 5.2.5). Facilitating conditions is defined as *"the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system"* (Venkatesh et al., 2003, p. 453). UTAUT proposes a direct relationship between performance expectancy, effort expectancy, social influence and behavioral intention and drops attitude as a mediating construct. Following TRA, intention is a direct predictor of use behavior. Facilitating conditions is also proposed as a direct predictor of use behavior. Furthermore, age, gender, experience and voluntariness of use are considered as moderating factors in UTAUT (see Figure 5.4). Later, UTAUT 2 (Venkatesh, Viswanath., Thong, James, Y.L. & Xu, 2012) was introduced to study acceptance in a personal use context.

RELEVANCE OF UTAUT

With regard to its relevance for AAL acceptance, UTAUT has been tested with older adult users (Niehaves & Plattfaut, 2013; Pan & Jordan-Marsh, 2010) and has also been applied to technologies from the healthcare domain (e.g., BenMessaoud, Kharrazi, & MacDorman, 2011; De Veer et al., 2015; Liu et al., 2014; Maillet, Mathieu, & Sicotte, 2014). The Almere model (Heerink et al., 2010) used UTAUT as a theoretical foundation to explain the acceptance of assistive social agents among older adults. Moreover, UTAUT offers a more holistic approach to technology acceptance than TAM by including the variables social influence and facilitating conditions and taking into account individual and contextual moderators such as age, gender, experience and voluntariness. Moreover, UTAUT is attributed with a high explained variance (Venkatesh et al., 2003). Finally, according to Van Dijk et al. (2018), UTAUT is appropriate to study the stages of early acceptance that deal with the individual's expectations, affections, feelings, perceptions and attitudes and that lead up to the use intention.

LIMITATIONS OF UTAUT

The main critique of UTAUT is that it is an eclectic model that used a statistical approach to select factors from various existing theories, rather than build on a strong theoretical foundation. While this approach increases the models explained variance, it does offer little theoretical advancement in understanding technology acceptance behavior (Bagozzi, 2007; Tsai & LaRose, 2015). Moreover, Van Raaij and Schepers (2008) point out that UTAUTs high explained variance is only achieved when the moderators are included, which is at the expense of the models parsimony. Indeed, Rana, Dwivedi, and Williams (2015) found in their meta-analysis that the majority of UTAUT studies excluded the moderators and explained an average of 39% in variance. This is in contrast to UTAUT's superior 69% in the original study (Venkatesh et al., 2003). When disregarding the moderators, UTAUT is essentially an oversimplified version of TPB (Benbasat & Barki, 2007). Finally, like TAM, UTAUT originates in an organizational context, includes its core construct PE and PEOU, and measures them in a similar generic manner. This leads to the same problems of mainly emphasizing the utilitarian value of technologies and providing little meaningful information about why a technology is considered to be useful (LaRose et al., 2012).

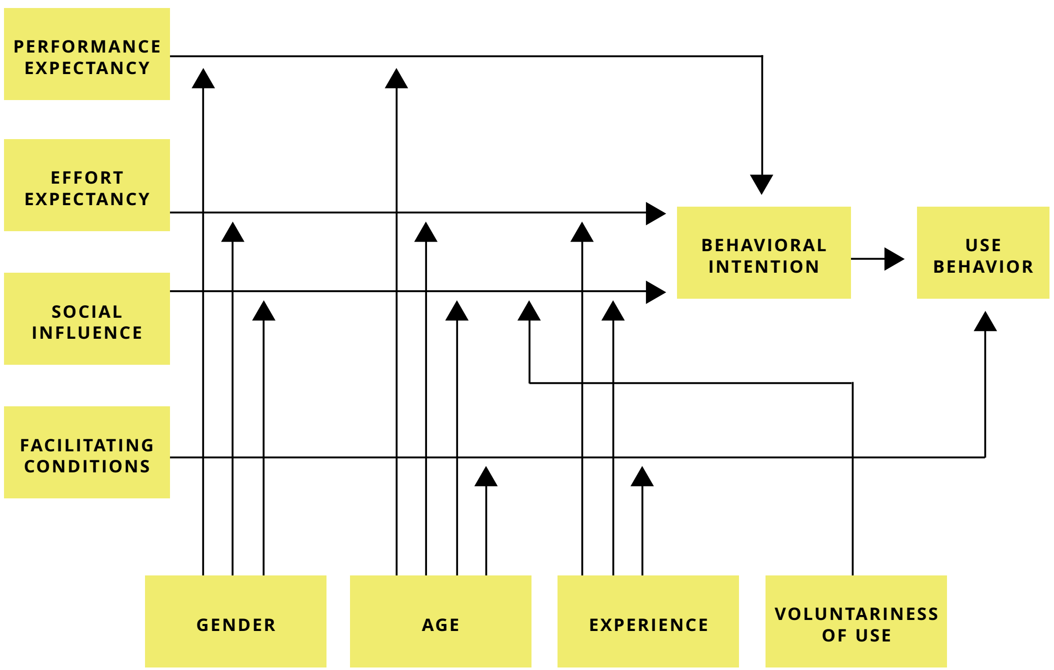

Figure 5.4. Unified Theory of Acceptance and Use of Technology (UTAUT) (reproduced from Venkatesh et al., 2003, p. 447)

We chose against using UTAUT as a theoretical basis because we agree that it lacks a strong theoretical foundation (Bagozzi, 2007; LaRose et al., 2012; Tsai & LaRose, 2015). We also think that UTAUT does not provide enough insight into the psychological and behavioral mechanisms of technology acceptance that are necessary to provide meaningful implications for the future of AAL technologies.

5.2.4 SOCIAL COGNITIVE THEORY

Social Cognitive Theory (SCT) is an overarching theory of human behavior and stems from the field of psychology. SCT depicts human behavior as a triadic reciprocal causation of behavior; cognitive, affective and biological events; and environmental influences. It advocates an 'agentic perspective', meaning that humans are self-organizing, proactive, self-reflecting, and self-regulating rather than just reactive to environmental influences or inner impulses. SCT specifies several capabilities which are distinct to human behavior (Bandura, 1986, 1999; Bandura & Erlbaum, 2001):

(1) **Symbolization** refers to the human capability to transform experiences into cognitive models and attribute them with meaning, form and continuity.
(2) **Vicarious Capability** refers to the human capability to learn by observing others and the consequences of their actions.
(3) **Forethought** refers to the human capability to anticipate the outcomes of one's actions. Individuals use their forethought to set goals, plan actions and adapt their behavior to achieve the desired outcomes while avoiding unpleasant consequences.
(4) **Self-Regulation** refers to the human capability of regulating one's own behavior through internal standards and self-evaluative reactions.
(5) **Self-Reflection** refers to the human capability to reflect on the validity and appropriateness of one's thoughts and actions.

According to SCT, self-efficacy is an essential determinant of human motivation and behavior. It can be defined as *"people's judgment of their capabilities to organize and execute courses of action required to attain designated types of performances"* (Bandura, 1986, p. 391). Self-efficacy regulates human motivation through the goals people set out to achieve, the commitment to these goals, the outcomes they expect, and the level of perseverance in the face of obstacles and set-backs when pursuing a goal (Bandura, 1997, 1998). According to Bandura (1998), self-efficacy beliefs can be strengthens in the following ways: (1) personal achievements (mastery experience); (2) achievements by 'social models' (vicarious experience); (3) encouragement by others (social persuasion); (4) a positive emotional and physical state. Another core construct in SCT are outcome expectancies. This construct describes an individual's beliefs about the likely consequences of his/her actions. While positive outcome expectancies form incentives for behavior, negative outcomes expectancies function as disincentives. Beliefs about the expected outcomes can be either grounded in one's own direct experience (enactive learning) or through observing others (observational or vicarious learning) (Bandura, 1986, 1997).

While outcome expectancies are an important predictor of human motivation and action across different types of behavior, the conceptualization and operationalization of outcome expectancies is inconsistent and seems to strongly depend on the application context. Looking at the field of technology acceptance, Compeau and Higgins (1995) found two underlying dimensions for outcome expectancies for computer use, namely performance-related outcome expectations and personal outcome expectations. The Model of Media Attendance (MMA) (LaRose & Eastin, 2004) mainly focuses on the positive outcome expectancies for internet usage. MMA distinguishes between six dimensions: status, activity, self-reactive, social, novel sensory, and monetary. Those dimensions were also applied in the context of social network use (Khang, Han, & Ki, 2014) and mobile phone use (Peters, 2008). The MMA is displayed in Figure 5.5. In a health behavior context Bandura (1998, 2004, p.144) specifies three dimensions: (1) physical: pleasurable and aversive effects of the behavior and the accompanying material losses and benefits; (2) social: social approval and disapproval the behavior produces in one's interpersonal relationships (3) self-evaluative: the positive and negative self-evaluative reactions to one's behavior. Bandura's proposed socio-cognitive causal model is displayed in Figure 5.6.

RELEVANCE OF SCT

SCT is a prominent theory in health behavior research (Painter, Borba, Hynes, Mays, & Glanz, 2008). Other socio-cognitive models have been successfully applied in the technology acceptance field (Compeau & Higgins, 1995; Khang et al., 2014; LaRose et al., 2012; LaRose & Eastin, 2004). SCT has also been used to develop technology-based interventions for improving health behaviors (Hageman, Walker, & Pullen, 2005; Riley et al., 2011). The strength of SCT is that, in contrast to TAM, UTAUT and DOI, it offers an overarching and in-depth theoretical understanding of human behavior. As a broad theory of human behavior, SCT can be applied

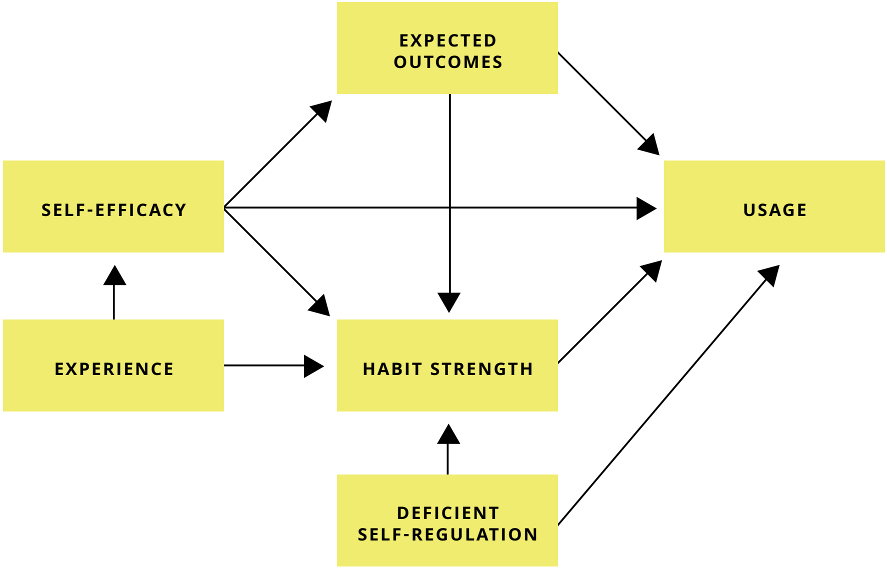

Figure 5.5. Model of Media Attendance (reproduced from LaRose & Eastin, 2004, p. 366)

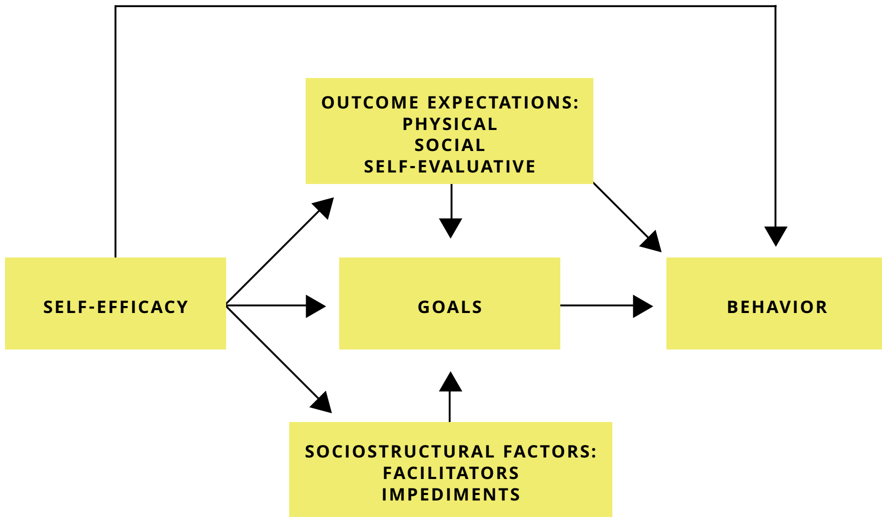

Figure 5.6. Socio-Cognitive Causal Model (reproduced from Bandura, 2004, p.146)

to motivation or intentional behavior (intention to use technology) as well as ongoing behavior (continuous use of technology).

LIMITATIONS OF SCT

SCT research has been criticized for underemphasizing the role of emotional factors although one's emotional state is explicitly included in the original theory and is closely related to self-efficacy and motivation (Carillo, 2010). In line with this argument, IS research has been criticized for restricting SCT to the factor self-efficacy and ignoring other important factors such as outcome expectations, emotional factors or the role of social encouragement and vicarious learning (Carillo, 2010). Finally, due to its comprehensiveness and complexity there is no consistent and widely accepted approach to the operationalization of SCT.

Although at first glance SCT seems a good theoretical starting point, we chose against SCT as theoretical foundation for the conceptual model of AAL acceptance for several reasons: (1) Although SCT is an overarching theory of human behavior and is appropriate to explain the underlying factors of motivation and intentional behaviors, SCT emphasizes that intentions and motivations are grounded in personal past experience and by learning through others. As AAL is a fairly novel concept that uses state-of-the art technologies, we suspect that there is not enough personal experience and learning experience that people can draw on to form clear-cut goal intentions. For this reason, we prefer a theory with a narrower focus on intentional behavior, which places greater emphasis on the relevant beliefs that are decisive in the consideration phase and lead up to initial expectations and use intentions. (2) A second, more practical consideration is that, due to its comprehensiveness and complexity, there is no widely accepted operationalization of SCT across the fields of technology acceptance and health behavior research, which makes the theory difficult to operationalize in the context of the current study.

5.2.5 THEORY OF PLANNED BEHAVIOR

Similar to SCT, the Theory of Planned Behavior (TPB) is a broad theory of human behavior and stems from the field of psychology. TPB is an extension of the earlier Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). The aim was to broaden the original model beyond behaviors of complete volitional control by including *"people's perceptions of the extent to which they have control over a behavior"* (perceived behavioral control (PBC)) as an additional construct. In TPB, behavior is determined by a person's intention which is *"an indication of a person's readiness to perform a given behavior"*. This relationship is moderated by people's actual behavioral control (ABC)[6]: *"the extent to which a person has the skills, resources, and other prerequisites needed to perform the behavior in question"*. Intention in turn, is determined by three predictors: attitude towards the behavior, subjective norm (SN) and perceived behavioral control. Attitude is *"the degree to which performance of the behavior is positively or negatively valued"* and SN is the *"perceived social pressure to engage or not to engage in a behavior"*. Following an expectancy-value approach, attitude is determined by a set of salient behavioral beliefs about the outcome of a given behavior, weighted by the evaluation of that outcome (i.e., $ATT= \sum b^i e^i$). SN is determined by a set of normative beliefs concerning the expectations of important referents, weighted by the motivation to comply (i.e., $SN= \sum nb^i mc^i$). Finally, PCB is determined by several control beliefs, weighted by its perceived power (i.e., $PCB = \sum cb^i p^i$) (Ajzen, 1991, 2006b; Ajzen & Fishbein, 2005) (see Figure 5.7)

RELEVANCE OF TPB

We chose TBP as a theoretical starting point for the following reasons:

(1) TPB offers a comprehensive and robust theory of human behavior that has proven its effectiveness across different contexts and fields. According to a meta-analysis of 185 independent studies, TPB explained 39% of the variance in intention and 27% of the variance in behavior (Armitage & Conner, 2001).

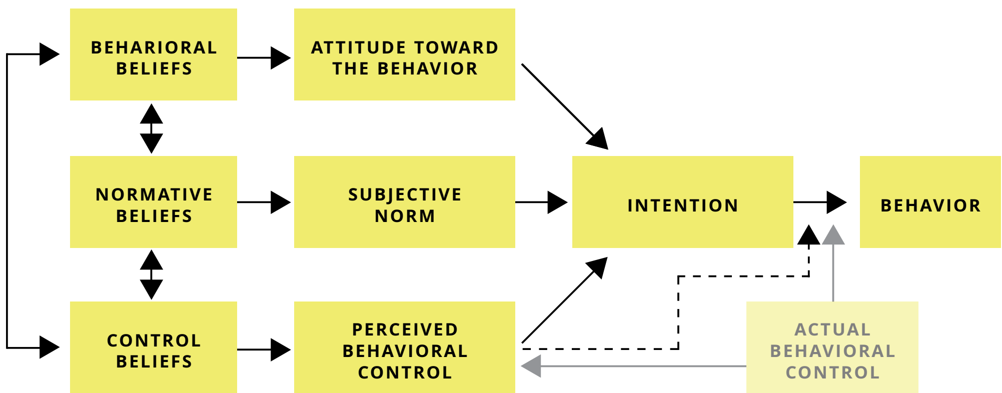

Figure 5.7. Theory of Planned Behavior (TPB) (reproduced from Ajzen, 2006b)

[6] Perceived behavioral control can serve as a proxy for actual behavioral control

(2) As a broad theory of human behavior, TPB has been successfully applied in technology acceptance research (De Graaf, Ben Allouch, & Van Dijk, 2017; Mathieson, 1991; Pavloe & Fygenson, 2006; Taylor & Todd, 1995a, 1995b) as well as to understand and change a wide range of health-related behaviors (Glanz & Bishop, 2010; Glanz, Rimer, & Viswanath, 2008; Godin & Kok, 1996). Roelands, Van Oost, Depoorter, and Buysse (2002) used TPB as a framework to understand the use and non-use of assistive devices among older adults. As this dissertation deals with acceptance of ICT-based assistive solutions for the purpose of healthy and independent aging, TPB is regarded as a good starting point.

(3) As AAL has not been widely diffused into society, this research focuses on the early stages of acceptance. TPB provides an in-depth understanding of these early stages by specifically focusing on the belief structure that leads up to the intention to use a technology. It encourages researchers to elicit the behavioral, normative and control beliefs that are relevant for a specific behavior. In the context of technology acceptance, these beliefs are very informative for the development and implementation of technology. These beliefs provide in-depth insights into the expected outcomes that factor into attitude formation, identify the important social referents and depict perceived internal and external barriers with regard to using a technology.

(4) Finally, TPB is explicitly open to the inclusion of more variables (Ajzen, 1991, p.199) and therefore forms a good starting point for developing a new model of AAL acceptance.

LIMITATIONS OF TPB

The main criticism of TBP is that it considers behavioral decisions as rational processes, thereby ignoring the role of emotions, impulses and or subconscious mechanisms (Armitage, Conner, & Norman, 1999; Conner & Armitage, 1998; Van der Pligt & De Vries, 1998). In consequence, this criticism also holds for TAM and UTAUT that adopted TRA/TPB's rational approach. A related shortcoming of TPB (as well as TAM and UTAUT) is that it does not account for habitual behaviors (H. Aarts, Verplanken, & Knippenberg, 1998; Conner & Armitage, 1998; Limayem & Hirt, 2003). Indeed, several technology acceptance studies have shown that habit influences decision making once a technology is in use (Limayem & Hirt, 2003; Limayem, Hirt, & Cheung, 2007; Peters, 2008). TPB is also criticized for reducing the role of the social context in behavioral decision making to the social approval or disapproval of others (injunctive social norm). Other relevant norms that have been proposed are descriptive social norms and personal norms (Armitage & Conner, 2001; Conner & Armitage, 1998; Godin & Kok, 1996; Sparks & Shepherd, 1992). Finally, the intention-behavior link that is suggested by TRA/TPB and since then, has been adopted by TAM and UTAUT, is criticized by several researchers (Bagozzi, 2007; Conner & Armitage, 1998). Bagozzi (2007) argues that, in the time gap between intention and behavior, obstacles, temptations and distractions might occur, and intentions might change. He therefore calls for the inclusion of various psychological and instrumental mechanisms that bridge the gap between intention formation and action initiation.

With regard to its limitations, we belief that the neglect of habit and the intention-behavior link are less relevant in the context of the current research. This is because our focus is on the early stages of the acceptance process and not on actual use. The following section (5.3) will explain, how the other limitations have been addressed in the proposed model of AAL acceptance.

5.3 INTRODUCING THE CONCEPTUAL MODEL OF AAL ACCEPTANCE

In this section, we will introduce our conceptual model of AAL acceptance. TPB was chosen as a theoretical framework due to its theoretical strengths, empirical robustness, proven effectiveness in related areas, and theoretical fit with the current research goals. In the following, we will integrate our findings from related AAL research and our own qualitative work with the theoretical foundations of TPB. This results in the conceptual model of AAL acceptance which is displayed at the end of this section (see Figure 5.8).

5.3.1 DECOMPOSED BELIEF STRUCTURE

Taylor and Todd (1995b) proposed a new approach to TPB, by decomposing the underlying belief structure and separate the behavioral, normative, and control beliefs into multi-dimensional belief constructs. This approach was also been applied by De Graaf et al. (2017); Hsieh, Rai, and Keil (2008); and Pavloe and Fygenson (2006). It has several advantages over the orginal approach:

(1) Belief structures which are combined into summated multiplicative composites, as suggested by the original TPB, treat all belief-evaluation pairs as equally important. This obscures information about the relative importance and contribution of each salient belief (Bagozzi, 2007).

(2) Summated multiplicative composites do not provide insights on the underlying relationships between salient beliefs (Bagozzi, 2007).

(3) By providing a stable set of beliefs, the model can be applied across different settings and can be more easily operationalized than TPB (Taylor & Todd, 1995b).

(4) The decomposed TPB provides a better and more detailed understanding of the social, normative, and behavioral antecedents of behavior and therefore, a better guidance for design and implementation efforts (Taylor & Todd, 1995b). Indeed, Taylor and Todd (1995b) found that their suggested decomposed TPB strengthened the ability of the model to explain behavioral intention, compared to TAM and the original TPB.

Following Taylor and Todd (1995b), a decomposed belief structure for the conceptual model is proposed. This means that behavioral, normative and control beliefs are treated as separate multidimensional belief constructs. By drawing the attention to the specific underlying beliefs of AAL technology acceptance, we strive to indentify the beliefs that are most important in the context of AAL acceptance. With this approach, we also answer to Benbasat and Barki (2007), who call upon technology acceptance researchers to move beyond the overused and oversimplified Technology Acceptance Model (TAM) and its *"black box of usefullness"* (p. 217). These researchers suggested to go back to TPB and its underlying belief structure for a comprehensive understanding of the drivers and barriers of technology acceptance. Insights on the importance and relevance of the underlying beliefs can then be translated into specific guidelines, which support the design and implementation efforts of future AAL technologies.

Ajzen (1991) argues that salient beliefs differ across behaviors and should be elicited directly from the members of the target population. For the conceptual model, the relevant behavioral, normative and control belief constructs for AAL acceptance were elicited from findings from earlier AAL user research (see Chapter 3) as well as the in-depth insights from our own qualitative user studies (see Chapter 4).

5.3.2 INTENTION TO USE AAL

Following the TPB, we propose intention to use AAL as the key dependent variable. Intention to use AAL is defined as: *'an indication of a person's readiness to use AAL technologies in the future'*. As pointed out earlier, most AAL technologies are still in a pilot and trial phase, and substantial mainstreaming has yet to occur (Liu et al., 2016). Therefore, the focus is on the initial intention to use AAL technology, rather than actual use behavior. Intentions are considered to *"capture the motivational factors that influence a behavior"* (Ajzen, 1991, p.181). They are an *"indication of a person's readiness to perform a given behavior"* (Ajzen, 2006b). As we investigated AAL in an early acceptance stage, intention to use AAL should be regarded as an initial indication of future use of AAL technologies.

5.3.3 ATTITUDE TOWARDS USING AAL

Similar to the TPB, we regard the overall attitude towards the behavior as a direct predictor of a person's intention. Attitude towards using AAL is defined as: *'the degree to which using AAL technology is positively or negatively valued'*. We consider attitude to have an instrumental as well as an affective component. Therefore, attitude will be operationalized in instrumental (e.g. *'valuable/worthless'* (ATT03)) as well as affective terms (e.g. *'enjoyable/unenjoyable'* (ATT06)) (see Appendix 1 for a complete list of items). This line of operationalization is encouraged by many TPB researchers (e.g. Norman, Conner, & Bell, 2000; Taylor & Todd, 1995b), including Ajzen himself (Ajzen, 2006a). However, critics have argued that the affective component should not merely be included in the overall attitude construct but also within the behavioral beliefs in terms of affective outcomes (Conner & Armitage, 1998; Manstead & Parker, 1995; Van der Pligt & De Vries, 1998; Wolff, Nordin, Brun, Berglund, & Kvale, 2011). Similar arguments have been proposed in the field of technology acceptance and human-computer interaction, and researchers have emphasized the importance of hedonic and affective values of technologies (Hassenzahl, 2004; Karapanos et al., 2009; Mahlke, 2007; Van der Heijden, 2004). Hence, during the operationalization of the belief constructs, we will also include items that reflected the affective component of outcome expectations, e.g.: *'If I use AAL technology, I will feel safer in my home'* (SAF02); *'Using AAL technology will feel like an invasion into my personal space'* (LP05).

5.3.4 BEHAVIORAL BELIEF CONSTRUCTS

Following the (decomposed) TPB, attitude is determined by several behavioral beliefs. Behavioral beliefs refer to the expected outcomes of a certain behavior (Ajzen, 2006b). Safety, independence, and relief of family burden are identified as the salient positive behavioral belief constructs. In contrast, loss of privacy and loss of human touch are proposed as the key negative behavioral belief constructs. These outcomes are anchored in the results of our own qualitative studies (Chapter 4) and also supported by previous studies in field of AAL acceptance (Chapter 3).

SAFETY

Safety outcomes were consistently mentioned as important benefits of AAL during earlier research and our own qualitative user studies (Sixsmith, 2000; Van Hoof et al., 2011; Wild et al., 2008). Participants expected that AAL could provide immediate response to emergencies, detect and prevent falls or other emergencies, and increase their overall feeling of safety and assurance. Anchored in these qualitative findings, safety beliefs are defined as: *'people's judgement of the likelihood that using AAL technology will lead to an enhanced sense of safety and security, faster detection and response to harmful situations in the home environment, and prevention of harmful situation in the home environment'*. Safety outcomes will be operationalized along these three aspects: feeling safe and secure, detection and response of emergencies, and prevention of emergencies.

INDEPENDENCE

Maintaining a high degree of independence is one of the key promises of AAL technologies (Van den Broek et al., 2010). The literature review showed that this is in line with the perceptions of potential users, who considered AAL technologies to facilitate independence and allow them to age in their own home environment. This is important to older adults, who are usually attached to their own home and often have a negative view on nursing homes (Steele et al., 2009; Van Hoof et al., 2011). Surprisingly, in our own qualitative studies, independence was not consistently mentioned as an explicit outcome expectation of AAL use (Chapter 4). However, as independence was identified as a prevalent driver in the literature review, it was decided to include independence as a behavioral belief construct in the conceptual model. In the context of the current research independence beliefs are defined as: *'people's judgement of the likelihood that using AAL technology will enhance their independence and allow them to age in their own home environment'*. For the operationalization we looked at the *'Attitudes toward Assistive Devices'* scale and the *'Perceived Consequence of Assistive Device Use'* scale that contain a few items about independence outcomes. Looking at these items, Roelands et al. (2002) operationalized independence outcomes in terms of independent living, less need for assistance and increased self-reliance (*'doing things independently'*). These aspects are in line with the findings from our own studies and will therefore form the basis for operationalization.

RELIEF OF FAMILY BURDEN

In the previous studies, AAL technologies were perceived as good tools for caregiver support and for reducing the overall burden on family caregivers. Participants expected that AAL technologies could reduce the concerns of their family members and provide them with peace of mind. Informal family caregivers reported that, next to the emotional burden, AAL technologies could also relieve them of their physical burden in terms of relieving their overall workload and providing them with more time for themselves. Based on these previous findings, relief of family burden is defined as: *'people's judgement of the likelihood that using AAL technology will reduce family caregivers'* emotional and physical burden'. For the operationalization we will include items reflecting the relief of emotional burden as well as physical burden (Rowan & Mynatt, 2005; Sixsmith, 2000; Wild et al., 2008). For the wording of the items we will also look at related scales, i.e. the short version of the 'Zarit burden interview' (Bedard et al., 2001).

LOSS OF PRIVACY

Concerns about privacy, data security and potential intrusion were consistently mentioned as a major barrier towards AAL use. Older adults felt uneasy about being constantly monitored and were afraid that personal information could get in the wrong hands or be misused. Even family members might use this information to patronize them or interfere with their personal life. Participants also felt that AAL technologies could intrude upon their personal space and their body, and interfere with their normal routine. (Beringer et al., 2011; Boise et al., 2013; Marquis-Faulkes & McKenna, 2003). Leino-Kilpi et al. (2001) distinguish four dimensions of privacy: (1) physical, referring to personal space and territoriality; (2) psychological: referring to privacy as a felt need or right (3) social, referring to control over social interactions and ; (4) informational, referring to data protection and data integrity. These dimensions of privacy were also reflected in the findings of our own work and will therefore form the basis for the operationalization of loss of privacy beliefs. These beliefs are defined as: *'people's judgement of the likelihood that using AAL technology will compromise their physical, psychological, social and informational privacy'*. Besides our own findings, we will also look at the work of Boise et al. (2013) and Kirchbuchner, Grosse-Puppendahl, and Hastall (2015) for the wording of the items.

LOSS OF HUMAN TOUCH

The previous studies showed that potential users of AAL are concerned that AAL would lead to a reduced human touch in caregiving and could create more distance between caregivers and care receivers (Beer & Takayama, 2011; Demiris et al., 2004; Marquis-Faulkes & McKenna, 2003). Hence, loss of human touch beliefs are defined as: *'people's judgement of the likelihood that using AAL technology will decrease the human touch in care and face-to-face interaction'*. Next to our own qualitative findings, we will consult the 'attitudes toward assistive devices' scale and the 'perceived consequence of assistive device use' scale (Roelands et al., 2002) that contain a few items about loss of human touch as a potential outcome of assistive device use.

For the sake of parsimony and to focus on the most salient beliefs, not all outcomes expectations that resulted from our previous work (Chapter 3 and Chapter 4) were incorporated into the conceptual model. Other expected outcomes that were mentioned during earlier studies included health outcomes, social connectedness, support with daily activities, enjoyment and leisure, self-confidence and status, and education and information outcomes. Health outcomes were not included in the model, as the survey used AAL examples with no explicit medical focus (see Chapter 6). Social connectedness showed conflicting findings in the literature review and was therefore not included in the conceptual model. Support with daily activities was mentioned across several studies, but was less prevalent than safety or relief of family burden. Enjoyment and leisure, self-confidence and status, and education and information outcomes showed low prevalence across the different studies.

Table 5.1 shows example quotes from our user studies and the respective literature evidence for the behavioral belief constructs.

Table 5.1 Example Quotes and Literature Evidence for the Behavioral Belief Constructs

BEHAVIORAL BELIEF	EXAMPLE QUOTES FROM QUALITATIVE USER STUDIES	LITERATURE EVIDENCE
Safety	*"Essentially, you minimize the chance that somebody lies on the floor for one or two hours, or maybe days"* (informal caregiver, user study 2). *"Well If somebody falls who is living on his own... That's I think the main benefit of it"* (older adult, user study 1). *"It would feel secure I think"* (older adult, user study 1). *"A feeling that someone is looking after me"* (older adult, user study 2).	Peek et al., 2014 Sixsmith, 2000 Van Hoof et al., 2011 Wild et al., 2008
Independence	*"I am an advocate of staying independent for as long as possible. And if you use these technologies then you stay independent"* (informal caregiver, user study 2). *"Staying in her own environment is very important to my mother"* (informal caregiver, user study 2). *"I am not the type of person that is going to live in a senior flat"* (older adult, user study 3).	Peek et al., 2014 Steele et al., 2009 Van Hoof et al., 2011
Relief of Family Burden	*"If I get to the point, where I didn't contact my family, and they start worry. It could be a real relief to them to know what is happening to me, and that I am moving around and get up and stuff"* (older adult, SONOPA in-home field trial[7]). *"I think something like this may be able to relieve the workload of the informal caregiver. The caregiver doesn't have to visit to check-in. He can check on him or her [the care receiver] in a different way"* (informal caregiver, user study 3).	Rowan & Mynatt, 2005 Sixsmith, 2000 Peek et al., 2014 Wild et al., 2008
Loss of Privacy	*"But I don't know whether you would creep around the house, thinking, oh dear they can see me [...] That would be horrible, sort of spy on the wall"* (older adult, user study 1). *"I think, as an informal caregiver, I would still feel awkward if I saw this and would interfere with it. Because who am I to tell her that she must move around"* (informal caregiver, user study 3). *"If you have a sweet tooth, which I have...That they know: oh, my mother has eaten candy again. That's nobody's business."* (older adult, user study 3).	Boise et al., 2013 Beringer et al., 2011 Marquis-Faulkes & McKenna, 2003 Peek et al., 2014
Loss of Human Touch	*"Knowing they have those things at home, you might visit your mother or father less often to check on them"* (informal caregiver, user study 2). *"You want someone with you to hold your hand and hug you from time to time. Well, good luck with this robot"* (informal caregiver, user study 2)	Beer & Takayama, 2011 Demiris et al., 2004 Marquis-Faulkes & McKenna, 2003

[7] The results of the SONOPA field trial have not been included in this dissertation.

5.3.5 SOCIAL NORM

In line with the TBP, subjective norm is considered as the second predictor of intention to use AAL. In our model the term 'subjective norm' is substituted with the term 'social norm' to clearly distinguish this concept from 'personal norm'. Following Ajzen (2006b), social norm is defined as: *'perceived social pressure to use AAL technology'*. Social influences have been found to be especially important in the early stages of technology implementation, when user have limited or no direct experience with a technology (Hartwick & Barki, 1994). For the operationalization, we will use items from earlier TPB research (Mathieson, 1991; Taylor & Todd, 1995b).

5.3.6 SOCIAL NORMATIVE BELIEF CONSTRUCTS

According to the (decomposed) TPB, social normative beliefs determine the overall social norm. For the conceptual model we propose to broaden Ajzen's original definition to make it more compatible to the concept of social stigma that was identified as one of the social normative belief constructs. Social normative beliefs are defined as: *'the perception of how important referent groups think about the use of AAL technology'*. Based on our earlier studies, social stigma and caregiver influence were identified as key social normative belief constructs. Social stigma is hypothesized to have a negative effect on social norm, while caregiver influence is suggested to have a positive effect on overall social norm.

SOCIAL STIGMA

From the qualitative studies and the literature review, it became clear that several older adults were hesitant to use technologies that draw attention to the fact that they are aging and need assistance, as these could stigmatize them as frail or dependent (Bright & Coventry, 2013; Demiris et al., 2004; Steele et al., 2009). Ageist stereotypes are pervasive and older adults are often confronted with age-related discrimination or negative stereotypes (Abrams et al., 2011; Ory et al., 2003). Some older adults perceived that the use of AAL technologies could reinforce this perception and stigmatize them as frail, needy and incompetent. Stigma is a familiar concept in the context of assistive devices (Parette & Scherer, 2004) and was therefore identified as one of the key social normative belief constructs. We define social stigma as: *'people's perception that important others will think they are old, frail and dependent when using AAL technology'*. Next to our own qualitative findings, we will also look at the 'perceived consequence of assistive device use' scale (Roelands et al., 2002) that also contains items about stigma.

CAREGIVER INFLUENCE

Based on the previous studies, it was concluded that informal caregivers are important social referents for older adults and are closely involved in care-related decision making. Their influence varies from careful phrased suggestion, to a strong advisory role, to even making decisions for the care receiver. Older adults stated that they would consider to use AAL, if their informal caregivers would advise them to do so. Some prior studies in the AAL field showed that formal caregivers might also influence AAL adoption (Courtney et al., 2008; Lorenzen-Huber et al., 2011; Peek et al., 2014). We therefore propose to include caregiver influence as the other key social normative belief construct in the conceptual model. Caregiver influence is defined as: *'people's perception that caregivers would encourage their use of AAL technology'*. We will operationalize caregiver influence in accordance with earlier TPB research (Ajzen, 2006a; Taylor & Todd, 1995b).

Table 5.2 shows example quotes from our user studies and the respective literature evidence for the social normative belief constructs.

Table 5.2 Example Quotes and Literature Evidence for the Social Normative Belief Constructs

SOCIAL NORMATIVE BELIEF	EXAMPLE QUOTES FROM QUALITATIVE USER STUDIES	LITERATURE EVIDENCE
Social Stigma	*"In France, there are many older people who do not want to use a walking cane because it is a sign of dependence"* (older adult, user study 1). *"If someone would come to me with the intention to assist me, I would say: But I am not old yet, I don't need help"* (informal caregiver, user study 3).	Steele et al., 2009 Demiris et al., 2004 Peek et al., 2014 Bright & Coventry, 2013
Caregiver Influence	*"They can be so stubborn at this age. Then I say well, mom, you cannot do these things anymore, so you have to"* (informal caregiver, user study 3). *"Then we would discuss this, and if they really think that this is also easier for them, then I would agree"* (older adult, user 3).	Courtney et al., 2008 Lorenzen-Huber et al., 2011 Luijkx et al., 2015)

5.3.7 PERSONAL NORM

In addition to social norm, we propose the concept of personal norm as another predictor of intention to use in the conceptual model. Reviews and meta-analysis of TPB have suggested to look beyond the social approval or disapproval of others as the only normative influences, and consider other normative mechanisms (Armitage & Conner, 2001; Godin & Kok, 1996). Cialdini, Kallgren, & Reno (1991) differentiate between three normative influences: (1) injunctive social norm, (2) descriptive social norm, and (3) personal norm. Injunctive social norm concerns *"the perception of what most people approve or disapprove"* (p. 203) and is thus similar to TBP's subjective norm (or social norm in our model). Descriptive social norm concerns *"the perception of what most people do"* (p.203). As AAL technologies are not widely diffused among potential users, we assume that descriptive social norm does not have a strong influence on AAL use at this current diffusion stage. We define personal norm as: *'people's self-based standards or expectations for AAL use that flow from one's internalized values'*, thereby referring to (Schwartz, 1977, p.226). Earlier TPB research has operationalized personal norm in terms of moral norms or in terms of self-identity (Armitage & Conner, 2001; Conner & Armitage, 1998). In our view, AAL use is not directly connected to moral obligations. Hence, personal norm will be operationalized in terms of self-identity, drawing on the work of Y. Lee, Lee, and Lee (2006) and Sparks and Shepherd (1992).

5.3.8 PERSONAL NORMATIVE BELIEF CONSTRUCTS

Following the decomposed belief structure, we propose that the overall personal norm is routed in several personal normative beliefs. Based on the literature review and our own qualitative studies, human touch norm, privacy norm and personal innovativeness are identified as key personal normative belief constructs in the context of AAL technologies. Human touch norm and privacy norm is hypothesized to have a negative effect on personal norm, while personal innovativeness is suggested to have a positive effect on personal norm.

HUMAN TOUCH NORM

Although most potential users in the previous studies have emphasized that technologies cannot and should not replace human care, it was observed that some people were more open to the idea of AAL technologies taking over and supporting care-related tasks than others. For example, while some people can imagine to use a robot for certain support tasks and even prefer the robot over human support, others would always prefer human care (Smarr et al., 2014). In user study 2, one of the male informal caregivers stated that his father and he himself would prefer a robot for intimated personal care tasks, such as bathing, over the often female formal caregiver.

In contrast, people with high human touch norm perceive that AAL technologies cannot offer the same qualities as face-to-face interaction with a human caregiver. Based on this previous work, we define human touch norm as: *'people's judgement of the importance of the human touch in care and face-to-face interaction'*. For the operationalization, we will draw on the work of Phang, Sutanto, and Kankanhalli (2006) and Dabholkar (1996) who examined the concept of preference for human contact in the context of e-government services and technology based self-services respectively.

PRIVACY NORM

Although privacy was identified as an important barrier towards AAL use, some researchers found that privacy and security were just minor concerns to their older adult participants (e.g., Steele et al., 2009; Van Hoof et al., 2011; Wild et al., 2008). Indeed, several people perceived the benefits of AAL use to outweigh privacy concerns. Privacy researcher Alan Westin has proposed clustered of people with different levels of privacy concerns: privacy fundamentalists, privacy pragmatists and privacy unconcerned (see Kumaraguru & Cranor, 2005 for a review of Westin's work). We therefore propose that the older adults' privacy norm affects their overall personal norm towards AAL technologies. In the context of the current work, privacy norm is defined as: *'people's judgements of the importance of privacy and data security when using AAL technology'*. For the wording of the items, next to our own work, we will consult related scales such as the 'beliefs in privacy' scale (Yao, Rice, & Wallis, 2007) and the 'concerns for information privacy' scale (Angst & Agarwal, 2009).

PERSONAL INNOVATIVENESS

Personal innovativeness in the domain of IT (PIIT) is a concept suggested by Agarwal and Prasad (1998) and is defined as *"people's willingness to try out any new information technology"* (p.206). According to these researchers, PIIT plays an important role in the acceptance of new information technology. Indeed, PITT has been successfully applied in acceptance research across different applications, including health-related applications (Jackson, Yi, & Park, 2013; Lu, Yao, & Yu, 2005; Rai, Chen, Pye, & Baird, 2013). Agarwal and Prasad (1998) describe PIIT as a trait-like concept. Our previous work has shown that older adults differ with regard to their personal innovativeness. Several older adults viewed themselves as non-technical persons and therefore, were less inclined to use AAL technology. Hence, it was hypothesized that people with higher personal innovativeness will have a higher overall personal norm. The validated scale of Agarwal and Prasad (1998) will be used to operationalize personal innovativeness.

Table 5.3 shows example quotes from our user studies and the respective literature evidence for the personal normative belief constructs.

Table 5.3 Example Quotes and Literature Evidence for the Personal Normative Belief Constructs

PERSONAL NORMATIVE BELIEF	EXAMPLE QUOTES FROM QUALITATIVE USER STUDIES	LITERATURE EVIDENCE
Human Touch Norm	*"For me human contact is still most important [...]. Thus, I prefer no computer"* (older adult, user study 1). *"With these [technological] aids, I still think that human contact stays important"* (older adult, user study 1). *"I think technology can be a supporting tool, but the humans should stay in control"* (informal caregiver, user study 2).	Smarr et al., 2014 Demiris et al., 2004 Wild et al., 2008 Marquis-Faulkes & McKenna, 2003
Privacy Norm	*"I think most of us like to be very private when we want to be private"* (older adult, user study 1). *"Your privacy is not sacred to other people, it is only to you. If you allow your privacy to be invaded, you have no control over where it goes"* (older adult, user study 1). *"In that phase safety is more important"* (informal caregiver, user study 2).	Steele et al., 2009 Boise et al., 2013 Kanis et al., 2011
Personal Innovativeness	*"I expect I can make myself use them if you want me to, but it's not my second nature to use them"* (older adult, SONOPA in-home field trial) *"I am not a technical person"* (older adult, user study 3).	Demiris et al., 2004 Van Hoof et al., 2011 Joe et al., 2014

5.3.9 PERCEIVED BEHAVIOR CONTROL

In line with the TBP, we consider perceived behavioral control as the final predictor of intention to use AAL. Following Ajzen and Fishbein (2005), perceived behavior control is defined as: *'people's perception of the extent to which they have control over using AAL technologies'*. For the operationalization, we will use items from earlier TPB research (Taylor & Todd, 1995b).

5.3.10 CONTROL BELIEF CONSTRUCTS

Control beliefs refer to the perception of factors likely to facilitate or inhibit the performance of a specific behavior. Control beliefs can refer to both internal factors (e.g. abilities, information, skills) and external factors (financial resources, access, dependence on others). Together these control belief constructs form the overall perceived behavior control (Ajzen, 1991; 2006; Taylor & Todd, 1995b). For the conceptual model, the salient control beliefs for AAL acceptance, which were elicited from the literature review and the insights from the user studies, were self-efficacy, reliability, user control, and financial cost. We hypothesize that self-efficacy, reliability, and user control positively affects perceived behavior control, while financial cost negatively affects overall control perceptions.

SELF-EFFICACY

Self-efficacy is a concept from Social Cognitive Theory (SCT) and is an essential determinant of behavior control. In accordance with Bandura (1986) we define self-efficacy as: *'people's judgment of their capabilities to organize and execute courses of action required to use AAL technology'*. Researchers, who have applied SCT to explain technology acceptance, have found self-efficacy to play a significant role in the acceptance process (Compeau & Higgins, 1995; LaRose & Eastin, 2004). Previous research has suggested that older adults often show low technology self-efficacy (Marquis-Faulkes & McKenna, 2003). This was confirmed by the results of our own studies. Many older adults worried whether they would have the necessary skills to be able to use and interact with AAL technologies. Following other researchers (Hsieh et al., 2008; Pavloe & Fygenson, 2006), we suggest self-efficacy as one of the control beliefs that affect the overall perceived behavioral control. For the operationalization, we will look at related scales such as the 'internet self-efficacy' scale (LaRose et al., 2012) and the 'technology anxiety' scale (Meuter, Ostrom, Bitner, & Roundtree, 2003).

RELIABILITY

The literature study and our own user studies showed that participants had doubts about the reliable functioning of AAL technologies and questioned their accuracy and ability in ensuring health and safety. Participants stated that one could not completely trust AAL technologies because they might not work all the time. Reliability was previously identified as an important predictor of acceptance in the context of assistive technology use (McCreadie & Tinker, 2005). We therefore suggest reliability as the second salient control belief. Following Mcknight, Carter, Thatcher, and Clay (2011), reliability beliefs are defined as: *'people's belief that AAL technology will consistently operate properly'*. We will adapt the reliability subscale from Mcknight et al. (2011) to measure reliability.

USER CONTROL

According to the literature study, the level of user control was a matter of concern to the older adult user. Most older adults wanted to have some level of control over AAL technology (Steele et al., 2009; Ziefle & Röcker, 2010). Consequently, the lack of user control was perceived as a barrier to AAL acceptance. This was also confirmed by our user studies. The expected feeling of control while interacting with AAL technology is therefore proposed as the third salient control belief. In line with Trevino and Webster (1992), user control is defined as: *'people's perceived sense of control over the interaction with AAL technology'*. We will draw on the work of Webster, Trevino and Ryan (1993) for operationalizing user control.

FINANCIAL COST

Financial cost is proposed as the final and fourth control belief construct and defined as: *'people's belief that AAL technology use is associated with high financial expenses'*. In the previous studies, several older adults have stated that, due to their limited income, AAL systems would either not be affordable to them or they would not to be willing to spend a lot of money on such technologies. For the operationalization, we will look at the work of Luarn and Lin (2005), who operationalized perceived financial cost in the context of mobile banking acceptance.

Table 5.4 shows example quotes from our user studies and the respective literature evidence for the control belief constructs.

5.3.11 CONCEPTUAL MODEL OF AAL ACCEPTANCE

In summary, our conceptual model of AAL acceptance proposes that intention to use AAL technology is explained by the attitude towards AAL use, one's social norm, one's personal norm and the perceived behavioral control. Attitude in turn, is positively influences by beliefs about safety, independence and relief of family burden, and negatively influences by beliefs about loss of privacy and loss of human touch. The overall social norm is negatively affected by beliefs about social stigma, and positively affected by caregiver influence. The overall personal norm is negatively influenced by one's human touch norm and privacy norm, and positively affected by one's personal innovativeness. Finally, perceived behavioral control is positively affected by self-efficacy, beliefs about the reliability of the technology, and beliefs about the sense of user control during interaction. The expected financial cost are hypothesized to negatively influence perceived behavioral control. Figure 5.8 displays the conceptual model of AAL acceptance and the hypothesized relationships.

Table 5.4 Example Quotes and Literature Evidence for the Control Belief Constructs

CONTROL BELIEF	EXAMPLE QUOTES FROM QUALITATIVE STUDIES	LITERATURE EVIDENCE
Self-Efficacy	*"I think in our generation, generally a lot of people are really computer shy. And I don't know how much input you would need to get that system to run"* (older adult, user study 1). *"I am still quite a new boy on this whole thing really. And you see, I was 74 when I started doing this, and it does not sort of come quite naturally, if you are an old person and you use it"* (older adult, SONOPA in-home field trial). *"Because my cognition keeps deteriorating, and I will get less and less access to this"* (older adult, user study 3).	Steele et al., 2009 Coughlin et al., 2007 Wherton & Prendergast, 2009
Reliability	*"Glitches like you have on the computer, what happens then"* (older adult, user study 1). *"It might just go off with your natural things"* (older adult, user study 1). *"It's technology so it can break down, you can't completely trust these"* (informal caregiver, user study 2).	Steele et al., 2009 Van Hoof et al., 2011 Coughlin et al., 2007
User Control	*"I think you have to be able to manage it in the way you want to manage it, like all these aspects. That must be built into this technology"* (older adult, user study 1)	Steele et al., 2009 Peek et al., 2014 Marquis-Faulkes & McKenna, 2003
Financial Cost	*"It all depends on costs, frankly, doesn't it"* (older adult, user study 1). *"I think immediately: gosh this costs a lot of money. This is not affordable for the average older adult"* (informal caregiver, user study 2).	Steele et al., 2009 Demiris et al., 2004 Sixsmith, 2000

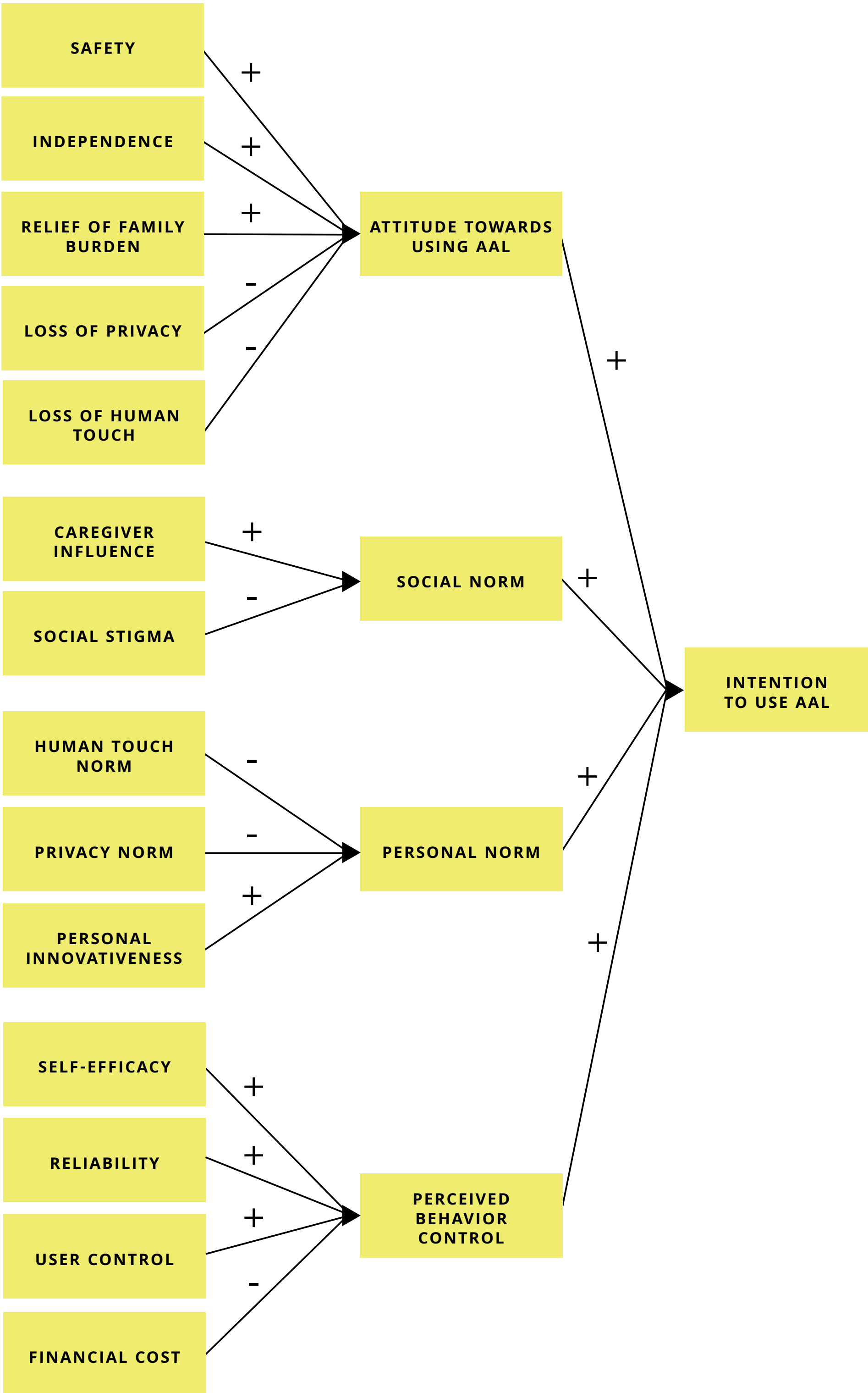

Figure 5.8. Conceptual Model of AAL Acceptance.

6 Validating the Conceptual Model of AAL Acceptance

In Chapter 5, a theoretical framework for the different acceptance factors identified from the literature review (Chapter 3) and the qualitative user studies (Chapter 4) was provided. This resulted in a conceptual model of AAL acceptance. To test the proposed model, an online survey among the Dutch older adult population was conducted. By employing a large-scale quantitative approach, we aim to make statistically grounded and externally valid inferences about the relative importance of different acceptance factors, their underlying relationships, and their explanatory power for the intention to use AAL technologies (RQ3). Large-scale quantitative studies are still rare in the AAL field (Liu et al., 2016; Peek et al., 2014). Therefore, this study aims to provide more theoretical and statistically grounded insights on how and why older adults will accept or reject these technologies in the future. These insights can also help developers of AAL applications to make more informed design decisions, before these applications are widely diffused into society. The current chapter discusses the scope (6.1) and design (6.2) of the survey instrument as well as the results (6.3) and implications (6.4) of the pilot study (n = 320). This pilot study was used to validate the measurements. Chapter 7 will present the results and implications of the main online survey of AAL acceptance among Dutch older adults (n = 1296).

6.1 SCOPE OF THE AAL ACCEPTANCE SURVEY

The focus of the AAL acceptance survey is on older adults as they are currently regarded as the primary users of AAL applications. Dutch older adults between 55 and 85 years were specified as the target population to include a broad range of older adults with different living- and work situations, different perceptions of health and quality of life, different support needs and different levels of technology experience to adequately represent this highly heterogeneous target group (Gregor & Newell, 2001). The lower boundary of the age requirement was set at 55 years to also include the perspective of the future generation of older adults.

As the majority of AAL applications is still in a development phase, the focus of this acceptance survey was on the early stages of the acceptance process (see Chapter 5). More specific, we were interested in the expectations and perceptions towards these technologies in terms of outcomes, consistency with personal and social norms, and personal and practical constrains (*consideration stage*), rather than investigating actual use experience *(initial use stage and continuous use stage*). Therefore, participants had no active interaction with AAL applications during the survey, and responses were based on the exposure to a video scenario and several other visual stimuli to trigger awareness of AAL (Section 6.2.2).

As a large, representative sample was required to validate the conceptual model with the appropriate statistical techniques, online surveying was chosen to gather large amounts of data in an efficient and cost-effective manner. The other advantage compared to telephone surveying is that supporting audiovisual stimuli could be included in the survey, which we regarded as highly necessary for a relatively new and rather complicated concept such as AAL. We therefore accepted that our sample had a bias towards older adults with internet connection and basic technology skills. It should be noted that according to Statistics Netherlands (2017a), 98% of older adults between 55 and 64 years, 95% of older adults between 65 and 74 years, and 78% of older adults who are 75 years or over had an internet connection in 2017. Of these age groups, 3%, 13% and 36% respectively have never used the internet although having the appropriate facilities. Hence, it can be concluded that the sample was representative for a large part of the Dutch older adult population, and the aforementioned bias especially concerns the group of older adults who are 75 years or over.

The online survey was administered by a Dutch ISO-certified research agency specialized in online fieldwork. Their panel consists of 110.000 members with diverse demographic background to ensure representativeness of the Dutch population. The pool of members is regularly refreshed and panel members are monitored for structural response bias to ensure the reliability and validity of the collected data.

6.2 DESIGN OF THE AAL ACCEPTANCE SURVEY

As AAL is still a relatively young and emerging research field and due to the lack of quantitative approaches, there was little choice in validated measurement instruments that could be utilized for the purpose of this study. Hence, new scales were developed for the majority of factors included in the conceptual model (6.2.1). Furthermore, due to the novelty of AAL, careful attention was given to the representation of the AAL concept in the survey (6.2.2) and the overall structure of the survey (6.2.3). Cognitive interviews with target group members were conducted to improve the quality of the survey instrument, before the final pilot survey was launched (6.2.4).

6.2.1 MEASUREMENTS

Several steps were performed before the final list of items for the survey instrument was retrieved. First, the literature was searched for existing scales, preferably in the context of AAL or related fields. Thereby, we applied the following selection criteria for the inclusion of existing scales: (1) conceptual fit with the construct definitions (see Chapter 5); (2) validated scale; (3) contains multiple items that represent the underlying variable; (4) concise enough to be included in an online survey that incorporates multiple scales. If the scales were validated but did not fit the context, items were rephrased into the context of AAL. For example, for the variable attitude towards using AAL the item *'Using CRC is a (bad/good) idea'* (Taylor & Todd, 1995b) was rephrased into *'Using AAL is a (bad/good) idea'* (ATT01). In most cases, scales either did not meet the selection criteria or no relevant (complete) scales could be found. Thus, in a second step, new scales were developed following the procedure described by DeVellis (2003). The insights from the literature review (Chapter 3), the qualitative user studies (Chapter 4) and the resulting theoretical framework (Chapter 5) were used as a starting point for creating the initial set of items. Moreover, single items from existing scales were rephrased and included in the initial item pool. In a third step, all items (validated, new or newly composed scales) were translated into Dutch. To maximize the content validity of these scales, the items were then presented to four senior researchers with expertise in the content area (AAL, technology acceptance, gerontechnology, medical informatics) as well as methodological expertise (psychometrics). During this first expert pre-test, the items were evaluated on relevance, clarity, conciseness, redundancy and missing aspects, and were adapted accordingly. For example, two items were removed from the scale for the variable loss of privacy (LP) due to redundancy, leaving a final set of six items. Finally, items were translated back to English by another researcher proficient in both languages to identify potential discrepancies. This back-translation process ensured that the Dutch items did not differ in meaning or nuance and stayed true to the original item. Table 6.1 gives a concise overview of the operationalization of the key variables included in the survey instrument. We refer to Appendix 1 for a more elaborate overview including the complete pool of items and the respective sources.

A five-point Likert type scale was chosen as a response format with 1 = strongly disagree and 5 = strongly agree. We chose the five-point over the seven-point response format because we did not expect participants to make extremely refined distinctions in their evaluations with regard to a novel concept such as AAL (Krosnick & Presser, 2010). Moreover, considering the overall length of the survey (100 items), the aim was to reduce the cognitive load for the older adult participants and counter the use of decision heuristics (Weathers, Sharma, & Niedrich, 2005). Several researchers have argued for five-point scales to maximize reliability (Jenkins & Taber, 1977; Lissitz & Green, 1975). For the attitude items a five-point semantic differential scale was used as a response scale. Due to the novelty of the concept of AAL, a 'don't know' option was included as we suspected that some participants would not have a strong enough tendency to formulate an opinion about certain items (D. B. Rubin, Stern, & Vehovar, 1995).

It should be noted that, although the Theory of Planned Behavior (TBP) was used as a theoretical starting point, it was decided not to follow the expectancy-value approach of summated multiplicative composites (i.e., $ATT= \sum b^i \; e^i$; $SN= \sum nb^i \; mc^i$; $PCB= \sum cb^i \; p^i$) (Ajzen, 1991) to measure the underlying beliefs structure (see Chapter 5). Instead, we chose to treat the beliefs as distinct, multi-dimensional constructs and to focus on the expectancy component. This decision was made on the following grounds: (1) summated multiplicative composites treat all belief-evaluation pairs as equally important and obscure information about the relative importance and contribution of each salient belief (Bagozzi, 2007); (2) summated multiplicative composites do not provide insights on the underlying relationships between salient beliefs (Bagozzi, 2007); (3) summated multiplicative composites are likely to account for little additional variance in the scores of the dependent variable in comparison with expectancy and value components considered separately (French & Hankins, 2003); (4) the aim of our conceptual model is not to test the expectancy-value interaction hypothesis but to determine the explanatory power of the underlying beliefs for the associated construct; (5) focusing on the expectancy component will result in a more parsimonious theoretical model (Myung, Pitt, & Kim, 2003) as well as a shorter and less demanding survey instrument.

Table 6.1 Overview of the Operationalization of the Key Variables

VARIABLE NAME	NO. OF ITEMS	EXAMPLE ITEM
Intention to Use AAL (ITU)	4	In the future, I intend to use AAL technology.
Attitude towards Using AAL (ATT)	6	I (like/dislike) the idea of using AAL technology.
Social Norm (SN)	3	Most people whose opinion I value, would think positively about my use of AAL technology.
Personal Norm (PSN)	3	I view myself as a user of technology for my health and well-being.
Perceived Behavioral Control (PBC)	4	Using AAL technology is entirely in my control.
Safety (SAF)	6	If I use AAL technology, I will feel safer in my home.
Independence (IDEP)	4	If I use AAL technology, I can do things independently.
Relief of Family Burden (FB)	6	My use of AAL technology will give my family members peace of mind.
Loss of Privacy (LP)	6	If I use AAL technology, I worry that my personal information might be shared with others without my permission.
Loss of Human Touch (LHT)	6	If I use AAL technology, I will get less personal attention.
Caregiver Influence (CI)	3	My caregivers would have a positive view on my use of AAL technology.
Social Stigma (STG)	4	If I use AAL technology, I am concerned that the technology will be visible to others.
Human Touch Norm (HTN)	4	I prefer personal care over care via AAL technology.
Privacy Norm (PN)	6	I think I have the right to control my personal information.
Personal Innovativeness (PI)	4	If I heard about a new information technology, I would look for ways to experiment with it.
Self-Efficacy (SEF)	7	If I had problems relating to using AAL technology I know I could work them out.
User Control (CTR)	3	I think that I will feel in control, when using AAL technology.
Reliability (REL)	4	I think that AAL technology is reliable.
Financial Cost (C)	3	I think that using AAL technology will be expensive.

Older adults are an extremely heterogeneous target group (Gregor & Newell, 2001). In order to take these differences into account several socio-demographic questions such as age, gender, living situation, education level and work situation were included in the survey instrument. Moreover, self-reported health and overall quality of life was assessed with a single item measure adapted from the Stanford Chronic Disease Self-Management Study *('In general, would you say your health is…')* (Lorig et al., 1996) and the WHO Quality of Life-BREF *('How would you rate your quality of life')* (WHO, 1997). A question about the level of received care (using the categories specified by Timmermans, 2003) and the caregiver was also included *("Do you regularly receive support with one of the following tasks?" and "By whom do you receive support?").* Furthermore, we included an item about the participant's anticipated need for future long-term care *("Compared to other people of your age, how likely is it that you will need care in the near future?")* (adapted from Eckert et al., 2004). Finally, two questions assessed the participants' prior knowledge and experience with AAL *("Have you heard about any of these technologies before?" and "Have you ever had the opportunity to try these technologies?").*

6.2.2 SURVEY MATERIAL

A short (2:25 minutes) video animation with a voice-over was created to explain the concept of AAL (https://youtu.be/TZfy5KW9kOY). Previous research has shown that spoken animations work well to communicate complex health-related information (Meppelink, Van Weert, Haven, & Smit, 2015). For this video animation, a scenario was written that centered on the persona Ben and his daughter Sophie. Personas and user-scenarios are tools that are frequently used in user-centered and participatory design activities to translate abstract ideas about the user into something more tangible. By creating fictional archetypes (i.e., personas), the user's wishes and needs are placed into context and the user becomes a 'face'. A user scenario tells a story about the user and the product/technology and describes why, how and in which context a product/technology is used. The aim of both tools is to create more insights about the user and the interaction with the product/technology in order to trigger a critical discussion among all stake-holders involved in the design process (Carroll, 1999; Cooper, 2004; Grudin & Pruitt, 2002; Miaskiewicz & Kozar, 2011; Pruitt & Adlin, 2006). In the context of this research, the aim of the scenario was to make the abstract and probably unknown concept of AAL more

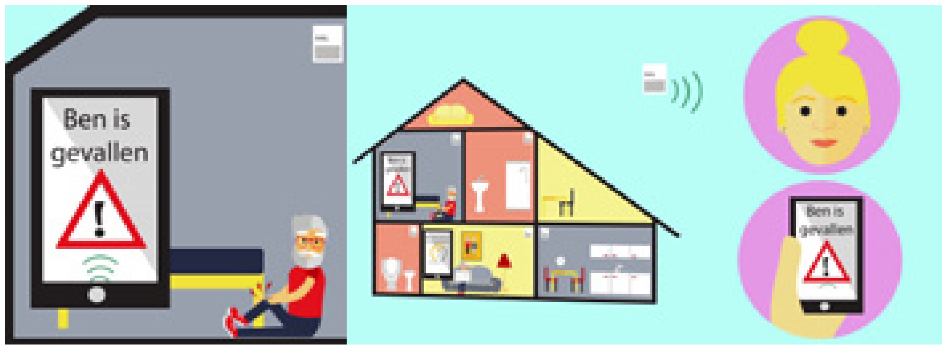

Figure 6.1. Two frames from the animated video showing how the AAL in-home monitoring system detects a fall and sends a message to the informal caregiver.

tangible for the survey participants, and trigger them to critically reflect on the concept of AAL. It was suspected that not all participants were aware of AAL, so the awareness stage was triggered by means of the scenario.

The first part of the scenario provided some background information about Ben and his daughter Sophie and explained how Ben became interested in AAL. The second part illustrated several examples of AAL technologies and displayed Ben interacting with these applications. As it was not feasible to include all forms of AAL technology, several examples were chosen that focused on assistance in the home domain (see Chapter 2):

(1) smart home technology for activity monitoring and fall detection;

(2) reminder system for medication and appointments;

(3) social service robot and social companion robot.

Figure 6.1 shows two frames from the animated video displaying how the in-home monitoring application detects a fall and sends a message to the informal caregiver Sophie.

Following the video, participants were presented with visuals from actual AAL products that are ready-to-market or already available on the Dutch market: the Sensara activity monitoring system (Sensara, 2017); Dayclocks reminder system (DayClocks International B.V., 2017) and the social companion robot Zora (Zora Robotics NV, 2017). The visuals were accompanied by a short description of the key features of each product (see Figure 6.2).

To check the participants understanding of the animated video and the visuals, a control question was included after both stimuli *("The video/pictures about AAL technology was/were clear to me").*

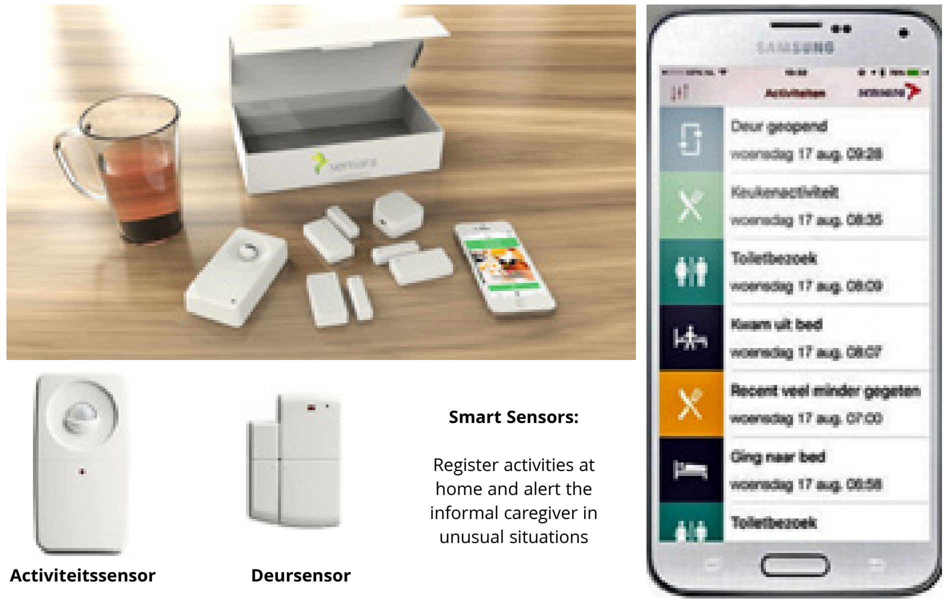

Figure 6.2. Visual used in the AAL survey instrument displaying the Sensara monitoring system
Note. Copyright visuals © Sensara B.V.

6.2.3 SURVEY STRUCTURE

After the welcome screen with some general context, the instructions and the informed consent, participants were asked to indicate their age and gender before they were directed to the first set of items. The first set of items included items from the construct personal innovativeness (PI) and personal norm (PSN).

After the first set of items, participants were directed to the animated video and the visuals of AAL products. Participants had the option to replay the video as often as they liked, before proceeding to the page with the AAL visuals. They were then asked about their prior knowledge and experience with AAL technology.

The next part of the survey included items from the behavioral beliefs variables safety (SAF), independence (IDEP), loss of human touch (LHT) and loss of privacy (LP). This was followed by items about the overall attitude (ATT). Next, the intention to use (ITU) and perceived behavior control (PBC) items were displayed. In the next section participants were asked to reflect on AAL and their social environment including items from the variables relief of family burden (FB), social stigma (STG), caregiver influence (CI) and social norm (SN). Hereafter, items from the variables reliability (REL), user control (CTR), self-efficacy (SEF), privacy norm (PN) and human touch norm (HTN) were displayed. Finally, participants were asked to reflect upon statements about the financial cost (C) of AAL.

The survey concluded with more questions about the socio-demographic background (living situation, education level and work situation), participants' self-rated subjective health and overall quality of live, received care and caregiver, and anticipated need for care.

In total, the survey consisted of 100 items together with the socio-demographic, background and control questions.
The average completion time was 16:35 min for the pilot study.

6.2.4 SURVEY PRE-TEST

Before the pilot study was launched, a second pre-test was deployed to further improve the quality of the survey instrument. The aim of this second pre-test was to evaluate the overall format quality (layout, structure and length), the clarity of the provided instructions, the comprehension of the animated video and visuals, and the comprehension and interpretation of the items and response scales. Furthermore, it was tested how well participants could navigate through the online survey environment (e.g., clicking, scrolling, playing the video).

Two female older adults (64 years and 71 years old) and one male older adult (59 years old) were recruited to participate in the pre-test. One participant had a lower education level, one participant had an intermediate education level, and the third participant had a tertiary education level according to the international standard classification of education (ISCED) (Statistics Netherlands, 2017b). All participants were living alone and two of them were still employed. None of them received care at the time the cognitive interviews were conducted. The participants had different levels of technology experience ranging from basic to good technology skills.

Cognitive interviews were used to evaluate the final draft of the survey. Cognitive interviewing or cognitive testing is a widely used method in survey design to understand how the target population comprehends, mentally processes and responds to the presented questions (Willis, 2005). Following the guidelines described by Willis (2005) a combination of think-aloud and verbal probing techniques were applied during the pre-test. Participants had to actively verbalize their thoughts while completing the survey. In addition, the interviewer introduced several probing questions to stimulate think-aloud reasoning and to further identify potential problems. Probes included questions such as *'Can you repeat this in your own words?'; 'How do you understand this term?'; 'How did you arrive at this answer?'* As a result, several problem areas were identified and the survey was adjusted accordingly. For example, initially items regarding the construct PI and PN were answered in relation to AAL technology instead of new technologies in general. To solve this issue, instructions for this part were rephrased and items were positioned before the AAL video and the AAL visuals.

6.3 PILOT STUDY

A pilot study among the target population was conducted between March and April 2017. The aim of this pilot study was twofold: (1) As a majority of the scales were newly developed or newly applied in the context of AAL, we wanted to explore the psychometric quality of these scales and refine them accordingly; (2) the second objective was to provide initial evidence for the proposed conceptual model of AAL acceptance.

6.3.1 SAMPLE

The online survey for the pilot study was administered by a Dutch ISO-certified research agency specialized in online fieldwork (see 6.1). Participants were invited via e-mail to participate in exchange for credits. Sampling was conducted using pre-defined age quota to achieve a sample that was representative for the Dutch older adult population (Statistics Netherlands, 2017c). In total, 443 older adults between 55 and 85 years started the survey. From these 443 participants, 92 participants aborted immediately after the introduction page. Another 31 participants were removed from the sample due to straight lining, exceptionally short response times, incomplete response patterns and insufficient understanding of the video and photos (measured by the control questions). This lead to a total of 320 cases for further analysis. The participants[8] who did not complete the survey or were removed from the sample did not significantly differ in terms of age ($t(411) = -1.66$, $p = .10$)[9], and there was no association between non-response and gender ($\chi 2(1) = .03$, $p = .87$).

The final sample ($n = 320$) was composed of 160 participants who were between 55 and 64 years old; 132 participants who were between 65 and 74 years old; and 28 participants who were between 75 and 85 years old ($M = 65.13$, $SD = 6.90$). In relation to the actual Dutch older adult population, this distribution contains a slight overrepresentation of the first (50% vs. 45%) and second age group (41% vs. 36%), and an underrepresentation of the last age group (9% vs. 19%). With 57% of the total sample, male participants were slightly overrepresented in comparison with the actual Dutch older adult population (49%). One third of the participants had a lower education level (33%); one third had an intermediate education level (37%); and one third had a tertiary education level (30%). About one third of the sample (29%) was still working. Regarding their living situation,

[8] From the participants who did not complete the survey ($n = 92$) or were removed ($n = 31$), only 93 participants indicated there age and gender. These participants were included in the non-response analysis.

[9] t-test assumptions of normality and homogeneity of variance were met

29% of the participants were living alone. Self-rated health and quality of life were measured on a five-point scale ranging from 1 = poor to 5 = excellent. In our sample, 8% of the participants rated their overall health as excellent, 20% rated their health as very good, 46% rated it as good, 21% reported their health to be fair, and 5% of the participant perceived their overall health to be poor. Regarding the overall quality of life, 9% of the participants perceived their quality of life as excellent, 28% perceived it as very good, 44% of the participants perceived their quality of life as good, 17% rated their quality of life as fair, and 2% of the participants rated it as poor. The majority of our participants (88%) reported that they did not receive any kind of care. Regarding their anticipated need for care, 9% regarded it as highly unlikely to need care in the near future, 15% regarded it as less likely than for others their age, 50% reported it to be equally likely, 7% regarded it as more likely than for others their age, and 5% anticipated their need for care in the near future as highly likely.

6.3.2 DATA ANALYSIS: SPECIFYING THE MEASUREMENT MODEL

Before we describe the data analysis process, it should be noted that the Likert scale items that were used in the AAL acceptance survey were treated as continuous variables. This is common practice in social sciences, and several scientist have argued that parametric procedures can be applied to Likert scale items (Atkinson, 1988; Carifio & Perla, 2008; De Winter & Dodou, 2010; Glass, Peckham, & Sanders, 1972).

Structural equation modeling (SEM) is a family of statistical techniques that originates in regression analysis and factor analysis (Kline, 2016). SEM allows researcher to specify, estimate and test hypothesized patterns of directional and non-directional relationships between multiple observed (indicator variables) and unobserved variables (latent variables) in a comprehensive and powerful manner (Maccallum & Austin, 2000; Savalei & Bentler, 2010). In this initial pilot study, the purpose was to explore the hypothesized relationships between the latent variables and their indicator variables (i.e., the measurement model) by the means of a Confirmatory Factor Analysis (CFA). Hence, the pilot study served as a calibration sample to validate the measurement model with respect to its convergent validity and discriminant validity, and to remove items (indicator variables) that poorly reflect the underlying variables (latent variables). Although this technique is labeled as 'confirmatory', it was used in an exploratory and iterative manner by paying attention to the post-hoc modification indices.
By specifying the relationships between the latent variables and its indicator variables a priori, we employed a theory-driven rather than a data-driven approach to validate our measurements (Jöreskog, 1993; Kline, 2016).

Prior to the data-analysis the data set was checked for normality with SPSS version 23. We followed recommendations of (Kim, 2013) for sample sizes $n > 300$ and inspected absolute skewness and kurtosis values in combination with the histograms of each indicator variable. As reference values, < 2 for skewness and < 7 for kurtosis[10] were used as suggested by West, Finch, and Curran (1995). Based on this inspection (skewness: -1.44 – .77; kurtosis: -3.81 – 6.99), it was concluded that the data were approximately normally distributed.

[10] This cut-off value refers to the proper kurtosis not the excess kurtosis which is calculated by some statistical packages including SPSS (by subtracting 3 from the original value). We therefore added 3 to the SPSS kurtosis value.

As a 'don't know' option was provided, the data set contained 9% missing values. The concentration of missing values was especially high for the indicator variables of the following latent variables: intention to use, caregiver influence, reliability and financial cost. From a theoretical perspective, this indicates that, at this early stage in the acceptance process, some participants were unable to express strong enough expectations about their use intention, their caregivers' opinion, the reliability of AAL and the financial cost of AAL. As 'don't know' is interpreted as having not a strong enough tendency to formulate an opinion, we regard the missing data as missing at random (MAR). This means that it is not dependent on the missing value itself (R. Little & Rubin, 2002; D. B. Rubin et al., 1995). To be able to continue the analysis using the information from all cases, without affecting the validity of parameter estimates, full information maximum likelihood (FIML) was used to deal with the missing values. It is considered a robust and state-of-the-art approach to handle missing data and is widely recommended in the methodological literature (Baraldi & Enders, 2010; T. D. Little, Jorgensen, Lang, & Moore, 2014). FIML is a model-based approach that does not actually impute missing data, but estimates parameters directly using all the available information (complete and incomplete cases) to substitute for the missing data points (Dong & Peng, 2013; T. D. Little et al., 2014). For SEM, FIML has been demonstrated to be a superior method to other missing data methods such as listwise deletion, pairwise deletion, mean substitution and regression imputation (Enders & Bandalos, 2001; Olinsky, Chen, & Harlow, 2003). Olinsky et al. (2003) showed that FIML produces unbiased factor loadings, regression parameters, goodness-of-fit measures and variances across different sample sizes and various percentages of missing data. Similar results were found by Enders and Bandalos (2001) and Enders (2001).

6.3.3 RESULTS OF THE CONFIRMATORY FACTOR ANALYSIS (CFA)

We used the Lavaan package version 0.5-23 (Rosseel, 2012) in R version 3.4.3 (R Core Team, 2017) to perform the CFA. Maximum likelihood estimation (ML) with FIML for the missing data was used because the data were approximately normally distributed.
Lavaan creates a variance-covariance matrix from the raw data which was used as an input. The hypothesized model (see Chapter 5) proposed 19 distinct latent factors and 86 indicator variables. The factor loading of one indicator of each latent variable was set to 1 to set the scale of the latent variable.
As conventional in a CFA, all latent variables were allowed to correlate (see Figure 6.3 for a partial extract of the initial measurement model).

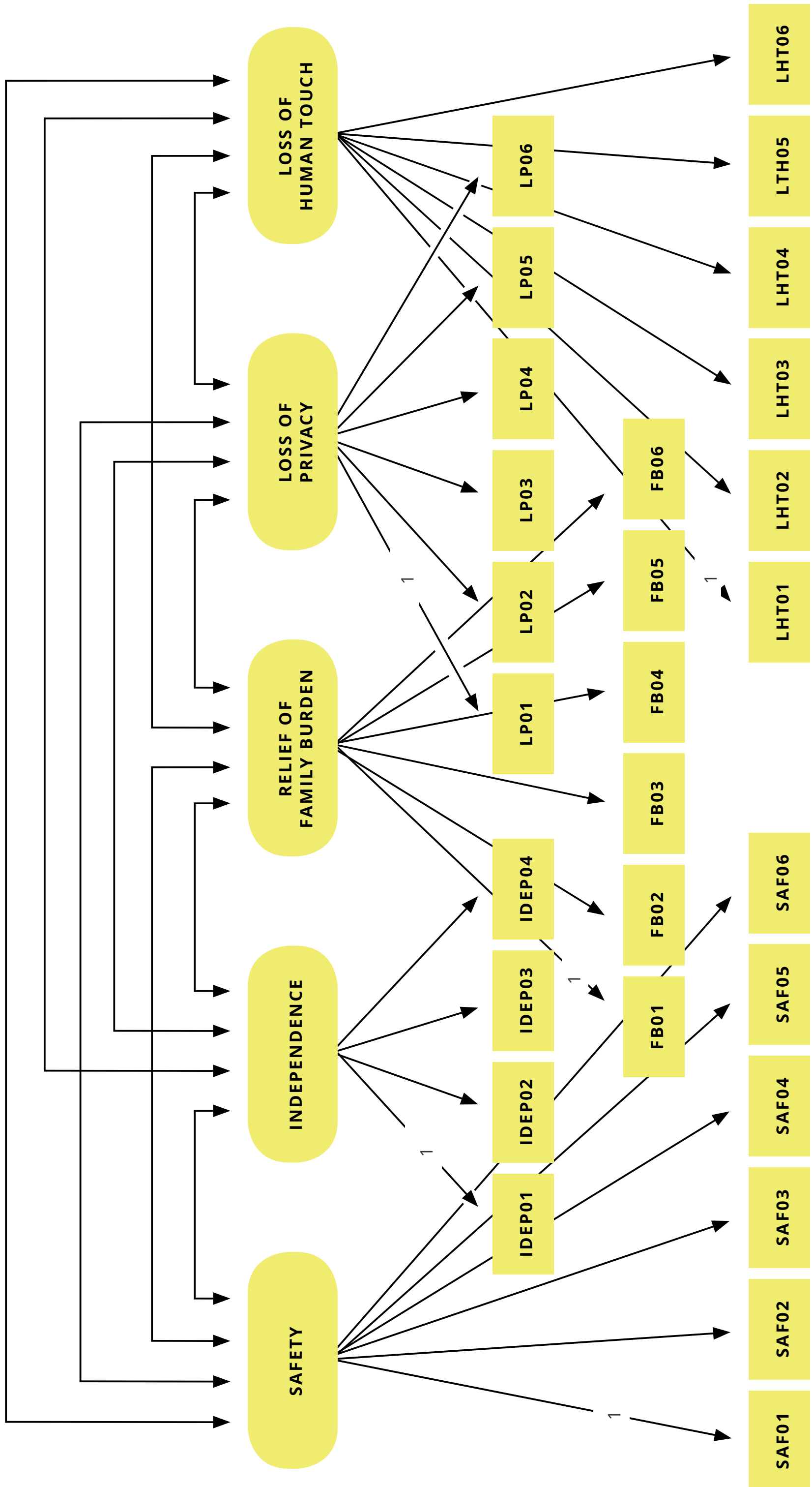

Figure 6.3. Partial extract of the initial measurement model for the latent variables safety, independence, relief of family burden, loss of privacy and loss of human touch. Single-headed arrows represent factor loadings, double headed arrows represent covariance. To simplify the schematic representation residuals are omitted from the figure.

INITIAL MEASUREMENT MODEL

First, we assessed the overall model fit using multiple goodness-of-fit indices. Following recommendations from literature (e.g., Hooper, Coughlan, & Mullen, 2008), the normed chi-square (χ^2/df)[11], the Root Mean Square Error of Approximation (RMSEA), the Standardized Root Mean Square Residual (SRMR), the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) were used to assess how well the hypothesized model fit the observed data. The chi-square value is an absolute fit index and assesses the discrepancy between the model implied covariance matrix and the sample covariance matrix. Models are accepted as fitting, when the value is non-significant at a $p < .05$ threshold indicating that the null hypothesis of 'no difference' is accepted (Barrett, 2007). Due to its sensitivity to sample size (Bentler & Bonnett, 1980), it was decided to use the normed chi-square (Wheaton, Muthen, Alwin, & Summers, 1977) for which Bentler (2006) recommends a ratio of ≤ 5.0. RMSEA is also an absolute fit measure that favors parsimonious models with lesser parameters (Hooper et al., 2008). Researchers recommend cut-off values ranging from ≤. 06 to ≤. 08 (Hu & Bentler, 1999; Schreiber et al., 2006). The SRMR is another absolute fit measure and is a standardized version of the Root Mean Residual Square (RMR). Hu & Bentler (1999) suggest a cut-off value of ≤ .08 that is frequently cited in the literature. CLI and TFI are incremental or comparative fit indices that compare the hypothesized model with the independence model. The independence model assumes that all latent variables are uncorrelated (Hooper et al., 2008). Although both indices take into account model complexity, TLI applies a more stringent penalty. CFI and TLI values should be at least .90 to accept the model (Hair, Black, Babin, Anderson, & Tatham, 2010).

As shown in Table 6.2 the absolute fit criteria normed chi-square (1.95) and RMSEA (.055) were within the recommended values. SRMR (.09) was slightly above the recommended value. The incremental fit criteria CFI (.81) and TLI (.79) were well below the required threshold. This led to the conclusion that the hypothesized measurement model in its current form does not fit the observed data.

Table 6.2 Goodness-of-Fit of the Initial Measurement Model

GOODNESS-OF-FIT	RECOMMENDED VALUE	INITIAL MEASUREMENT MODEL
X^2/df	≤ 5.0	1.95
RMSEA	≤ .06 - ≤ .08	0.55 (CI .053 - .056)
SRMR	≤ .08	.09
CFI	≥ .90	.81
TLI	≥ .90	.79

[11] The model chi-square was not used due to its sensitivity to sample size, meaning that models with large sample sized are nearly always rejected (Bentler & Bonnett, 1980).

RE-SPECIFIED MEASUREMENT MODEL

To improve the measurement model we further examined its psychometric properties in terms of the convergent validity and discriminant validity for each of the latent variables. In a CFA, convergent validity reflects the extent to which indicators of a latent variable that are hypothesized to be related are in fact related to each other. Discriminant validity reflects the degree to which indicators of each latent variable are different from indicators of another latent variable (Campbell & Fiske, 1959; Fornell & Larcker, 1981).

First, the standardized factor loadings were inspected. Upon inspection, several items were iteratively removed as they loaded low (< .50) on the respective latent variable: SAF05 (.46), FB06 (.10), FB05 (.26), LHT02 (.40), PN02 (.28), PN05 (.35). Two of the three indicators for the latent variable user control (CTR01 (.38) and CTR03 (.33)) also showed low standardized factor loadings. Hence, it was decided to exclude the factor user control for further analysis, as a minimum of three indicators is needed to represent the latent variable (Hair et al., 2010). All remaining indicators loaded significantly on the respective latent variable at a .001 level.
In a second step, indicators with low squared multiple correlations (*SMC* < .40) were removed. The squared multiple correlation of an indicator represents the estimated percent of variance explained by the latent variable. Upon inspection, several items were iteratively removed as they were below the aspiration value:
SAF06 (*SMC* = .31), IDEP02 (*SMC* = .32), FB04 (*SMC* = .35), LHT01 (*SMC* = .35), STG01 (*SMC* = .37), PN06 (*SMC* = .30), SEF05 (*SMC* = .34), REL03 (*SMC* = .31). Four items that were below the aspiration value were not excluded to meet the minimal requirement of three indicators to represent the latent variable (FB03, CI02, STG02, PN03). It should be noted that we applied a relatively strict threshold for squared multiple correlations, and some researchers recommend a value < .20 as a threshold (Hooper et al., 2008).

Third, post-hoc modification indices were inspected to further improve the measurement model. Following the post-hoc modification suggestions, we removed LP05 because it had too many cross-loadings. Furthermore, residual correlations between indicators LP03 and LP06, PBC03 and PBC04, and ATT02 and ATT03 were added. After modification, the squared multiple correlation of PBC03 moved below the aspiration value (.38).

To further evaluate the convergent validity of the measurement model we assessed McDonald's hierarchical omega (McDonald, 1999), Cronbach's alpha (Cronbach, 1951), and the average variance extracted (AVE) for each latent variable. We used the semTools package version 0.4-14 in R (semTools Contributors, 2016). All values for alpha and omega were above the recommended threshold of .70 (Nunnally & Bernstein, 1978), with the lowest values for the latent variable social stigma ($\alpha = .71$, $\omega^h = .77$) and perceived behavioral control ($\alpha = .81$, $\omega^h = .75$), and the highest value for the latent variable intention to use ($\alpha = .94$, $\omega^h = .93$). The AVE values were all above the recommended threshold of .50 (Fornell & Larcker, 1981), except for social stigma (*AVE* = .49) and perceived behavioral control (*AVE* = .47). This means that the variance due to measurement error in these variables is larger than the variance captured by the variable and its underlying indicators. As the value for social stigma is close to the required threshold and we used a validated scale for perceived behavioral control, we decided to keep the measurement model intact but pay close attention to these variables during the main study (Chapter 7).

The discriminant validity was examined through the heterotrait-monotrait ratio (HTMT) of the correlations, using the semTools package version 0.4-14 in R (semTools Contributors, 2016). The HTMT ratio represents the average of the correlation of indicators across different constructs (heterotrait-heteromethod correlations), relative to the average of the correlations of indicators within the same construct (monotrait-heteromethod correlations).
If the HTMT value is below .90, discriminant validity has been established (Henseler, Ringle, & Sarstedt, 2015). Table 6.4 shows that there was a multicollinearity problem between the latent variables safety (SAF) and independence (IDEP) (*HTMT* = .91).
It was therefore decided to collapse these two variables into a single latent variable called 'safe and independent living' (SAF-IDEP). The latent variables caregiver influence (CI) and social norm (SN) also had a high HTMT ratio (*HTMT* = .91). In the theoretical model CI is a director predictor of SN. From a theoretical perspective, the high HTMT ratio indicates that caregivers seem to be highly influential social referents for older adults, and caregivers might be mainly responsible for explaining their perceived social norm. Although closely related, it was concluded that for the main study (Chapter 7) both constructs should still be considered as separate variables.

As shown in Table 6.3, the modified measurement model with 17 latent factors, 68 indicators and 3 added residual correlations showed improved fit for all fit indices. Absolute fit indices, i.e., normed chi-square (1.72), RMSEA (.047) and SRMR (.06), where all well within the recommended values. The incremental fit criteria CFI (.89) and TLI (.88) also improved, but were still slightly below the required threshold. Cheung and Rensvold (2002) argue that complex models with many indicators and latent variables can yield smaller values in goodness-of-fit indices, due to small theoretically insignificant factor loadings and correlated residuals that are assumed to be zero in a CFA. As we tested a fairly complex model, it was decided to provisionally accept the current measurement model because CFI and TLI values were close to the required threshold.

Table 6.5 displays the final list of indicators with intercept (FIML mean), indicator mean (values with listwise deletion), standard deviation (values with listwise deletion), standardized factor loadings, hierarchical omega, Cronbach's alpha, and the average variance extracted (AVE). A partial extract of the re-specified measurement model is shown in Figure 6.4. The observed variance-covariance matrix can be requested from the author. For a theoretical discussion on the suggested modifications we refer to Section 6.5.

Table 6.3 Goodness-of-Fit of the Re-specified Measurement Model

GOODNESS-OF-FIT	RECOMMENDED VALUE	RE-SPECIFIED MEASUREMENT MODEL
X^2/df	≤ 5.0	1.72
RMSEA	≤ .06 - ≤ .08	0.47 (CI .045 - .050)
SRMR	≤ .08	.06
CFI	≥ .90	.89
TLI	≥ .90	.88

Table 6.4 Heterotrait-Monotrait Ratio (HTMT) Matrix between Latent Variables of the Initial Measurement Model to Assess Discriminant Validity

	ITU	ATT	SN	PSN	PBC	SAF	IDEP	FB	LP	LHT	CI	STG	HTN	PN	PI	SEF	REL	C
ITU	1.00																	
ATT	.82	1.00																
SN	.73	.65	1.00															
PSN	.50	.34	.41	1.00														
PBC	.49	.38	.47	.50	1.00													
SAF	.77	.70	.74	.38	.30	1.00												
IDEP	.75	.68	.69	.45	.34	**.91**	1.00											
FB	.59	.61	.84	.37	.43	.76	.75	1.00										
LP	.47	.57	.34	.11	.30	.36	.32	.23	1.00									
LHT	.32	.44	.22	.10	.12	.15	.19	.10	.64	1.00								
CI	.55	.50	**.91**	.38	.45	.57	.51	.81	.18	.10	1.00							
STG	.34	.40	.35	.14	.27	.21	.18	.15	.54	.53	.22	1.00						
HTN	.42	.47	.27	.12	.19	.21	.20	.23	.41	.50	.17	.28	1.00					
PN	.10	.18	.13	.17	.12	.14	.13	.10	.35	.26	.16	.12	.51	1.00				
PI	.39	.30	.34	.88	.57	.26	.39	.32	.15	.16	.30	.13	.14	.11	1.00			
SEF	.44	.44	.52	.45	.83	.28	.35	.38	.37	.23	.50	.52	.17	.19	.52	1.00		
REL	.58	.66	.59	.20	.45	.58	.51	.55	.66	.38	.51	.35	.46	.18	.21	.53	1.00	
C	.12	.14	.10	.16	.41	.10	.08	.09	.36	.29	.10	.18	.25	.21	.23	.28	.34	1.00

Note. HTMT values < .90 indicate that discriminant validity has been established (Henseler et al., 2015). SemTools uses absolute values of the correlations to calculate the HTMT matrix, meaning that values can range between 0.00 - 1.00. HTMT values > .90 are displayed in bold.

ITU = intention to use, ATT = attitude, SN = social norm, PSN = personal norm, PBC = perceived behavior control, SAF = safety, IDEP = independence, FB = relief of family burden, LP = loss of privacy, LHT = loss of human touch, CI = caregiver influence, STG = social stigma, HTN = human touch norm, PN = privacy norm, PI= personal innovativeness, SEF = self-efficacy, REL = reliability, C= financial cost

Table 6.5 Re-specified Measurement Model: Intercept, Mean, Standard Deviation, Standardized Factor Loadings, Squared Multiple Correlations, Cronbach's Alpha, Hierarchical Omega, and Average Variance Extracted

LATENT VARIABLE	INDICATOR	INTERCEPT / FIML MEAN	LISTWISE MEAN	LISTWISE SD	FACTOR LOADINGS	SMC	α	ω^h	AVE
ITU	ITU01	3.36	3.45	.92	.89	.79	.94	.93	.82
	ITU02	3.31	3.38	.89	.93	.87			
	ITU03	3.31	3.37	.90	.95	.91			
	ITU04	3.44	3.48	.87	.83	.69			
ATT	ATT01	3.96	3.96	.91	.82	.68	.93	.92	.68
	ATT02	4.02	4.02	.84	.78	.60			
	ATT03	3.96	3.96	.86	.79	.63			
	ATT04	3.44	3.44	1.04	.83	.68			
	ATT05	3.52	3.52	.97	.87	.76			
	ATT06	3.47	3.47	.90	.83	.69			
SN	SN01	3.48	3.54	.77	.75	.57	.85	.95	.70
	SN02	3.64	3.73	.75	.87	.76			
	SN03	3.68	3.74	.76	.88	.78			
PSN	PSN01	3.38	3.40	.90	.87	.76	.80	.82	.60
	PSN02	3.73	3.73	.82	.79	.63			
	PSN03	3.31	3.32	.95	.65	.42			
PBC	PBC01	3.73	3.76	.75	.83	.69	.81	.75	**.47**
	PBC02	3.17	3.21	.89	.70	.49			
	PBC03	3.19	3.19	1.00	62	**.38**			
	PBC04	3.33	3.34	1.01	.65	.42			
SAF-IDEP	SAF01	3.78	3.79	.77	.73	.54	.89	.91	.56
	SAF02	3.85	3.86	.82	.85	.72			
	SAF03	4.01	4.02	.66	.66	.44			
	SAF04	4.04	4.04	.73	.72	.51			
	IDEP01	3.86	3.89	.74	.75	.57			
	IDEP03	3.80	3.81	.65	.68	.46			
	IDEP04	3.86	3.88	.69	.77	.60			
FB	FB01	3.75	3.80	.81	.86	.73	.77	.80	.55
	FB02	3.75	3.79	.83	.75	.56			
	FB03	3.47	3.49	.84	.60	**.36**			

LATENT VARIABLE	INDICATOR	INTERCEPT / FIML MEAN	LISTWISE MEAN	LISTWISE SD	FACTOR LOADINGS	SMC	α	ω^h	AVE
LP	LP01	3.18	3.16	.96	.87	.76	.93	.87	.68
	LP02	3.27	3.26	.94	.88	.77			
	LP03	3.28	3.28	1.03	.76	.58			
	LP04	3.14	3.14	1.00	.89	.79			
	LP06	3.20	3.19	1.05	.75	.56			
LHT	LHT03	2.93	2.90	1.01	.72	.51	.88	.85	.64
	LHT04	3.35	3.34	0.99	.83	.69			
	LHT05	3.21	3.20	0.97	.87	.76			
	LHT06	3.16	3.16	1.06	.79	.62			
CI	CI01	3.61	3.67	0.74	.81	.66	.77	.86	.58
	CI02	3.41	3.44	0.81	.57	**.33**			
	CI03	3.60	3.66	0.66	.91	.83			
STG	STG02	2.94	2.94	1.00	.59	**.35**	.71	.77	**.49**
	STG03	2.46	2.43	0.84	.87	.76			
	STG04	2.25	2.21	0.83	.64	.41			
HTN	HTN01	4.25	4.26	0.67	.80	.63	.85	.85	.58
	HTN02	3.95	3.95	0.78	.76	.58			
	HTN03	4.03	4.03	0.74	.75	.56			
	HTN04	3.78	3.78	0.88	.76	.58			
PN	PN01	4.03	4.03	0.79	.66	.44	.74	.78	.52
	PN03	4.46	4.46	0.66	.60	**.36**			
	PN04	4.35	4.35	0.61	.92	.85			
PI	PI01	3.29	3.30	0.90	.84	.70	.83	.83	.56
	PI02	3.21	3.22	0.96	.65	.42			
	PI03	2.71	2.71	0.93	.77	.59			
	PI04	3.76	3.77	0.84	.73	.53			
SEF	SEF01	3.71	3.75	0.73	.72	.52	.86	.92	.53
	SEF02	3.98	4.01	0.67	.75	.57			
	SEF03	3.87	3.89	0.70	.77	.60			
	SEF04	3.28	3.30	0.84	.75	.56			
	SEF06	3.73	3.77	0.84	.71	.51			
	SEF07	3.56	3.57	0.89	.68	.47			
REL	REL01	3.46	3.50	0.70	.87	.75	.84	.81	.62
	REL02	3.36	3.42	0.73	.80	.64			
	REL04	2.92	2.93	0.87	.71	.51			
C	C01	3.92	3.94	0.80	.82	.67	.87	.84	.68
	C02	3.48	3.47	0.96	.71	.50			
	C03	3.86	3.91	0.81	.96	.93			

Note. Values below aspiration values are displayed in bold.

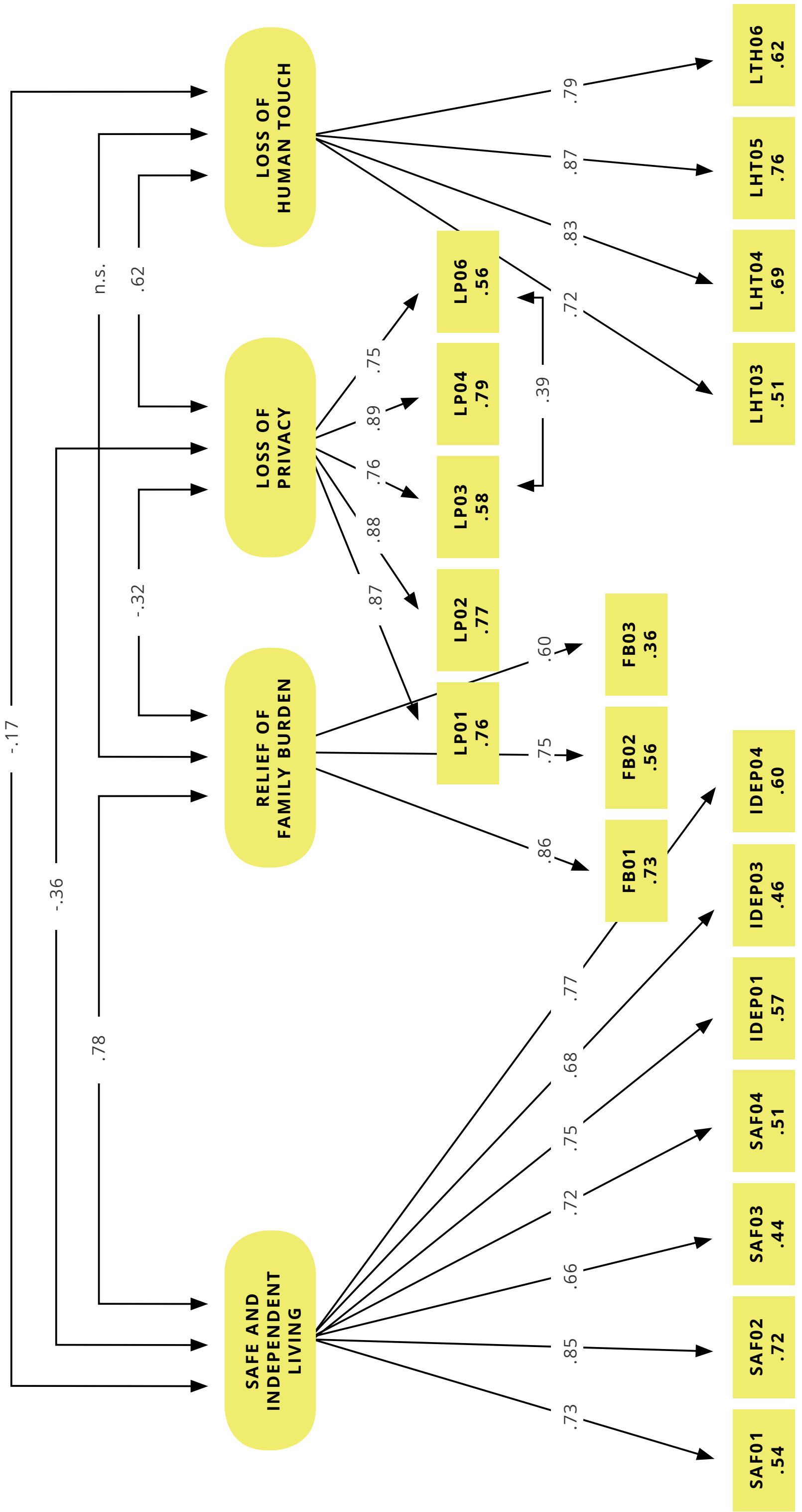

Figure 6.4. Partial Extract of the re-specified measurement model for the latent variables safe and independent living, relief of family burden, loss of privacy and loss of human touch. To simplify the schematic representation residuals are omitted from the model. Values adjacent to single-headed arrows represent standardized factor loadings. Values adjacent to double headed arrows represent correlation coefficients. Squared multiple correlations values are displayed below the indicator. To simplify the schematic representation, only the residuals that are correlated are included in the figure. Double-headed arrows between indicators represent residual correlations.

6.4 DESCRIPTIVE STATISTICS

To use a complete data set for the description of the sample, single imputation with the Expectation Maximization (EM) method was used to handle the missing data for the descriptive statistics. The EM algorithm is an iterative approach that alternates between two steps. In the E-step, missing values are filled with a conditional expectation given the observed data and the initial expectation of the covariance matrix. In the M step, maximum likelihood estimates of the mean vector and covariance matrix are computed using the statistics from the E-step. The algorithm repeats these steps until convergence is reached in the parameter estimates (Dempster, Laird, & Rubin, 1977; Enders, 2001). EM is a relative robust method compared to other imputation methods, such as listwise deletion or mean substitution (L. H. Rubin, Witkiewitz, Andre, & Reilly, 2007).

For the descriptive statistics of the pilot sample, the indicator scores from the re-specified measurement model were pooled into composite scores for each latent variable. Table 6.6 shows an overview of the composite mean and standard deviation for each latent variables (EM and listwise).

The intention to use AAL was moderately high in the pilot sample (*M* = 3.38, *SD* = .80). This means that older adult were in general relatively open to the idea of using AAL technologies in the future. The attitude towards using AAL was even more positive (*M* = 3.73, *SD* = .79). However, overall participants also had a high privacy norm (*M* = 4.28, *SD* = .56) and high human touch norm (*M* = 4.00, *SD* = .63).

6.5 CONCLUSION AND DISCUSSION

The purpose of this initial pilot study was to explore the psychometric quality of the used measurements and provide initial evidence for the proposed conceptual model of AAL acceptance.

In the process of refining the measurement model, several indicators were removed as they loaded poorly on the respective latent variables, had low squared multiple correlations or had too many cross- loadings. In total, 18 indicators were removed: SAF05, SAF06, IDEP02, FB04, FB05, FB06, LHT01, LHT02, LP05, STG01, PN02, PN05, PN06, SEF05, REL03, CTR01, CTR02 and CTR03. Many authors argue that theoretical reasoning is equally important to empirical reasoning when testing and modifying conceptual models in SEM, and model modifications should always be theoretical justified (Garson, 2015; Kline, 2016). Thus, each of the removed indicators was carefully revisited together with two senior researchers, who were previously involved in the development and pre-test of the measurements.

Based on these discussions and our theoretical framework, it was concluded that some of the dismissed indicators tapped into relevant aspects of the underlying variable. These indicators should not be dismissed solely on statistical grounds that are routed in one pilot study. Hence, it was decided to keep some of these indicators for the main study for re-evaluation (Chapter 7). These items included: SAF06 (*"dangerous situations at home can be avoided"*), IDEP02 (*"make me less dependent on personal assistance"*), FB04 (*"family members will feel less strained around me"*), LHT01 (*"will foster loneliness"*), LP05 (*"will feel like an invasion into my personal space"*), STG01 ("others will think I am dependent") and PN06 (*"AAL databases should be protected from unauthorized access no matter how*).

Table 6.6 Mean Composite Score and Standard Deviation per Latent Variable

LATENT VARIABLE	EM MEAN	EM SD	LISTWISE MEAN	LISTWISE SD
Intention to Use (ITU)	3.38	.80	3.48	.82
Attitude (ATT)	3.73	.79	3.73	.79
Social Norm (SN)	3.64	.64	3.70	.66
Personal Norm (PSN)	3.48	.76	3.50	.76
Perceived Behavioral Control (PBC)	3.37	.72	3.41	.72
Safe and Independent Living (SAF-IDEP)	3.89	.56	3.93	.55
Relief of Family Burden (FB)	3.67	.68	3.72	.69
Loss of Privacy (LP)	3.21	.85	3.20	.89
Loss of Human Touch (LHT)	3.16	.84	3.12	.88
Social Stigma (STG)	2.54	.71	2.51	.70
Caregiver Influence (CI)	3.57	.58	3.61	.61
Human Touch Norm (HTN)	4.00	.63	4.00	.63
Privacy Norm (PN)	4.28	.56	4.28	.56
Personal Innovativeness (PI)	3.25	.74	3.25	.74
Self-Efficacy (SEF)	3.69	.61	3.77	.58
Reliability (REL)	3.28	.62	3.29	.67
Financial Cost (C)	3.77	.69	3.79	.77

Furthermore, two items were rephrased for the main study. FB05 was positively rephrased into *"will relieve the burden on my family members"* and REL03 was rephrased into *"is ~~extremely~~ undependable"*. We also added a new item to the caregiver influence (CI) scale: "My caregivers would value my use of AAL technology" (CI04). The reason for this addition was that one of the other CI items performed rather poorly, but could not be removed without violating the condition of three items per measurement. Overall, this lead to 78 indicator variables for the main study.

The factor user control (CTR01, CTR02 and CTR03) was entirely removed. We suspect that, at this early stage of the acceptance process, older adults find it hard to express a clear and consistent expectation about their feeling of being in control when interacting with AAL technologies. These expectations might be more explicit in a later acceptance stage.

In addition, three residual correlations between LP03 and LP06, PBC03 and PBC04, and ATT02 and ATT03 were added to the measurement model. These adjustments seem theoretically justifiable, as the correlation occurred in the same subscale. A potential explanation for this residual correlations is a common method effect, as item pairs had a similar wording and structure and used the same response scale.

Finally, based on the analysis for discriminant validity, it was decided to merge the two latent variables safety and independence. Looking at the items of safety and independence, collapsing them into the factor 'safe and independent living' makes theoretical sense, as safety is often viewed as a precondition for independent living. In parts of the qualitative work, it was also found that independence is not always explicitly mentioned as a potential outcome of AAL. In these studies, it was inferred that safety outcomes might imply independence outcomes (Jaschinski & Ben Allouch, 2015b, 2015a).

The re-specified measurement model with 17 distinct latent factors, 68 indicators and 3 added residual correlations that was specified in the pilot study showed good fit when comparing the model implied covariance matrix and the sample covariance matrix. Comparison with the independence model showed values slightly below the recommended threshold. Although comparison with the independence model was slightly below the required threshold, it was decided to proceed with the main study. Hence, we are following the reasoning of Cheung and Rensvold (2002), who argue that models with many indicators and latent variables can yield smaller values in goodness-of-fit indices. The adapted conceptual model is shown in Figure 6.5.

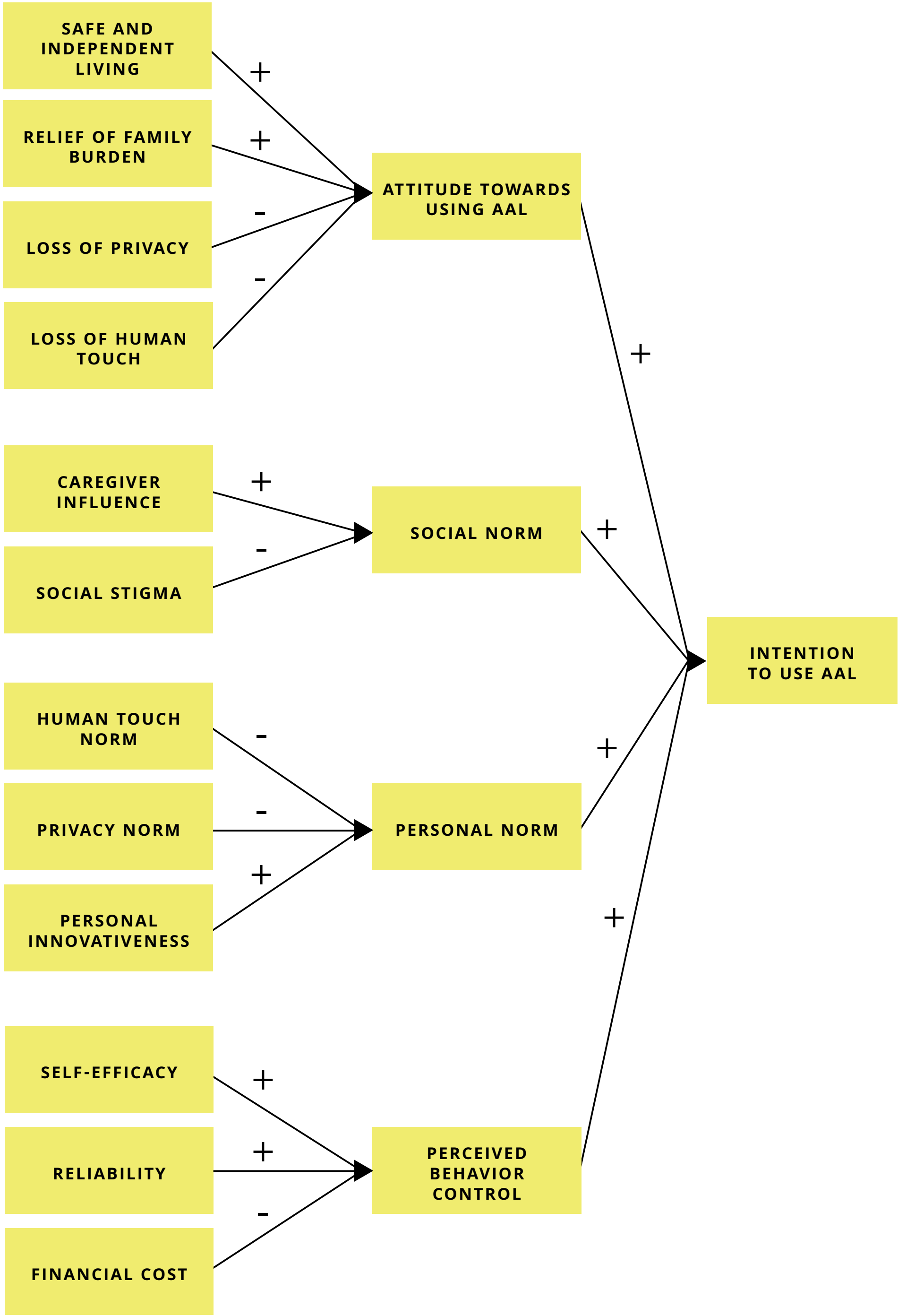

Figure 6.5. Adapted Conceptual Model of AAL Acceptance.

7 Explaning the Acceptance of AAL Technolocy among Dutch Older Adults

In Chapter 6, the scope and design of the online survey, which aims to investigate the acceptance of AAL technology among older adults, was described. Based on a pilot sample (*n* = 320) of the Dutch older adult population, the psychometric quality of the used measurements was explored, and initial evidence for the proposed conceptual model of AAL acceptance was provided. The pilot study resulted in refined measurements for the final survey instrument and an adapted conceptual model of AAL acceptance.
The current chapter present the results of the main online survey which was conducted among a second, larger sample (*n* = 1296) of the Dutch older adult population. Based on these findings, statistically grounded and externally valid inferences about the current state of early acceptance of AAL technology among the Dutch older population can be made. Secondly, the relative importance of different acceptance factors, their underlying relationships, and their explanatory power for the intention to use AAL technologies was compared, thereby attending to the third research question (RQ3). These insights provide further understanding on how and why older adults will accept or reject these technologies in the future.

In consequence, the results of this study have important implications for researchers, developers and policy makers alike, and we hope that our results will guide future research efforts, design decisions and policy directions in the AAL field.

7.1 PROCEDURE

Between May and July 2017, the adapted online survey was administered to a new sample of Dutch older adults (55 - 85 years) by the same research agency as in the pilot study. Similar to the pilot study, participants were invited via e-mail to participate in exchange for credits. For the sampling, we used pre-defined age quota to achieve a sample that was representative for the Dutch older adult population (Statistics Netherlands, 2017c).

The adapted survey instrument contained 92 items together with the demographic, background and control questions (see Table 7.1). We used the same response scales as in the pilot study, which was a five-point Likert scales with a 'don't know' option and a five-point semantic differential scale for the attitude items. The general structure of the survey was similar to the pilot study, with only small structural adaptions due to the removal of some items (see Chapter 6). Participants saw the same video scenario and visuals of AAL applications to explain the concept of AAL. The average completion time was 15:55 minutes for the main study.

Table 7.1 Overview of the Adapted Measurements

VARIABLE NAME	NO. OF ITEMS	VARIABLE NAME	NO. OF ITEMS
Intention to Use AAL (ITU)	4	Social Stigma (STG)	4
Attitude towards Using AAL (ATT)	6	Human Touch Norm (HTN)	4
Social Norm (SN)	3	Privacy Norm (PN)	4
Personal Norm (PSN)	3	Personal Innovativeness (PI)	4
Perceived Behavioral Control (PBC)	4	Self-Efficacy (SEF)	6
Safe and Independent Living (SAF-IDEP)	9	Reliability (REL)	4
Relief of Family Burden (FB)	5	Financial Cost (C)	3
Loss of Privacy (LP)	6	Demographics & Background	12
Loss of Human Touch (LHT)	5	Control Questions	2
Caregiver Influence (CI)	4		

7.2 SAMPLE

Upon invitation, 2113 older adults between 55 and 85 years started the survey. From these 2113 participants, 679 participants did not complete the survey. The majority of these participants stopped immediately after the introduction page. Another 138 participants were removed from the sample due to straight lining, exceptionally short response times, incomplete response patterns, and insufficient understanding of the video and photos (measured with the control questions).
This lead to a total response rate of 61% and 1296 cases for further analysis.
The participants[12] who did not complete the survey or were removed from the sample were slightly older ($M = 69.02$, $SD = 8.21$) than the participants who were included ($M = 66.65$, $SD = 7.72$). Although this difference was statistically significant ($t(1758) = -5.57$, $p < .001$)[13], looking at the absolute means this difference was minor. There was no significant association between non-response and gender ($\chi^2(1) = .41$, $p = .52$).

[12] From the participants who did not complete the survey (*n* = 679) or were removed (*n* = 138), only 464 participants indicated there age and gender. These participants were included in the non-response analysis.
[13] t-test assumptions of normality and homogeneity of variance were met.

The final sample was representative for the Dutch older adult population in terms of age and gender (see Table 7.2) (Statistics Netherlands, 2017c).

Table 7.2 Sample Characteristics in Relation to Dutch Older Adult Population

	SAMPLE (n = 1296, IN %)	DUTCH OLDER ADULT POPULATION IN 2016 (IN %)
Gender		
Male	49	49
Female	51	51
Age		
55-64	43	45
65-74	38	36
75-85	19	19

Sample characteristics in terms of living situation, education level, work situation, self-rated health, self-rated quality of life, current and expected need for support and AAL experience are displayed in Table 7.3

7.3 MEASUREMENT MODEL

The survey was administered to a new sample. In the pilot study, 18 indicators were removed as they loaded poorly on the respective latent variables, had low squared multiple correlations or had too many cross-loadings. Despite these weaknesses, 10 indicators were included for re-evaluation due to theoretical considerations (see Section 6.5). Hence, the measurement model had to be specified for the current sample, before continuing with the descriptive statistics and the structural model.

7.3.1 DATA SCREENING

The data set was checked for normality, prior to the data-analysis, with SPSS version 23. Similar to the pilot study, we followed recommendations of Kim (2013) for sample sizes $n > 300$ and inspected absolute skewness and kurtosis values in combination with the histograms of each indicator variable. As reference values, < 2 for skewness and < 7 for kurtosis[14] were used (West et al., 1995). The indicator PN06 from the latent variable privacy norm, which was previously dropped during the pilot study but was included for re-evaluation, was leptokurtic (kurtosis: 7.04). It was therefore decided to drop the indicator PN06 from the measurement model. The other indicators were approximately normally distributed (skewness: -1.46 – .74; kurtosis: -.78 – 6.52).

The collected data contained 9% missing values due to the 'don't know' option. Similar to the pilot study, the concentration of missing values was especially high for the indicator variables of the following latent variables: intention to use, caregiver influence, reliability and financial cost. This confirms our findings from the pilot study that, at this early stage in the acceptance process, some older adults are unable to express strong enough expectations about their use intention, their caregivers' opinion, the reliability of AAL, and the financial cost of AAL. To be able to continue the analysis using the information from all cases without affecting the validity of the parameter estimates, full information maximum likelihood (FIML) was used to deal with the missing values (see Section 6.3.2 for a detailed argumentation and description of the FIML method for missing values).

[14] This cut-off value refers to the proper kurtosis not the excess kurtosis which is calculated by some statistical packages including SPSS (by subtracting 3 from the original value). Therefore 3 was added to the SPSS kurtosis value.

Table 7.3 Sample Characteristics

	SAMPLE (n = 1296, IN %)
Living Situation	
Alone	30
With (partner/family/friend)	70
Education	
Low	36
Intermediate	34
Tertiary	30
Work Situation	
Working	26
Not-Working	74
Self-rated Health	
Excellent	7
Very Good	19
Good	42
Fair	27
Poor	5
Self-rated Quality of Life	
Excellent	9
Very Good	26
Good	44
Fair	19
Poor	2
Current Support Need*	
No support	83
Domestic Tasks	13
Psychosocial Support	7
Personal Care	4
Medical Care	2

	SAMPLE (n = 1296, IN %)
Support Provider*+	
Partner	43
Child	28
Family	6
Friend	9
Neighbor	6
Professional	52
Expected Support Need	
Highly unlikely	12
Less likely than others	14
Equally likely than others	44
More likely than for others	9
Highly likely	7
Don't know	14
AAL Experience (heard about before)	
Never	36
Once	24
Several times	27
Often	11
Very often	2
AAL Experience (tried out)	
Never	95
Once	2
Several times	2
Often	0,8
Very often	0,2

Note. *multiple answers were allowed, +of those who reported to receive support (n = 223)

7.3.2 INITIAL MEASUREMENT MODEL

For the data analysis, the Lavaan package version 0.5-23 (Rosseel, 2012) in R version 3.4.3 (R Core Team, 2017) was used to perform a Confirmatory Factor Analysis (CFA). Maximum likelihood estimation (ML) with FIML for the missing data was used because the data were approximately normally distributed. Lavaan creates a variance-covariance matrix from the raw data as an input. The hypothesized measurement model for the main study proposed 17 distinct latent factors and 77 indicators[15]. The factor loading of one indicator of each latent variable was set to 1 to set the scale of the latent variable. As conventional in a CFA, the covariance between all latent factors was freely estimated.

Similar to the pilot study, we used the normed chi-square (χ^2/df), the Root Mean Square Error of Approximation (RMSEA), the Standardized Root Mean Square Residual (SRMR), the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) to assess how well the modified measurement model fitted the observed data. Table 7.4 shows that the absolute fit criteria normed chi-square (3.53), RMSEA (.044) and SRMR (.06) were within the recommended values. The incremental fit criteria CFI (.88) and TLI (.87) were slightly below the required threshold. It was therefore concluded, that the modified measurement model in its current form does not quite fit the observed data.

Table 7.4 Goodness-of-fit of the Initial Measurement Model

GOODNESS-OF-FIT	RECOM-MENDED VALUE	INITIAL MEASUREMENT MODEL
χ2/df	≤ 5.0	3.53
RMSEA	≤ .06 - ≤ .08	.044 (CI .043 – .045)
SRMR	≤ .08	.06
CFI	≥ .90	.88
TLI	≥ .90	.87

[15] 68 indicators from the pilot study + 10 items for re-evaluation – PN06 (leptokurtic)

7.3.3 FINAL MEASUREMENT MODEL

To improve the measurement model, we once again examined psychometric properties in terms of the convergent validity and discriminant validity. Thereby, we followed the same procedure as in the pilot study. All indicators showed good standardized factor loadings (> .50) and loaded significantly on the respective latent variable (p < .001). However, several indicators still showed low squared multiple correlation values (*SMC* < .40): SAF06 (*SMC* = .33), IDEP02 (*SMC* = .27), FB04 (*SMC* = .26), LHT01 (*SMC* = .29), CI02 (*SMC* = .34), STG01 (*SMC* = .35), SEF04 (*SMC* = .37), REL03 (*SMC* = .35). Most of these indicators had already shown low values during the pilot study, but were included in the main study for re-evaluation. As values were low across the two independent samples, it was decided to remove these indicators from the final measurement model. The latent variable privacy norm (PN) had low or just acceptable squared multiple correlation values among all the remaining three indicators: PN01 (*SMC* = .30), PN04 (*SMC* = .39), PN03 (*SMC* = .42). As the variable showed relatively weak psychometric properties across the two independent samples, it was decided to remove this latent variable from the measurement model.

Two indicators (PSN03, STG02) that were below aspiration values were not excluded to meet the minimal requirement of three indicators to represent the latent variable (Hair et al., 2010). Another indicator below aspiration value (PI02) was included because it originated in a validated scale (Agarwal & Prasad, 1998). It should be noted that we applied a relatively strict threshold for squared multiple correlations and some researchers recommend a lower value < .20 as a threshold (e.g., Hooper et al., 2008). Finally, post-hoc modification indices suggested residual correlations between the following indicator pairs: PSN03 and PI02, ATT02 and ATT03, ATT04 and ATT05, LP03 and LP05, LP03 and LP06, LP05 and LP06, and FB03 and FB05. After adding these residual correlations to the model, FB03 showed squared multiple correlation that were just below the aspiration value.

To further evaluate the convergent validity of the measurement model we assessed McDonald's hierarchical omega (McDonald, 1999), Cronbach's alpha (Cronbach, 1951), and the average variance extracted (AVE) for each latent variable with the semTools package version 0.4-14 in R (semTools Contributors, 2016). The results were similar to the pilot study, and all of the latent variables showed good values above the recommended threshold of .70 (Nunnally & Bernstein, 1978) The latent variable stigma had the lowest values (α = .71, ω^h = .74). The AVE values were all above the recommended threshold of .50 (Fornell & Larcker, 1981), except for the latent variable stigma (*AVE* = .47). As stigma showed relatively weak psychometric properties across the two independent samples, it was decided to remove the latent variable from the measurement model.

The discriminant validity was examined through the heterotrait-monotrait ratio (HTMT) of the correlations using the semTools package version 0.4-14 in R (semTools Contributors, 2016). Table 7.5 shows that there were no multi-collinearity problems, except for the close relationship between caregiver influence (CI) and social norm (SN) that can be explained by the hypothesized regression path between both variables.

The final measurement model with 15 latent factors, 63 indicators and 7 added residual correlations showed acceptable to good fit for all fit measures: normed Chi Square (2.98), RMSEA (.039), SRMR (.05), CFI (.93), and TLI (.92) (see Table 7.6). This means that our final hypothesized measurement model fits the observed data.

Table 7.7 displays the final list of indicators with intercept (FIML mean), indicator mean (values with listwise deletion), standard deviation (values with listwise deletion), factor loadings, hierarchical omega, Cronbach's alpha, and average variance extracted (AVE). A partial extract of the re-specified measurement model is shown in Figure 7.1. The observed variance-covariance matrix can be requested from the author. The theoretical implication of all modifications are discussed in Section 7.6.2.

Table 7.5 Heterotrait-Monotrait Ratio (HTMT) Matrix between Latent Variables of the Final Measurement Model to Assess Discriminant Validity

	ITU	ATT	SN	PSN	PBC	SAF-IDEP	FB	LP	LHT	CI	HTN	PI	SEF	REL	C
ITU	1.00														
ATT	.81	1.00													
SN	.71	.63	1.00												
PSN	.45	.37	.31												
PBC	.58	.44	.49	.48	1.00										
SAF-IDEP	.74	.72	.68	.40	.41	1.00									
FB	.54	.50	.78	.24	.31	.63	1.00								
LP	.54	.64	.44	.21	.33	.46	.30	1.00							
LHT	.47	.58	.36	.22	.29	.38	.18	.67	1.00						
CI	.57	.52	**.95**	.27	.43	.58	.76	.32	.24	1.00					
HTN	.38	.43	.21	.19	.17	.26	.13	.44	.47	.09	1.00				
PI	.37	.31	.25	.86	.53	.33	.16	.19	.21	.21	.21	1.00			
SEF	.58	.53	.59	.46	.76	.51	.36	.39	.39	.59	.20	.51	1.00		
REL	.60	.67	.58	.28	.45	.65	.48	.60	.47	.46	.32	.25	.52	1.00	
C	.20	.18	.07	.15	.29	0.07	.03	.27	.24	.05	.24	.17	.19	.15	1.00

Note. HTMT values < .90 indicate that discriminant validity has been established (Henseler et al., 2015). SemTools uses absolute values of the correlations to calculate the HTMT matrix, meaning that values can range between 0.00 - 1.00. HTMT values > .90 are displayed in bold.

ITU = intention to use, ATT = attitude, SN = social norm, PSN = personal norm, PBC = perceived behavior control, SAF-IDEP = safe and independent living, FB = relief of family burden, LP = loss of privacy, LHT = loss of human touch, CI = caregiver influence, HTN = human touch norm, PI = personal innovativeness, SEF = self-efficacy, REL = reliability, C = financial cost

Table 7.6 Goodness-of-fit of the Final Measurement Model

GOODNESS-OF-FIT	RECOMMENDED VALUE	FINAL MEASUREMENT MODEL
χ2/df	≤ 5.0	2.98
RMSEA	≤ .06 - ≤ .08	.039 (CI .038– .040)
SRMR	≤ .08	.05
CFI	≥ .90	.93
TLI	≥ .90	.92

Table 7.7 Final Measurement Model: Intercept, Mean, Standard Deviation, Standardized Factor Loadings, Squared Multiple Correlations, Cronbach's Alpha, Hierarchical Omega, and Average Variance Extracted.

LATENT VARIABLE	INDICATOR	INTERCEPT / FIML MEAN	LISTWISE MEAN	LISTWISE SD	FACTOR LOADINGS	SMC	α	ω^h	AVE
ITU	ITU01	3,31	3,39	0,85	.91	.82	.94	.87	.78
	ITU02	3,31	3,37	0,89	.90	.81			
	ITU03	3,26	3,32	0,86	.90	.82			
	ITU04	3,39	3,44	0,83	.80	.65			
ATT	ATT01	3,94	3,94	0,90	.84	.71	.93	.91	.67
	ATT02	4,03	4,03	0,83	.79	.63			
	ATT03	3,97	3,97	0,82	.81	.66			
	ATT04	3,46	3,46	1,05	.78	.61			
	ATT05	3,50	3,50	0,94	.84	.71			
	ATT06	3,49	3,49	0,89	.83	.69			
SN	SN01	3,51	3,57	0,76	.72	.52	.81	.89	.63
	SN02	3,68	3,74	0,68	.86	.73			
	SN03	3,71	3,77	0,65	.81	.65			
PSN	PSN01	3,32	3,32	0,91	.86	.73	.77	.79	.55
	PSN02	3,63	3,63	0,86	.80	.64			
	PSN03	3,31	3,31	0,97	.56	**.32**			
PBC	PBC01	3,68	3,73	0,77	.83	.69	.82	.78	.50
	PBC02	3,11	3,13	0,90	.70	.50			
	PBC03	3,09	3,10	0,98	.64	.41			
	PBC04	3,35	3,37	0,99	.69	.47			
SAF-IDEP	SAF01	3,81	3,82	0,71	.76	.58	.88	.91	.53
	SAF02	3,89	3,91	0,72	.77	.60			
	SAF03	4,06	4,08	0,60	.69	.47			
	SAF04	4,06	4,07	0,66	.64	.41			
	IDEP01	3,87	3,88	0,74	.75	.56			
	IDEP03	3,85	3,86	0,64	.70	.49			
	IDEP04	3,89	3,91	0,69	.75	.56			
FB	FB01	3,80	3,84	0,68	.87	.75	.85	.84	.57
	FB02	3,73	3,76	0,79	.83	.68			
	FB03	3,47	3,49	0,85	.62	**.39**			
	FB05	3,62	3,66	0,83	.73	.54			

LATENT VARIABLE	INDICATOR	INTERCEPT / FIML MEAN	LISTWISE MEAN	LISTWISE SD	FACTOR LOADINGS	SMC	α	ω^h	AVE
LP	LP01	3,14	3,14	1,01	.86	.74	.93	.85	.63
	LP02	3,22	3,22	1,02	.91	.82			
	LP03	3,24	3,24	1,10	.74	.55			
	LP04	3,12	3,12	1,02	.90	.81			
	LP05	2,97	2,97	1,03	.64	.40			
	LP06	3,15	3,15	1,01	.70	.50			
LHT	LHT03	2,87	2,84	1,03	.69	.48	.87	.84	.61
	LHT04	3,35	3,36	0,98	.81	.65			
	LHT05	3,10	3,10	0,96	.84	.71			
	LHT06	3,20	3,20	1,06	.78	.61			
CI	CI01	3,63	3,69	0,68	.75	.56	.82	.92	.65
	CI03	3,72	3,77	0,67	.86	.74			
	CI04	3,74	3,78	0,68	.81	.65			
HTN	HTN01	4,19	4,19	0,73	.82	.67	.87	.88	.63
	HTN02	3,97	3,98	0,76	.79	.62			
	HTN03	3,99	4,00	0,76	.82	.68			
	HTN04	3,74	3,75	0,88	.76	.58			
PI	PI01	3,22	3,22	0,92	.84	.71	.84	.83	.57
	PI02	3,22	3,22	1,00	.62	**.38**			
	PI03	2,64	2,63	1,01	.75	.56			
	PI04	3,70	3,70	0,87	.82	.67			
SEF	SEF01	3,67	3,71	0,72	.80	.64	.82	.87	.50
	SEF02	4,08	4,10	0,67	.71	.50			
	SEF03	3,87	3,91	0,66	.75	.56			
	SEF06	3,71	3,73	0,87	.69	.48			
	SEF07	3,58	3,60	0,92	.63	.40			
REL	REL01	3,40	3,44	0,71	.84	.70	.84	.78	.60
	REL02	3,41	3,45	0,75	.76	.58			
	REL04	2,88	2,88	0,82	.74	.54			
C	C01	3,89	3,92	0,76	.85	.72	.86	.86	.68
	C02	3,58	3,57	0,98	.73	.54			
	C03	3,94	3,97	0,79	.92	.85			

Note. Values below aspiration values are displayed in bold.

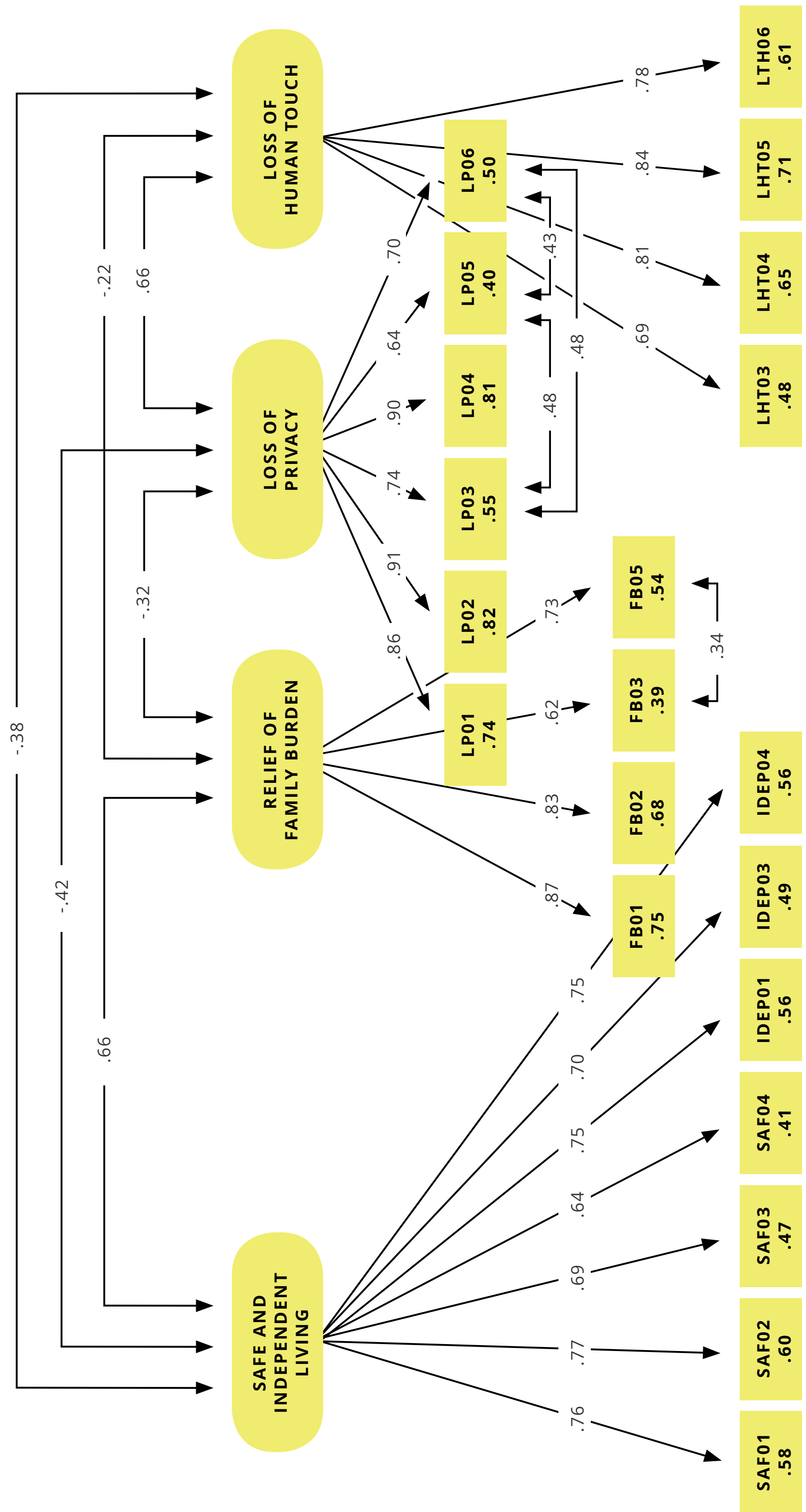

Figure 7.1. Partial extract of the re-specified measurement model for the latent variables safe and independent living, relief of family burden, loss of privacy and loss of human touch. Values adjacent to single-headed arrows represent standardized factor loading. Values adjacent to double headed arrows represent correlation coefficients. Squared multiple correlations of indicators are displayed below the indicators. To simplify the schematic representation, only the residuals that are correlated are included in the figure. Double-headed arrows between indicators represent residual correlations.

7.4 DESCRIPTIVE STATISTICS AND EXPLORATIVE GROUP DIFFERENCES

Older adults are an extremely heterogeneous target group (Gregor & Newell, 2001), and these different personal backgrounds might influence the acceptance of AAL. After a comprehensive literature review, Niehaves and Plattfaut (2013) identified age, gender, education and income as the most relevant demographic variables in technology acceptance and digital divide research. The AAL literature review (Chapter 3) showed that other background factors, such as older adults' health status and health expectations, might also influence AAL acceptance. This was also in line with our user studies, in which many older adults reported to feel too healthy to need AAL in their current situation. However, findings about the influence of personal background factors from previous AAL research were inconsistent. Therefore, these variables were not included in the conceptual model. Nevertheless, we were interested in the potential differences in AAL acceptance among younger and older participants, male and female participants, well-educated and low-educated participants and healthy and less healthy participants. Hence, explorative analysis about potential group differences on the overall acceptance of AAL were performed. Questions about income were not included in the survey and could therefore not be included in the analysis.

Descriptive statistics and explorative analysis about potential group differences were performed in SPSS version 23. To be able to compare groups with a complete and imputed dataset, single imputation with the Expectation Maximization (EM) method was used to handle the missing data for the group comparison. The EM algorithm is an iterative approach that alternates between two steps. In the E-step, missing values are filled with a conditional expectation given the observed data and the initial expectation of the covariance matrix. In the M step, maximum likelihood estimates of the mean vector and covariance matrix are computed using the statistics from the E-step. The algorithm repeats these steps until convergence is reached in the parameter estimates (Dempster et al., 1977; Enders, 2001). EM is a relative robust method compared to other imputation methods, such as listwise deletion or mean substitution (L. H. Rubin et al., 2007).

To explore differences between groups, one-way analysis of variance (ANOVA) and an independent sample t-test were performed. Indicator scores from the final measurement model were pooled into a composite score for each latent variable. Table 7.8 shows an overview of the composite mean and standard deviation for each latent variable.

7.4.1 INTENTION TO USE

The overall intention to use AAL technology was moderately high in the current sample ($M = 3.34$, $SD = .73$). This means that, in general, older adults were relatively open to the idea of using AAL technologies in the future.

Age was analyzed categorically in accordance with the pre-defined age quota. Looking at the three age groups (55-64 years; 65-74 years; 75-85 years), there was no significant difference in their intention to use AAL ($F(2, 1293) = 2.89$, $p = .056$). As displayed in Figure 7.2, the intention to use AAL was moderately high across the three age groups.

Table 7.8 Mean Composite Score and Standard Deviation per Latent Variable

LATENT VARIABLE	EM MEAN	EM SD	LISTWISE MEAN	LISTWISE SD
Intention to Use AAL (ITU)	3.34	.73	3.42	.80
Attitude towards Using AAL (ATT)	3.73	.78	3.73	.78
Social Norm (SN)	3.67	.57	3.73	.59
Personal Norm (PSN)	3.42	.75	3.43	.76
Perceived Behavioral Control (PBC)	3.32	.71	3.35	.74
Safe and Independent Living (SAF-IDEP)	3.92	.52	3.96	.51
Relief of Family Burden (FB)	3.67	.65	3.72	.64
Loss of Privacy (LP)	3.14	.87	3.14	.89
Loss of Human Touch (LHT)	3.13	.83	3.11	.86
Caregiver Influence (CI)	3.73	.56	3.78	.57
Human Touch Norm (HTN)	3.97	.67	3.99	.67
Personal Innovativeness (PI)	3.19	.78	3.19	.78
Self-Efficacy (SEF)	3.79	.60	3.86	.58
Reliability (REL)	3.26	.59	3.26	.67
Financial Cost (C)	3.81	.68	3.83	.75

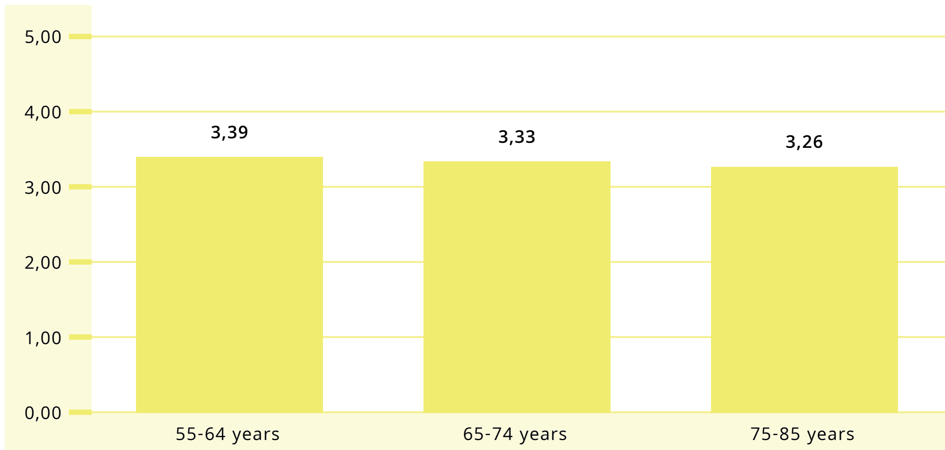

Figure 7.2. Mean ITU scores per age group.

Note. Indicators of intention to use AAL were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree)

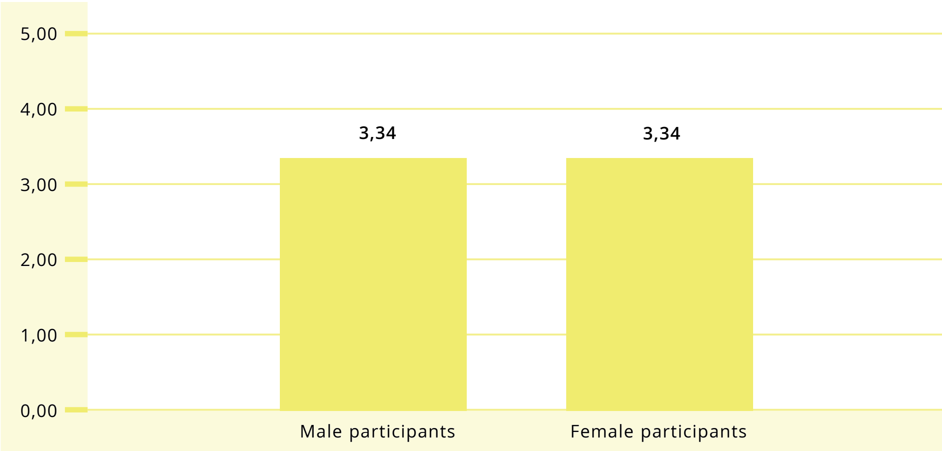

Figure 7.3. Mean ITU scores per gender group.

Note. Indicators of intention to use AAL were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree)

Next, differences between male and female older adults were examined. Figure 7.3 shows that the intention to use AAL was moderately high for male and female participants alike (t(1280.2) = -0.84, p = .93)[16].

Comparing the different levels of education (low; intermediate; high), a Welch ANOVA[17] revealed a significant difference in intention to use AAL between older adults with different education levels (*Welch F*(2, 828.27) = 3.37, p = .04). Games-Howell post-hoc tests showed that older adults with a high education level had a higher intention to use AAL (M = 3.40, SD = .82) than older adults with a lower education level (M = 3.27, SD = .70) (p < 0.5). However, looking at the absolute values this difference was relatively small, which is also reflected in the small effect size $\eta 2$ = .005 (Cohen, 1988). Furthermore, there was no significant difference between older adults with an intermediate education level and older adults with low education level, or older adults with an intermediate education level and older adults with a high education level.
Figure 7.4 shows the intention to use AAL across the different education levels.

Finally, it was explored if older adults differed in their intention to use AAL across different levels of subjective health (poor; fair; good; very good; excellent) and expected need for support (highly unlikely; more likely than others; equally likely than others; more likely than others; highly likely) Results showed that there was no significant difference between older adults with different perceptions of subjective health (F (4, 1291) = .60, p = .66) and different expected support need (F(4, 1112) = .52, p = .72). Figure 7.5 shows the intention to use AAL across the different perception of subjective health and expected support need.

[16] The Welch t-test was used as Levene's test of homogeneity of variance was significant at p <. 05
[17] A Welch Anova was used as Levene's test of homogeneity of variance was significant at p < .001

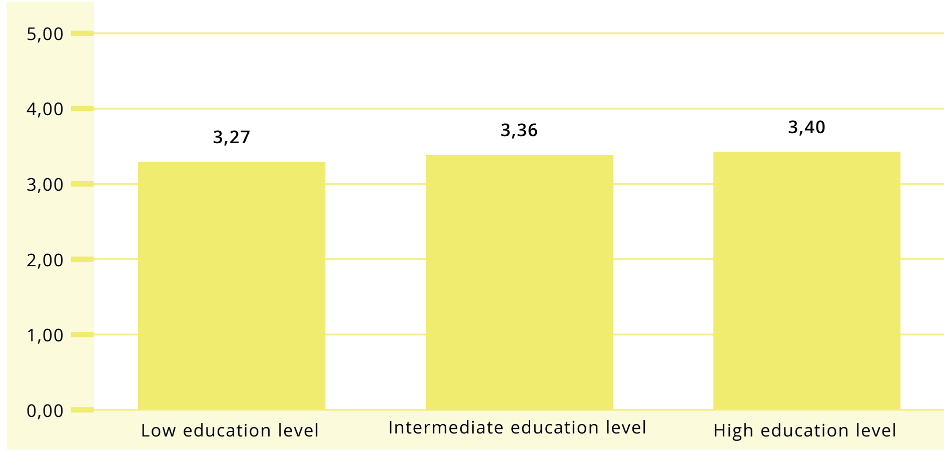

Figure 7.4. Mean ITU scores per education level.

Note. Indicators of intention to use AAL were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree)

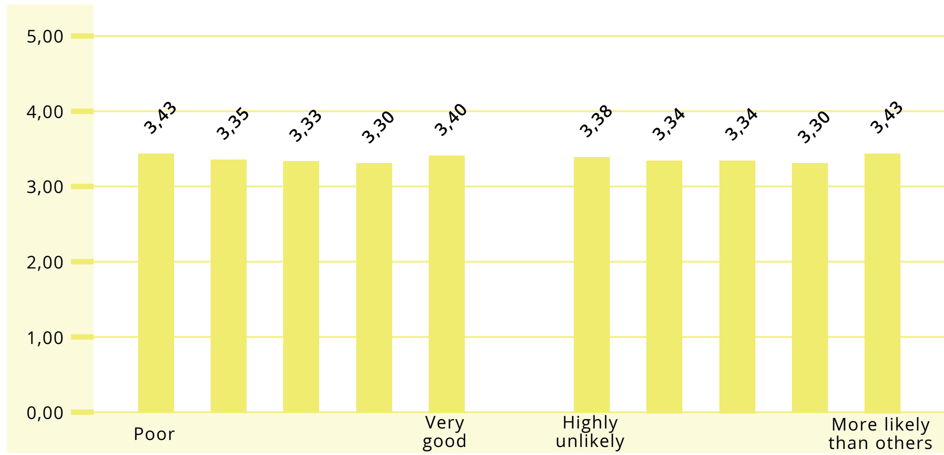

Figure 7.5. Mean ITU scores per perceived subjective health rating (left side) and expected need for support rating (right side).

Note. Indicators of intention to use AAL were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree)

Overall, it can be concluded that the average intention to use AAL technologies in the future was moderately high across all groups of older adults, independent of their age, gender, subjective health, and expected support need. The only significant difference was found between older adults with low education level and older adults with high education level. However the effect size of this difference was very small.

7.4.2 ATTITUDE AND BEHAVIORAL BELIEFS

The overall attitude towards using AAL technologies was positive among the older adults in the current sample (*M* = 3.73, *SD* = .78). Looking at the attitudinal beliefs, participants had strong beliefs that AAL technologies could benefit their safety and independence. Participant also expected that AAL could relieve the physical and emotional burden of their family members. Loss of privacy and loss of human touch scored slightly above the midpoint of the scale. Figure 7.6 displays the mean composite scores of the overall attitude towards using AAL and the behavioral belief constructs.

7.4.3 SOCIAL NORM AND SOCIAL NORMATIVE BELIEFS

Older adults in the current sample scored high on the overall social norm, meaning that older adults believed that important people from their social environment would think positively about their use of AAL (*M* = 3.67, *SD* = .57). Drawing the attention to the underlying social normative belief constructs, participants had strong beliefs that caregivers would encourage their use of AAL. Figure 7.7 displays the mean composite scores of the overall social norm and the social normative belief caregiver influence.

7.4.4 PERSONAL NORM AND PERSONAL NORMATIVE BELIEFS

Older adults in the current sample scored moderately high on personal norm (*M* = 3.42, *SD* = .75). This means that overall older adults in the sample could, to some extent, identify as users of AAL and thought of AAL as something that is compatible with their internalized norms and values. However, older adults also had a high human touch norm. The scores on personal innovativeness were close to the midpoint of the scale. Figure 7.8 displays the mean composite scores of the overall personal norm and the personal normative belief constructs.

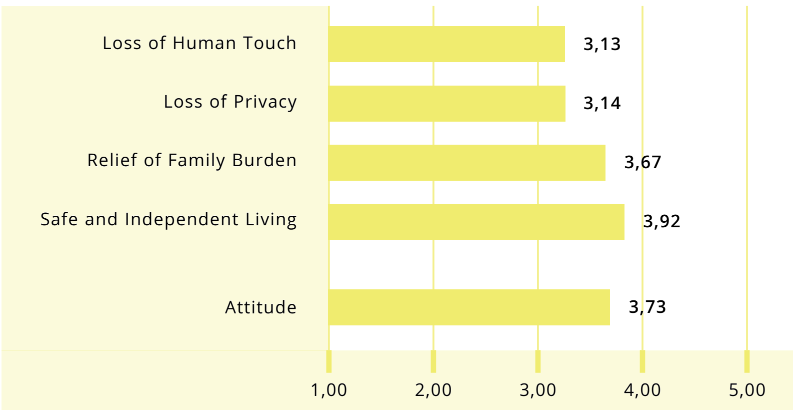

Figure 7.6. Mean composite scores of the overall attitude towards using AAL and the behavioral belief constructs

Note. Indicators of the behavioral belief constructs were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Attitude was scored on a 5-point semantic differential scale.

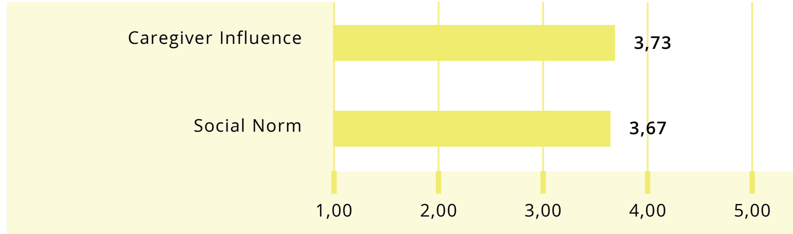

Figure 7.7. Mean composite scores of the overall social norm and the social normative belief construct caregiver influence.

Note. Indicators of the social normative belief constructs were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

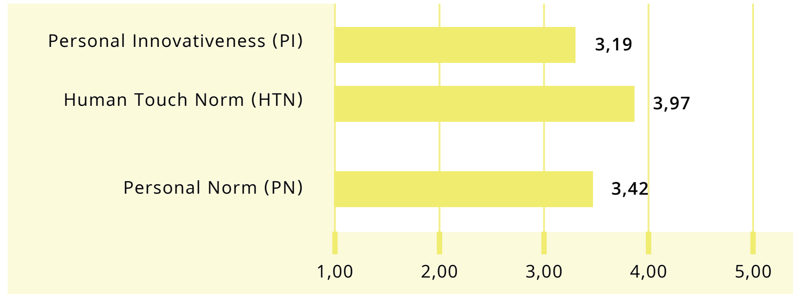

Figure 7.8. Mean composite scores of the overall personal norm and the personal normative belief constructs

Note. Indicators of the personal normative belief constructs were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

7.4.5 PERCEIVED BEHAVIORAL CONTROL AND CONTROL BELIEFS

Older adults in the current sample scored moderately high on perceived behavioral control (*M* = 3.32, *SD* = 0.71). This means that overall older adults in the sample had moderately high expectations to have control over using AAL. They also had high levels of self-efficacy. However, older adults also expected AAL to be expensive. Reliability scores were also moderately high. Figure 7.9 displays the mean composite scores of the overall perceived behavioral control and the control belief constructs.

7.5 STRUCTURAL EQUATION MODEL

Building on the re-specified measurement model, the structural equation model was analyzed using Lavaan package version 0.5-23 (Rosseel, 2012) in R version 3.4.3 (R Core Team, 2017). In this step, the comprehensive model (measurement part and structural part) was tested. The structural part refers to the hypothesized relationships between the latent variables (see Chapter 6 for the adapted conceptual model). Following earlier

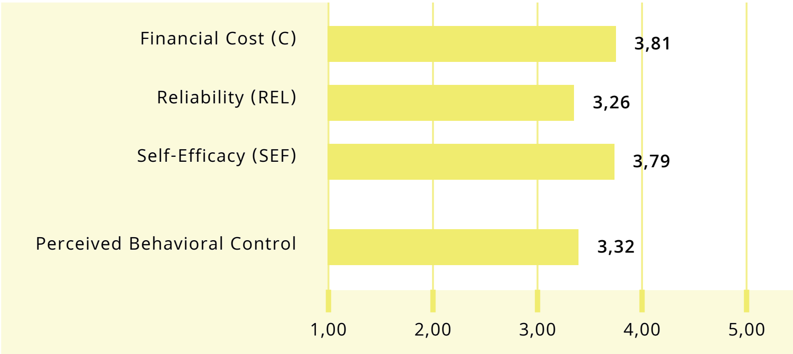

Figure 7.9. Mean composite scores of the overall perceived behavioral control and the control belief constructs

Note. Indicators of the control belief constructs were scored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

procedures, Maximum likelihood estimation (ML) with FIML for the missing data was used because the data were approximately normally distributed. The factor loading of one indicator of each latent variable was set to 1, to set the scale of the latent variable. The covariance between the exogenous latent variables safe and independent living, relief of family burden, loss of privacy, loss of human touch, caregiver influence, human touch norm, personal innovativeness, self-efficacy, reliability and financial cost was freely estimated.

7.5.1 OVERALL MODEL RESULTS

As displayed in Table 7.9, the hypothesized structural equation model showed adequate overall fit with the observed data: normed chi-square (3.06), RMSEA (.040), SRMR (.06), CFI (.93) and TLI (.92). We can therefore continue to interpret standardized path coefficients and variance explained in the latent variables.

Our overall hypothesized model accounted for 69% of the variance in intention to use AAL (R^2 = .69). All but two of the hypothesized paths showed significant standardized path coefficients at a $p < .001$ level (see Figure 7.10 for the structural part of the structural equation model).

Table 7.9 Goodness-of-Fit of the Structural Equation Model

GOODNESS-OF-FIT	RECOM-MENDED VALUE	STRUCTURAL EQUATION MODEL
χ^2/df	≤ 5.0	3.06
RMSEA	≤ .06 - ≤ .08	.040 (CI .039– .041)
SRMR	≤ .08	.06
CFI	≥ .90	.93
TLI	≥ .90	.92

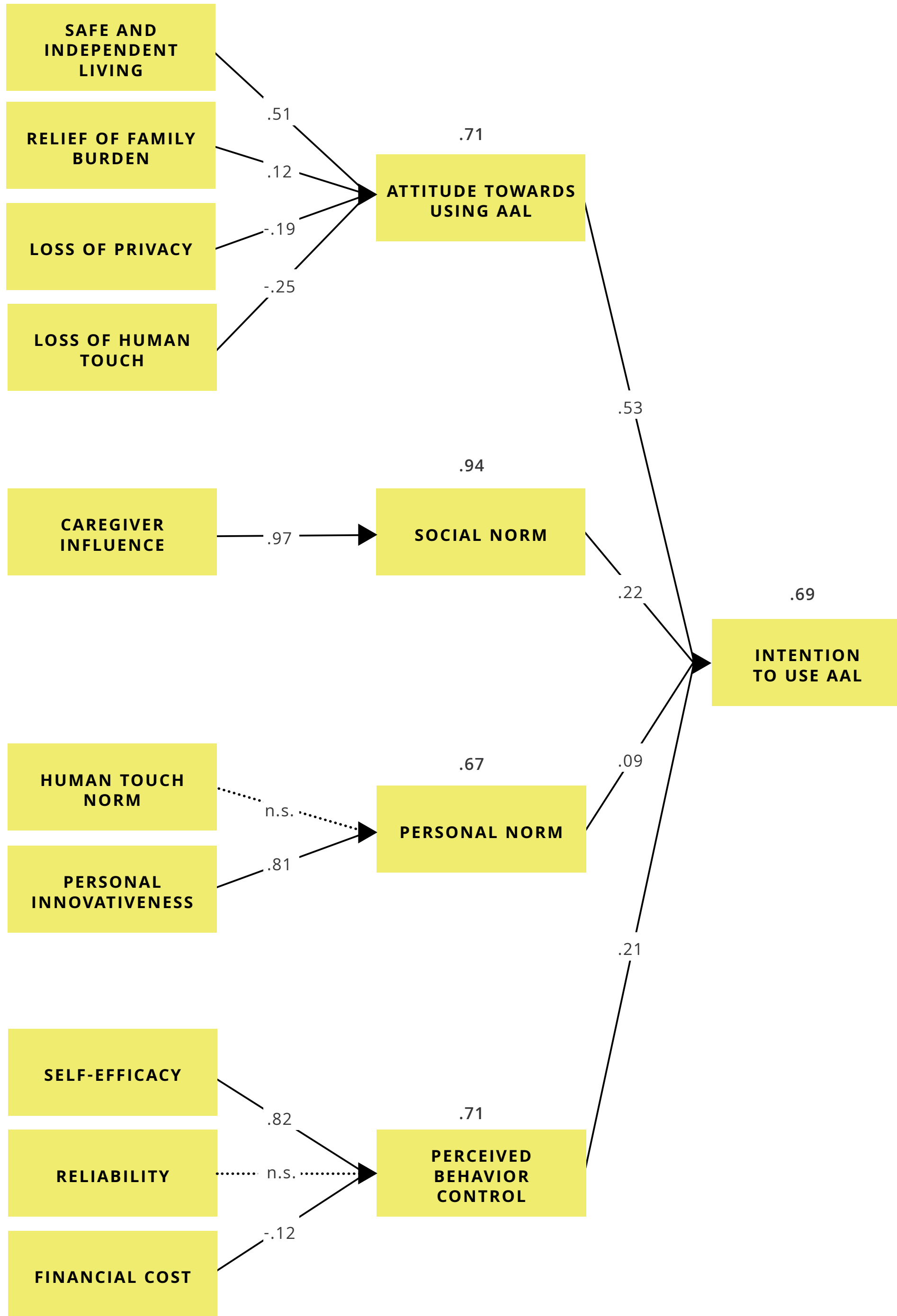

Figure 7.10. Structural part of the AAL acceptance model. Values adjacent to single-headed arrows represent standardized regression coefficients ($p < .001$). Dotted lines represent non-significant paths. Values above variable rectangles represents the variance explained in the latent variables (R^2).

7.5.2 ATTITUDE, SOCIAL NORM, PERSONAL NORM AND PERCEIVED BEHAVIOR CONTROL

As hypothesized, attitude, social norm, personal norm and perceived behavior control significantly affected the intention to use AAL. Attitude was the most important influencer of intention (β = .53), followed by social norm (β = .22) and perceived behavior control (β = .21). Although significant, personal norm only showed a weak influence (β = .09). This means that, in this early acceptance stage of AAL, the overall positive attitude towards using AAL is the most important contributor to the readiness to use AAL technologies in the future. Expectations about social referents' opinion and the overall perceived control over AAL use are less important than attitude, but still relevant for forming the intentions to use AAL technologies. One's self-based standards and expectations regarding AAL use are only weak influencers of older adults' use intention.

7.5.3 SAFE AND INDEPENDENT LIVING, RELIEF OF FAMILY BURDEN, LOSS OF PRIVACY AND LOSS OF HUMAN TOUCH

In accordance with our expectations, the attitude towards using AAL technologies was affected by older adults' beliefs about safe and independent living (β = .51), relief of family burden (β = .12), loss of privacy (β = -.19) and loss of human touch (β = -.25). Together these variables explained 71% of the variance in attitude (R^2 = .71). Attitude in turn influenced use intention. Safe and independent living was the most important influencer of attitude towards using AAL. This means that older adults who expect that using AAL technology will enhance their feeling of safety and security, will result in faster detection and response to harmful situations in the home, and allow them to age independently in their trusted home environment, are likely to have positive opinion about AAL. The expectation that using AAL technologies will reduce family caregivers' emotional and physical burden also showed a positive influence on attitude. However, relief of family burden was the least important influencer on attitude among these behavioral belief constructs. In contrast, the fear that using AAL technology will decrease the human touch in care contributes to a negative attitude towards using AAL. Another important negative contributor was the concern that using AAL technology will compromise the older adults' privacy.

7.5.4 CAREGIVER INFLUENCE

As the variable stigma showed weak psychometric properties in terms of convergent validity across the two independent samples (pilot and main study), caregiver influence remained as the only predictor of social norm in the hypothesized model. Caregiver influence predicted 94% of the variance in social norm (R^2 = .94). Social norm in turn directly affected use intention. The standardized regression path coefficient revealed that caregiver influence was a strong contributor of social norm (β = .97). This means that caregivers are important social referents to older adults in the AAL context.

7.5.5 PERSONAL INNOVATIVENESS AND HUMAN TOUCH NORM

Personal norm was hypothesized to be predicted by older adult's personal innovativeness and human touch norm. Older adult's privacy norm was originally hypothesized as a third predictor, but showed weak psychometric properties across the two independent samples and was therefore excluded from the final model. The hypothesized influence of human touch norm was not significant (p > .05) and personal innovativeness therefore remained as the only significant predictor of personal norm (β = .81). This means that people's willingness to try out new information technology in general, positively affects the self-based standards and expectations regarding AAL use. Personal innovativeness explained 67% of the variance in personal norm. Personal norm in turn, weakly affected use intention.

7.5.6 SELF-EFFICACY, RELIABILITY AND FINANCIAL COST

Perceived behavior control was hypothesized to be affected by beliefs about one's own self-efficacy, the reliability of AAL and the expected financial cost. The expected influence of reliability was not significant (p >.05). Therefore, only self-efficacy and financial cost remained as predictors of perceived behavior control. Together these variables explained 71% of the variance in perceived behavior control. Perceived behavior control in turn affected use intention. Self-efficacy had a strong positive influence on perceived behavior control (β = .81). This means that older adults' confidence in their personal capabilities to organize and execute courses of action required to use AAL technology positively affects their perception of overall control. In consequence, the lack of self-efficacy can hinder the overall control perception. The expected financial cost showed a negative influence on the overall control perception (β = -.12), meaning that expectations about high financial costs will contribute to a lower control perception.

7.5.7 CORRELATION BETWEEN BELIEF CONSTRUCTS

In line with the original theory of planned behavior, most of the belief constructs, i.e. safe and independent living, relief of family burden, loss of privacy, loss of human touch, caregiver influence, human touch norm, personal innovativeness, self-efficacy, reliability and financial cost were significantly associated with each other. Correlation coefficients varied between .83 (caregiver influence and relief of family burden) and -.57 (reliability and loss of privacy). As TPB is unspecific about the nature of relationships between underlying beliefs and there was little empirical evidence in AAL research one could built on, we did not specify any a-priori relationship between these beliefs. However, some of these correlations could point to a directional relationship which should be further explored in future research.

7.6 CONCLUSION AND DISCUSSION

The aim of the AAL acceptance survey was to make statistically grounded and externally valid inferences about the current state of early acceptance of AAL technology among the Dutch older adult population. Specifically, this study aimed to compare the relative importance of different acceptance factors, their underlying relationships, and their explanatory power for the intention to use AAL technologies, thereby attending to the third research question (RQ3). To the best of our knowledge, this study is one of first studies that models the relationships of AAL acceptance factors and validates the model with a large-scale sample that is representative for the population of interest.

7.6.1 REFLECTION ON THE MAIN RESULTS OF THE AAL ACCEPTANCE SURVEY

The conceptual model of AAL acceptance showed adequate model fit and explained 69% of the variance in intention to use. It can therefore be concluded, that our model has a strong explanatory power in explaining the intention to use AAL among Dutch older adults. Furthermore, the theory of planned behavior (TPB) proved to be a valuable theoretical framework in the context of AAL. Our results also suggest empirical support for decomposing TPB's belief structure into separate multi-dimensional belief constructs (see left hand side of the model), thereby following Pavloe and Fygenson (2006) and Taylor and Todd (1995b).

The overall intention to use AAL technologies was moderately positive across both independent samples. This means that Dutch older adults are relatively open to the idea of using AAL technologies in the future. We found no difference in use intention between age groups, gender groups, people with different subjective health rating and people with different expected support need. The only significant difference was found between older adults with low education level and older adults with high education level. However, the effect size of this difference was very small. This is in line with findings from Ziefle and Röcker (2010) who found that age, gender and subjective health status did not influence the willingness to use AAL across different applications. However, this might change in a later acceptance stage.

As expected, intention to use was predicted by attitude toward use, social norm, personal norm and perceived behavioral control. Attitude was the most imortant predictor, followed by social norm and perceived behavior control. The results only showed a weak influence for personal norm. Aijzen argues that:

> *"The relative importance of attitude, subjective norm, and perceived behavioral control in the prediction of intention is expected to vary across behaviors and situations"* (Ajzen, 1991, p. 188).

From the results, we can conclude that in an early acceptance stage, in which people have none or limited experience with AAL technologies, the overall attitude towards using AAL is the most important influencer of use intention. In this stage, older adults are also receptive to the opinion of important social referents to form their use intention. Moreover, the older adults' perceived overall control about using AAL technologies is contributing to the use intention. However, both factors are less important than the attitude towards use. Answering to criticism of earlier reviews and meta-reviews (Armitage & Conner, 2001; Godin & Kok, 1996), the concept of personal norm was included in the conceptual model. Our results show that the influence of personal norm was significant but weak. We therefore conclude that, in this early acceptance stage, older adults' self-based standards and expectations regarding AAL use are only a minor influencer of older adults' use intention. However, this might change in a later acceptance stage, when use intention is transformed into the decision to acquire AAL technology and the older adult starts using and experiencing AAL.

Safe and independent living was the most important positive influencer of attitude towards using AAL, which in turn influenced use intention. This is in line with previous AAL research (Sixsmith, 2000; Steele et al., 2009; Van Hoof et al., 2011; Wild et al., 2008) and our own qualitative user studies (see Chapter 4). These previous studies suggested that older adults regarded the increased feeling of safety and assurance and the facilitation of independent living as a major advantage of AAL. We also found empirical evidence for the claim that safety benefits often supersede other concerns, as the influence of safe and independent living was stronger than the influence of loss of human touch and loss of privacy. Nevertheless, both factors still substantially contributed to a negative attitude towards using AAL. This is in line with previous research (Beringer et al., 2011; Demiris et al., 2004; Marquis-Faulkes & McKenna, 2003) and our own qualitative studies. These studies showed that older adults were worried that AAL technologies might reduce personal care and human interaction and jeopardize their privacy. The literature review (Chapter 3) (Rowan & Mynatt, 2005; Sixsmith, 2000; Wild et al., 2008) and the qualitative user studies suggested that older adults perceive AAL technologies as good tools for reducing the overall burden on caregivers. The results of the AAL acceptance survey support this claim, as relief of family burden positively contributed to older adults' attitude towards using AAL.

Previous research and our own qualitative work suggested that the influence of caregivers, especially informal family caregivers is important for the acceptance of AAL technologies (Courtney et al., 2008; Lorenzen-Huber et al., 2011; Luijkx et al., 2015). Although we did not distinguish between formal and informal caregiver influence, the findings of the AAL acceptance survey indeed identified caregivers as crucial social referents for building social norm. Social norm in turn influenced use intention. However, comparing the overall effect of attitude and social norm, the older adult's personal attitude was still more important in forming the intention to use AAL technologies. For future research, it would be interesting to explicitly distinguish between formal and informal caregiver influence.

In line with our qualitative user studies, older adults general willingness to try out new information technology, i.e. personal innovativeness, positively contributed to the older adults' overall personal norm. However, the effect of personal norm on intention to use was weak in the current acceptance stage. In contrast to our expectations, human touch norm had no significant influence on personal norm. An explanation for this finding is that many older adults would probably prefer human care over care via AAL technology, but could still identify as users of AAL. So indeed human touch norm might not have a significant influence on the overall personal norm.

Self-efficacy is a concept from social cognitive theory, and according to this theory *"people's judgment of their capabilities to organize and execute courses of action required to attain designated types of performances"* (Bandura, 1986, p. 391) is an essential determinant of human motivation and behavior (Bandura, 1997, 1998). Previous AAL research and our own user studies suggested that older adults' lack of confidence in their personal capabilities related to AAL use can be a barrier to AAL acceptance (Steele et al., 2009). In consequence, high levels of self-efficacy can foster overall control perceptions. Hence, it was hypothesized that self-efficacy would positively affect use intention via perceived behavior control. This hypothesized relationship was confirmed through the results of the AAL acceptance survey. Moreover, in line with previous research (Sixsmith, 2000; Steele et al., 2009) and the user studies, expectations about high financial cost negatively contributed to the perceived behavior control. The hypothesized relationship between perceived behavioral control and reliability was not significant. We suspect that in this early acceptance stage with none or limited experience of AAL, users found it hard to formulate concrete and consistent expectations about the expected reliability of AAL. However, we do expect that reliability will be considered in a later acceptance stage and future research should take this variable into account.

Overall, it can be concluded that safe and independent living and caregiver influence were the strongest drivers towards AAL acceptance, while loss of human touch and loss of privacy are the strongest barriers towards AAL acceptance. Self-efficacy also scored high in the current sample and was therefore another driver. In consequence, low self-efficacy is a barrier towards AAL acceptance. These factors influence the intention to use AAL through indirect paths via attitude, social norm and perceived behavioral control respectively. Relief of family burden and personal innovativeness were also significant drivers of AAL acceptance through indirect paths via attitude and personal norm, but were less importantin the current acceptance stage. Likewise, financial cost was a significant barrier towards AAL through an indirect path via perceived behavior control. However, financial cost was also less important in the current acceptance stage.

7.6.2 REFLECTION ON MODEL MODIFICATIONS

During the testing of the conceptual model several modifications were made. We only performed modifications that were theoretical plausible. With little large-scale empirical evidence to build on, some modifications were expected and even desired especially with regard to the new measurements. Moreover, parsimony is important in modeling, and models should describe the data in the least complex way (Myung et al., 2003). Hence, if theoretical justifiable, less parameters are preferred. Hereafter, we will reflect and reason on all of the performed modifications during the pilot study and main study.

The variables user control, privacy norm and social stigma were removed due to weak psychometric properties. We suspect that the lack of convergent reliability for privacy norm and social stigma can be partially explained by the fact that older adults have none or limited use experience in this early stage of acceptance. Therefore, some of the indicators of these latent variables might be hard to answer, consequently leading to incosistencies and measurement error. Future research should further improve and validate these measurements.

As already argued in Chapter 6, the merge of safety and independence into the latent factor 'safe and independent living' is theoretically plausible and improves model parsimony. Safety is often viewed as a precondition for independent living and might not be empirically distinguishable from independence. The results of some of our qualitative studies actually reinforced this view (Jaschinski & Ben Allouch, 2015b, 2015a).

Several items were removed due to weak psychometric properties. This is common practice when a CFA is performed on a calibration sample for item reduction and measurement refinement. Table 7.10 displays the items that were removed and offers a potential explanation for the weaknesses of these items.

Finally, seven residual correlations between the following indicator pairs were added: PSN03 and PI02, ATT02 and ATT03, ATT04 and ATT05, LP03 and LP05, LP03 and LP06, LP05 and LP06, and FB03 and FB05. These adjustments seem theoretically justifiable as the correlation occurred in the same subscale except for PSN03 and PI02. A potential explanation for these residual correlations, is a common method effect as item pairs had a similar wording and structure and used the same response scale. In case of PSN03 and PI02, items were located in the same subsection of the survey instrument and were introduced with the same introduction text. Moreover, both items were negatively phrased and measured on the same response scale.

Table 7.10 Overview of the Removed Items per Variable

VARIABLE NAME	ITEM/INDICATOR CONTENT	POTENTIAL REASONING
Safe and Independent Living (SAF_IDEP)	Using AAL technology will prevent accidents at home. (SAF05) With the help of AAL technology, dangerous situations at home can be avoided. (SAF06)	Prevention of emergencies is conceptually different from detection/reaction to emergencies (SAF01-SAF04) and older adults might respond differently to these items.
	Using AAL will make me less dependent on assistance by other people. (IDEP02)	Wording issue: 'less likely to depend' would be clearer
Relief of Family Burden (FB)	If I use AAL technology, my family members will feel less strained around me. (FB04)	This items refers to an indirect outcome (relational improvement) of relieving the emotional stress on family members rather than a direct outcome, such as peace of mind (FB02) or more time (FB03)
	Using AAL technology will give my family members more responsibilities (-) (FB06)	Negatively worded items did not perform well in the current sample.
Loss of Human Touch (LHT)	Using AAL technology will foster loneliness (LHT01) Using AAL technology will replace personal assistance (LHT02)	Wording is too extreme: 'increase' (LHT01) and 'reduce' (LHT02) would be better.
Caregiver Influence (CI)	My caregivers would think I should use AAL technology (CI02)	Wording: judging about what other people think is difficult
Self-Efficacy (SEF)	If I had problems relating to using AAL technology I know I could work them out.	Expectation is relatively specific and might be difficult to answer.
	When given the opportunity to use AAL technology, I fear I might damage it in some way (-) (SEF05)	Negatively worded items did not perform well in the current sample.
Reliability (REL)	I think that AAL technology is undependable (-) (REL03)	Negatively worded items did not perform well in the current sample.

7.6.3 REFLECTION ON THE METHODOLOGY OF THE AAL ACCEPTANCE SURVEY

Our sample was largely representative for the Dutch older adult target population. However, by using an online survey, we accepted that our sample had a bias towards older adults with internet connection and basic technology skills. As pointed out earlier, this bias is mostly present is the last age cohort (75 – 85 years) (Statistics Netherlands, 2017a). Using an online survey, had several advantages: (1) gathering large amounts of data required for SEM in an efficient and cost-effective manner, (2) inclusion of an animated video that is highly effective for communicating complex health-related information (Meppelink et al., 2015), (3) no interviewer bias.

Furthermore, the participants' responses about AAL acceptance were based on an animated video and several visuals of AAL technologies. There was no direct interaction with AAL technologies. This could have limited the participants' impression of AAL technologies. In our opinion, this actually fits the phases of early acceptance *(consideration*) and increases the ecological validity of our study. In real-life situations, people will not necessary try out a technology before forming their initial use intention and uncertainty and misconceptions about specific features are likely to occur in the consideration stage.
To ensure the basic understanding of the concept of AAL, the material was pre-tested and control questions were included after the visual stimuli.

By including a 'don't know' option we accepted the occurrence of missing data points. Due to the novelty of the concept of AAL, we suspected that some older adults would not have a strong enough tendency to formulate an opinion about certain items (D. B. Rubin et al., 1995). Results showed that this was especially true for indicators of the variables intention to use, caregiver influence, reliability and cost. To be able to continue the analysis using the information from all cases without affecting the validity of parameter estimates, full information maximum likelihood (FIML) was used to deal with the missing values. FIML is considered a robust and state-of the art approach to handle missing data and is widely recommended in the methodological literature (Baraldi & Enders, 2010; T. D. Little et al., 2014).
Olinsky et al. (2003) showed that FIML produces unbiased factor loadings, regression parameters, goodness-of-fit measures and variances across different sample sizes and across various percentages of missing data. Similar results were found by Enders and Bandalos (2001) and Enders (2001).
As FIML does not actually impute the missing values, for the descriptive analysis and explorative groups differences we used single imputation with the EM algorithm. This method is still relatively robust and superior to other methods such as mean substitution and listwise deletion.

Finally, reaching acceptable model fit in SEM, does not imply that the hypothesized model is the only fitting model. Other equivalent or near-equivalent models might show equal or even better fit (Kline, 2016). However at this stage, the AAL field does not offer a rich theoretical discourse to inspire potential alternative models (Blackman et al., 2016). Moreover, the measurement part of the model was in fact cross-validated across two independent samples. Finally, the hypothesized relationships built on a strong and well-established psychological theory (TPB), a literature review and several qualitative user studies. We therefore accept our model as a first approximation of reality in explaining the AAL acceptance process among older adults.

PART IV

From Science to Practice

8
General Discussion

Who takes care of our older adults? According to the European Union, smart technologies that support independent living and active aging, introduced as 'Ambient Assisted Living' (AAL), are the future for our aging population. Promises of AAL include saving long-term care costs, improving the quality of care, unburdening family caregivers, and increasing the older adults' independence and overall quality of life. While the policy enthusiasm for AAL technology is high, it is unclear if the potential users of AAL are willing to embrace AAL technologies into their daily lives.

This dissertation addressed this issue by focusing on the perspective of older adults and their caregivers. Using a combination of qualitative and quantitative approaches, we have developed a comprehensive and theoretically grounded understanding of how and why users perceive AAL technologies in a certain way. Important factors that drive or hinder the acceptance have been identified. These insights resulted in a validated model of AAL acceptance. This dissertation contributes to a more user-driven approach in AAL research and development that prioritizes the wishes, concerns and needs of the prospective users.

8.1 'GOOD, BUT NOT FOR ME AT THE MOMENT': REFLECTION ON THE MAIN FINDINGS

8.1.1 DEFINING AMBIENT ASSISTED LIVING

Ambient Assisted what…? Despite the increased attention from government, industry and research, there is no common agreement among members of different disciplines on how AAL should be understood. This led to the first research question (RQ 1):

> *How can Ambient Assisted Living (AAL) be defined?*

Hence, before turning to the acceptance of AAL, the first contribution of this dissertation is a clear definition of AAL and an overview of its main characteristics, application domains, tools and techniques (Chapter 2).

After studying the descriptions and definitions of earlier research in this multidisciplinary field (Acampora et al., 2013; Blackman et al., 2016; Van den Broek et al., 2010; Queirós et al., 2015; Rashidi & Mihailidis, 2013), we propose the following definition for AAL:

> *State-of-the-art ICT-based solutions that build on the principles of ambient intelligence to create intelligent environments that provide all-encompassing, non-invasive, and pro-active support to older adults and have the ultimate goal to maintain their independence, enhance their overall quality of life, and support their caregivers.*

This definition is rooted in three core characteristics of AAL:

1. **AAL builds on the principles of Ambient Intelligence** by applying the classic principles of Ambient Intelligence (i.e., embedded, context-aware, personalized, adaptive, anticipatory) (E. H. L. Aarts & Encarnação, 2006) to a new generation of assistive technologies. The overall aim is to move from single obtrusive devices to integrated smart environments that provide all-encompassing, non-invasive, and pro-active assistance to the user.

2. **AAL comprises various state-of-the-art ICT-based technologies and advanced computational techniques** with a strong emphasis on smart home technology, mobile and wearable sensors, and assistive robotics (Rashidi & Mihailidis, 2013).

   A smart home is a home which is equipped with a network of various types of sensors and actuators to collect continuous and rich contextual information about the environment and the resident. In the context of AAL, this information is aggregated and used to provide a safe and supportive home environment by means of in-home security, automation, environmental control, cognitive and sensory assistance and health- and activity monitoring (Demiris & Hensel, 2008; Liu et al., 2016; Rashidi & Mihailidis, 2013)

   Mobile and wearable technologies provide powerful tools for health monitoring and indoor and outdoor activity monitoring. Sensors can be embedded in smartphones and smartwatches (e.g., Casilari & Oviedo-Jiménez, 2015), smart garments and e-textile (e.g., Cheng et al., 2013), flexible skin-like systems (epidermal electronic systems) (Imani et al., 2016), or inserted directly into the body (in-vivo systems) (Juhl et al., 2010). By continuously monitoring physiological parameters, tracking location and movement, and detecting and analyzing activity patterns, these applications aim to support health management and rehabilitation from home, detection of physical and cognitive decline, prevention of accidents, and immediate response in case of emergencies.

   Assistive robotics in AAL can be broadly categorized in rehabilitation robots, social service robots, and social companion robots (Broekens et al., 2009; Robinson et al., 2014). Rehabilitation robots are not perceived as social entities and include robotic mobility aids (e.g., Spenko et al., 2006), exoskeletons (e.g., O'Sullivan et al., 2015), or robots that help with physical training (e.g., Johnson et al., 2006). Social service robots assist with various daily life tasks but also have social features (e.g., Kittmann et al., 2015). Social companion robots are mainly targeted at enhancing the user's emotional well-being and providing companionship (e.g., Kort & Huisman, 2017).

   Other commonly used technologies in the AAL field include care management systems (Bossen et al., 2013), reminder and planning systems (Szymkowiak et al., 2005), social network and communication applications (Wherton & Prendergast, 2009), ambient awareness systems (Judge et al., 2010) and serious games (e.g., Anderiesen, 2017).

Together these various types of technologies are used to create smart and supportive environments for the older adult users and their caregivers. To provide the intelligence to these environments, advanced algorithms and computational techniques are used, including the following: activity recognition, behavioral pattern discovery, anomaly detection, context modeling, planning and scheduling, and location and identity identification (Acampora et al., 2013; Rashidi & Mihailidis, 2013).

3. **AAL aims to maintain older adults' independence and to enhance their general quality of life while also supporting their caregivers.** Older adults are considered as the primary users of AAL. The aim is to offer all-encompassing support across all areas of living, including a safe and supportive home environment (aging well at home), facilitating social relationships and active participations in the community (aging well in the community), and creating safe and supportive working environments (aging well at work). A secondary user group of AAL are informal and formal caregivers. AAL technologies aim to reduce the burden on caregivers, provide peace of mind, help them to manage and coordinate care tasks, and facilitate remote communication and connectedness between caregivers and older adults.

8.1.2 THE THEORETICAL GROUNDWORK TO UNDERSTANDING AAL ACCEPTANCE

User acceptance is one of the big hurdles to the implementation and diffusion of AAL systems in real-life settings (Peek et al., 2014; Rashidi & Mihailidis, 2013; Robinson et al., 2014). Although the number of user-acceptance studies has somewhat increased during the last years (Liu et al., 2016), AAL acceptance research still lacks strong theory-driven approaches (Blackman et al., 2016; Peek et al., 2014). Addressing this shortcoming, the second contribution of this dissertation is a comprehensive theoretical understanding of the underlying social, psychological, and behavioral mechanisms in the acceptance process of AAL technologies. This has resulted in the conceptual model of AAL acceptance (Chapter 5) that has been validated among two representative samples of the Dutch older adult population (Chapter 6 and Chapter 7). The results contributed to the third research question (RQ 3):

> *Which factors are the most important determinants for the acceptance of AAL technology among older adults in an early acceptance stage and how are these factors related?*

Building upon earlier research (Ben Allouch, 2016; De Graaf et al., 2016; Van Dijk et al., 2018; Hirsch & Silverstone, 2003; Karapanos et al., 2009; E. M. Rogers, 2003; Silverstone & Haddon, 1996), we argue that acceptance of new technologies should be considered as a process over time that consists of several stages of acceptance: (1) **Awareness**, when the user becomes aware of a new technology; (2) **Consideration**, when the user assesses his/her need for a technology, weighs potential positive outcomes of using a technology against potential negative outcomes, and reflects upon the use of a technology against personal norms, values and social expectations; (3) **Decision**, when intention is transformed into explicit action to acquire the technology; (4) **Initial Use**, when the user tries out the technology, explores if the technology meets his/her prior expectations, and starts adapting the technology to his/her personal needs and wishes; and finally (5) **Continuous Use**, when a technology is used on a regular basis and over a longer period of time, and the technology is integrated into the user's everyday life. However, the stages are neither clear-cut nor strictly linear and users can, for example, proceed through several consideration cycles. Hence, the process of full acceptance and integration of a technology into everyday life can take months, or even years (Van Dijk et al., 2018).

The focus of this dissertation is on the early stages of the acceptance process, specifically the consideration stage. Due to its novelty and the overall low technology readiness (Liu et al., 2016), it was suspected that most users had limited knowledge and experience with AAL technologies. This was confirmed in the AAL acceptance survey (Chapter 6 and 7). In both samples, 55% (pilot study) and 60% (main study) had never, or only once, heard about AAL technologies, and 97% (pilot study) and 95% (main study) had no direct use experience with AAL. After reviewing several popular theories and models from technology acceptance research and examining their strengths and limitations, the theory of planned behavior (TPB) (Ajzen, 1991) was chosen as a theoretical starting point to understand the early acceptance of AAL. TPB was chosen because of its theoretical strengths, empirical robustness, proven effectiveness in related areas and, most importantly, due to its adequateness for understanding early acceptance, by specifically focusing on the belief structure that leads up to the intention to use a technology.

Following TPB, our conceptual model of AAL acceptance suggested that intention to use AAL technology can be explained by the attitude towards AAL use, the perceived social pressure to use AAL (social norm), the perceived fit with personal norms and values (personal norm), and the perceived overall control over using AAL (perceived behavioral control). Personal norm was added to the original TPB to address earlier criticism regarding the neglect of personal normative mechanisms (Armitage & Conner, 2001; Godin & Kok, 1996). Following Taylor and Todd (1995b) and other researchers (De Graaf et al., 2017; Hsieh et al., 2008; Pavloe & Fygenson, 2006), TBP's underlying belief structure was decomposed into separate multi-dimensional belief constructs. The salient beliefs for AAL acceptance were anchored in the findings from a literature review (Chapter 3) and several user studies (Chapter 4). It was hypothesized that attitude was positively influenced by beliefs about safety, independence, and relief of family burden, but negatively influenced by beliefs about loss of privacy and loss of human touch. The overall social norm was hypothesized to be positively affected by caregiver influence, but negatively affected by beliefs about social stigma. The overall personal norm was hypothesized to be positively affected by one's personal innovativeness, but negatively influenced by one's human touch norm and privacy norm. Finally, perceived behavioral control was expected to be positively affected by self-efficacy beliefs, beliefs about the technology's reliability, and beliefs about the sense of user control during interaction, but negatively affected by the expected financial cost.

The conceptual model was validated in a large-scale online survey among two independent samples that were representative for the Dutch older adult population. Structural equation modeling was used to analyze the data. The purpose of the pilot study (n = 320) was to validate the measurements by performing a confirmatory factor analysis (Chapter 6). The aim of the main study ($n = 1296$) was to cross-validate the adapted measurements and to test the hypothesized relationships of the conceptual model (Chapter 7). During the validation of the measurements, which were in part newly developed or newly composed by combining items from existing scales, the constructs user control, social stigma, and privacy norm were removed from the conceptual model due to a lack of convergent validity. We suspect that, due to the limited use experience in this early stage of acceptance, some of the formulated items belonging to these constructs were difficult to answer for the participants. Consequently, this might have lead to inconsistencies and measurement error. Furthermore, the behavioral belief constructs safety and independence were combined into one factor called 'safe and independent living' because of low discriminant validity between these constructs. Safety is often viewed as a precondition for independent living, and it might therefore not be empirically distinguishable from independence. The results of some of our qualitative studies actually reinforce this view (Jaschinski & Ben Allouch, 2015b, 2015a). The other measurements, including the newly developed and newly composed scales, showed good psychometric properties in terms of convergent validity and discriminant validity across the two independent samples.

The results of the acceptance survey (Chapter 7) showed that the adapted model of AAL acceptance showed adequate model fit for the observed data (normed chi-square (3.06), RMSEA (.040), SRMR (.06), CFI (.93) and TLI (.92)) and explained 69% of the variance in intention to use. All hypothesized paths were significant, except for the path between human touch norm and personal norm, and the path between reliability and perceived behavior control. The hypothesized behavioral belief constructs explained 71% of the variance in attitude; the hypothesized social normative belief constructs accounted for 94% in variance of social norm; the personal normative belief constructs accounted for 67% in variance of personal norm; and the control belief constructs explained 71% of the variance in perceived behavioral control.

It can therefore be concluded that our established theoretical model provides a valuable framework for understanding and explaining older adults' acceptance of AAL technologies in an early acceptance stage (*consideration*). Moreover, we have established empirical support for the decomposed theory of planned behavior as a valid theoretical framework for understanding technology acceptance in an early stage. The final model of AAL acceptance is displayed in Figure 8.1.

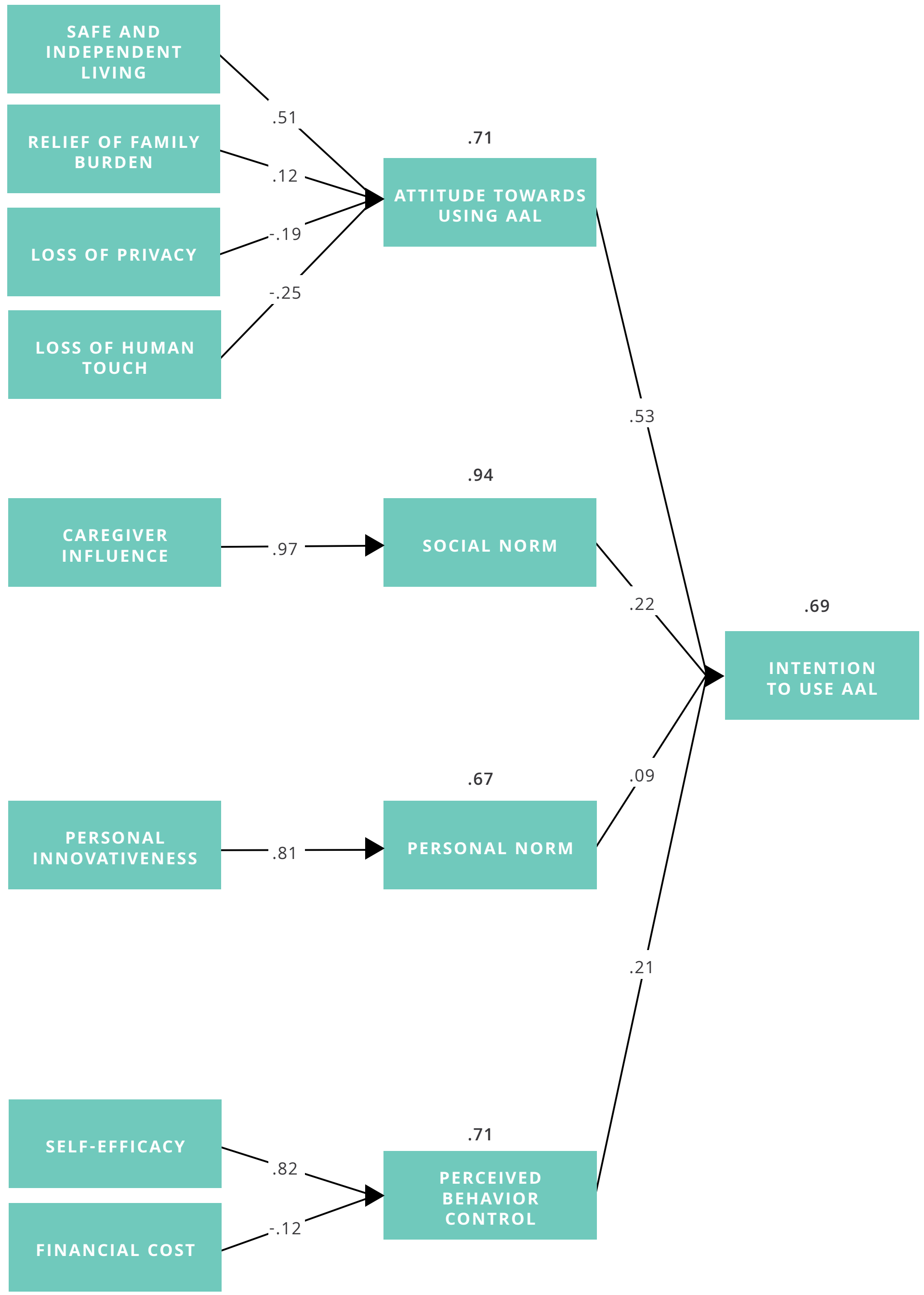

Figure 8.1. Final model of AAL Acceptance (non-significant paths are omitted). Values adjacent to single-headed arrows represent standardized regression coefficients ($p < .001$). Values above variable rectangles represents the variance explained in the latent variables (R^2).

To the best of our knowledge, this work is one of the first theory-driven quantitative frameworks for understanding AAL acceptance that has been validated with a representative sample of the target population. We believe that, although further cross-validation is needed, our work contributes to the development of a theoretical discourse in the AAL field that is desperately needed to develop a better understanding of the needs and concerns of the user regarding AAL technologies.

8.1.3 THE CURRENT STATE OF AAL ACCEPTANCE

What makes AAL acceptable and what are the main concerns about AAL? The third contribution of this dissertation are insights into the current state of acceptance among older adults and their caregivers and explaining what drives or hinders the acceptance of AAL. By reviewing earlier literature (Chapter 3), collecting rich qualitative insight across different user studies (Chapter 4), and examining the underlying relationships and relative importance of the different acceptance factors with a large scale, quantitative approach (Chapter 6 and Chapter 7), we have identified and provided empirical evidence for the most important drivers and barriers of AAL acceptance. These results contributed to the second and third research questions (RQ 2 & RQ 3):

> *Which factors do older adults and their caregivers perceive as potential drivers and barriers towards AAL acceptance?*
>
> *Which factors are the most important determinants for the acceptance of AAL technology among older adults in an early acceptance stage and how are these factors related?*

GENERAL PERCEPTION OF AAL

Earlier AAL research and our own qualitative user studies showed that, overall, older adults and their caregivers seem to be receptive to the idea of AAL technologies. This is also confirmed by the AAL acceptance survey that showed that older adults from both samples had a moderately positive intention to use AAL technologies in the future. However, the qualitative user studies revealed that, although the majority of older adults had a positive attitude towards AAL, they often did not feel the need to use AAL in their current situation. This unfelt need for support was found among the healthier and independent older adults as well as older adult who already received support from an informal or formal caregiver. *'It's very good, but not for me at the moment'* was a frequently heard notion during our qualitative user studies. Similar to what was reported by Peek et al. (2014), we observed that many older adults talked either about a hypothetical older person or a peer who would benefit from AAL, rather than themselves. Earlier AAL user research also reported the absence of need in their user sample (Sixsmith, 2000; Steele et al., 2009; Wild et al., 2008). Wild et al. (2008) concluded that many older adults find it difficult to imagine the future need for support as long as they still feel relatively healthy. Other researchers suggest that even the more frail older adults might find it hard to admit the need for support (Bright & Coventry, 2013). According to these researchers, this denial of need is often connected to a sense of pride and not wanting to show weakness. Steele et al. (2009) suggested that AAL concepts might be too abstract for older adults to fully understand all the benefits.

The absence of need was also observed among the group of informal caregivers. Similar to the older adults, most of the informal caregivers from the user studies stated that, in their current situation, they would be able to manage the care on their own and without the help of AAL. This finding was surprising, as the pressure on informal caregivers in the Netherlands and elsewhere in Europe is further increasing. Paralleling suggestions of Bright and Coventry (2013) about older adults; Klerk, Boer, Schyns, and Kooiker (2015) stated that informal caregivers often need support, but might be too ashamed or proud to ask for help. Schorch, Wan, Randall, and Wulf (2016) suggested that experienced informal caregivers often view themselves as care-experts and have difficulty entrusting the care tasks to somebody else. 'Somebody else' might include technologies such as AAL, as these are often perceived as a (partial) replacement of human care. We also found that many informal caregivers, wanted to honor the wishes of the care receiver and thought that their care receiver would not be receptive to the idea of AAL.

These findings imply that the initial positive perception and intention to use AAL in the future, which we found in the qualitative user studies as well as the AAL acceptance survey, might not necessarily translate into the decision to actually acquire and use AAL. Although most of the older adults and informal caregivers could imagine the use of AAL when their need for support increases, in reality, this need for support might be hard to admit. It seems that, despite the recognized benefits, most of the older adults and informal caregivers perceive AAL as a relatively extreme form of support and want to postpone its use to some distant future. However, at this stage, these are just speculations, and future research should investigate the later stages of AAL acceptance as soon as AAL technologies have been further developed and diffused into our society.

Nevertheless, based on user study 2 and user study 3, it can be concluded that informal caregivers are somewhat more open towards the idea of using AAL and might be more likely to be willing to use AAL in the near future. In user study 2, 65% of the informal caregivers had an overall positive attitude towards AAL and in user study 3, 44% had an overall positive attitude. Moreover, 33% of the informal caregivers in user study 3 wanted to use AAL in their current situation. In comparison, only 25% of the older adults in the same study had an overall positive opinion towards AAL and none of the participants could imagine the use of AAL in their current situation. It should be noted that older adults in user study 1 were a bit more positive and 17% could imagine using the presented AAL system in their current situation. As informal caregivers play an important advisory role in care-related decision making, they could act as gatekeepers to introduce AAL to older adults. It is also recommended to involve informal caregivers (not just older adults) in the research and development of AAL, even when they are not the primary target users.

Furthermore, user study 2 showed that some AAL applications might be more acceptable than other applications. For example, ambient sensors were more acceptable to informal caregivers than visual sensors (cameras) or wearable sensors, especially when these were attached to the skin or implanted into the body. These tools were perceived as too invasive. This is in line with findings from the literature review that revealed that visual sensors are typically less acceptable because of privacy and invasiveness issues (Beach et al., 2009; Demiris et al., 2004; Marquis-Faulkes & McKenna, 2003). AAL applications that contain familiar elements like a smart wheeled walker were perceived as more acceptable than unfamiliar tools like an assistive robot. Informal caregivers argued that these seemingly familiar tools would be more acceptable to their care receiver as they are already used to 'normal' wheeled walkers. Related research follows the same line of argumentation to introduce social network services to older adults via Smart TVs. These researchers argue that Smart TVs can facilitate the user acceptance of social network services, as ‘normal’ TVs are already familiar to this target group (Coelho, Rito, Luz, & Duarte, 2015). Informal caregivers’ statements also revealed that an assistive robot was perceived as a replacement of their own human care, while a smart wheeled walker was regarded as a supplement for support.

We found no differences in overall intention to use between age groups, gender groups, people with different subjective health rating and people with different expected support need. The only significant difference was found between older adults with low education level and older adults with high education level. However the effect size of this difference was very small. This is in line with findings from Ziefle and Röcker (2010) who found that age, gender and subjective health status did not influence the willingness to use AAL across different applications. However, there might be some differences between these groups in a later acceptance stage.

DRIVERS AND BARRIERS OF AAL ACCEPTANCE

The AAL acceptance survey confirmed that the TPB factors attitude towards use, social norm and perceived behavior control positively affected the older adults’ intention to use AAL. The added factor personal norm also positively affected the use intention. Thus, we can conclude that future users of AAL positively value using AAL, believe that important people from their social circle have a positive view on their AAL use, feel in control over using AAL, and perceive that using AAL fits their internalized values. In contrast, older adults with a negative attitude, who perceive that their social environment would discourage their AAL use, who do not feel in control about using AAL, and who expect that AAL does not fit their internalized values, are unlikely to use AAL in the future.

Attitude was the most important predictor of use intention, followed by **social norm** and **perceived behavior control.** The influence of **personal norm** was significant but weak. We therefore conclude that in this early acceptance stage, in which people have none or limited experience with AAL technologies, personal norm is only a minor influencer of older adults’ use intention. However, personal norm might become more important in a later acceptance stage when older adults start experiencing AAL.

Turning to the underlying belief structure of attitude, **safe and independent living** was the most important driver towards attitude which in turn influences the intention to use AAL. The literature review and our own qualitative user studies showed that safe and independent living was of utmost importance to older adults and their caregivers. They appreciated that AAL technologies could detect falls or other emergencies, provide immediate response to harmful situations, increase the older adults’ overall feeling of safety and assurance, and help them to age in place and stay independent for as long as possible. The AAL acceptance survey confirmed that safe and independent living had a strong positive influence on attitude towards using AAL. Previous research (Steele et al., 2009; Van Hoof et al., 2011; Wild et al., 2008) and our own user studies showed safety benefits often superseded concerns. Indeed, the AAL acceptance survey showed that safe and independent living was a stronger predictor of attitude than loss of human touch or loss of privacy. It should be noted that a few informal caregivers in user study 2 and 3 were against aging in place for as long as possible. Some preferred a nursing home over AAL technologies, as soon as the care need of their loved ones would increase.

Another driver of attitude was **relief of family burden.** The literature review and the qualitative user studies suggested that participants perceived AAL technologies as good tools for support and reducing the overall physical and emotional burden on caregivers. Older adults appreciated that AAL technologies could reduce the concerns of their family members and provide them with peace of mind. Informal caregivers expected that AAL tools would enable them to keep an eye on their loved ones, provide more care from distance, perform tasks more efficiently, and ultimately relieve some of their workload and worries. The AAL acceptance survey confirmed that relief of family burden positively affected attitude, which in in turn affected the intention to use AAL. However, this driver was less important than safe and independent living and the barriers loss of privacy and loss of human touch. Moreover, it should be noted that some informal caregiver participants from user study 2 and 3 were worried that having a large and consistent amount of data from AAL could also have the opposite effect. It could cause more worries and tasks for them as informal caregivers.

In contrast, the most important barrier towards a positive attitude was **loss of human touch.** The literature review and the qualitative user studies showed that older adults and informal caregivers worried that the use of AAL could reduce the personal contact and personal attention in care and could create more distance between caregivers and care receivers. In a care setting, technologies are often perceived as ‘cold’ in contrast to ‘warm human care’ (Pols & Moser, 2009). The AAL acceptance survey confirmed that loss of human touch negatively affected attitude. Interestingly, in the user studies that evaluated the conceptual SONOPA technology (user study 1 and user study 3), the barrier loss of human touch was less prevalent. This could be explained by the fact that SONOPA encompassed several features for social connectedness and mutual social awareness. Previous research has shown that social and mutual awareness features in AAL can help older adults feel closer to family members, provide new topics for communication and combat social isolation and loneliness (Cornejo et al., 2013; Lorenzen Huber et al., 2012; Rowan & Mynatt, 2005).

Loss of privacy was another important barrier. Loss of privacy is a well-known and much discussed barrier in AAL research and was a theme that was consistently mentioned in the qualitative user studies. Older adults felt uneasy about being constantly monitored. They worried that sensitive personal information could get into the wrong hands and potentially be misused. Even the older adults’ family members might misuse this information to patronize them or take too much control over their personal life. They also felt that AAL technologies could intrude upon their personal space and interfere with their normal routine. Informal caregivers felt evenly concerned about privacy issues and most of them were uncomfortable to ‘spy’ on the care receiver and have intimate information at their disposal. The results from the AAL acceptance survey confirmed these concerns, as loss of privacy negatively affected attitude.

Looking at the underlying beliefs of social norm, **caregiver influence** is the most important and only remaining influencer of social norm in the model of AAL acceptance. Social norm in turn affects intention. As noted earlier, user study 2 and 3 showed that informal caregivers play an important role in care-related decision making. Informal caregivers are often the one’s initiating the discussion about care measurements. Their influence can range from carefully phrased suggestions, to a strong advisory role, to even taking decisions for the older adult. Older adults stated that they would consider the use of AAL if their informal caregiver would ask them to. Although we did not distinguish between formal and informal caregiver influence, the importance of caregivers as social referents was confirmed by the AAL acceptance survey.

Personal innovativeness was proposed as one of the underlying drivers of personal norm. The user studies showed that older adults differ with regard to their personal innovativeness. Several older adults viewed themselves as non-technical persons or had a general negative attitude towards new technologies. Hence, we hypothesized that people who are more open to try out new technologies and have a higher personal innovativeness will have a higher overall personal norm and thus will be more inclined to use AAL in the future. This was confirmed by the AAL acceptance survey that showed that personal innovativeness positively affected intention to use through personal norm.

Based on the findings of the literature review and the user studies, **human touch norm** was proposed as a second underlying belief of personal norm. We expected some older adults to be more hesitant to the idea of applying technologies for care-related tasks than others. It was therefore hypothesized that human touch norm will negatively influence the intention to use AAL via personal norm. However, the relationship was **not significant.** It was concluded that many older adults would probably prefer human care over care via AAL technology but could still identify themselves as users of AAL. So indeed, human touch norm might not have a significant influence on the overall personal norm.

Looking at the underlying belief structure of perceived behavior control, **self-efficacy** was proposed as one of the underlying belief constructs. The literature review and the qualitative user studies suggested that many older adults had low confidence in their own technical skills and worried if they would be able to use AAL technologies. They repeatedly emphasized that they did not grow up with new technologies and therefore might lack the necessary skills. Informal caregivers confirmed this concern and also stated that their relatives would not be comfortable to use AAL. In turn, older adults with high self-efficacy were expected to feel more in control about using AAL, which in turn affects use intention. The participants from the AAL acceptance survey had a relatively high self-efficacy which positively affected their perceived behavior control.

Financial cost was expected to be another barrier towards use intention via perceived behavioral control. Several older adults stated that due to their limited income, AAL systems would not be affordable to them, or they would not to be willing to spend a lot of money on such technologies. Several informal caregivers voiced the same concern. The AAL acceptance survey showed that high expected financial cost had a negative influence on perceived behavioral control which in turn influenced use intention. However, the influence of cost was relatively weak in this early acceptance stage. We expect that financial cost becomes more important in the decision stage.

Another barrier concerns the expected **reliability** of AAL technology. It was hypothesized that the expected reliability will contribute to the overall level of perceived behavior control, which in turn affects use intention. However, the hypothesized relationship was **not significant.** It is suspected that in this early acceptance stage with none or limited experience of AAL, users found it hard to formulate concrete expectations about the reliability of AAL. However, it is expected that reliability will be considered in a later acceptance stage and future research should take this variable into account.

Based on our explorative work, expectations about social stigma, low user control and one's privacy norm were also expected to hinder AAL acceptance. However, the measurements showed weak psychometric properties and these variables were therefore removed from the model. As mentioned in the previous paragraph, it is suspected that participants' limited knowledge and experience with AAL might have led to inconsistencies and measurement error. Future research should further try to improve and validate these measurements.

The literature review and the qualitative user studies revealed more factors that could drive or hinder the acceptance of AAL. These factors were not included in the AAL acceptance survey to focus on the most salient beliefs and to create a more parsimonious model. The identified drivers were health outcomes, social connectedness, support with daily activities, enjoyment and leisure outcomes, self-confidence and status outcomes, and education and information outcomes. In contrast, the fear of negative health outcomes, such as illness caused by electromagnetic radiation, allergic reactions, and increased stress levels, was identified as a potential barrier (Beringer et al., 2011; Steele et al., 2009). Another factor was the general resistance to change. Finally, contextual limitations, such as the layout of the home environment, could potentially hinder the acceptance of AAL.

The main findings of this dissertation contribute towards a more theory-driven and user-driven approach in AAL research and development. While the provided theoretical framework is most relevant for AAL researchers, it can also have valuable implications for researchers from related and overlapping fields, such as ambient intelligence, medical informatics, human-robot interaction or mobile HCI. The theory of planned behavior provided a valuable framework for explaining user acceptance in an early consideration stage, when technologies are still conceptual and largely unknown to the prospective users. Hence, other researchers can leverage our theoretical approach to study the user acceptance of new technologies from their own field. While some of the found acceptance factors might be applicable to other technologies and user groups (e.g., loss of privacy, loss of human touch, financial cost), other factors might be specific to AAL or the broader health and well-being context (e.g., caregiver influence, relief of family burden). It is therefore recommended to follow our approach and verify and discover relevant belief constructs via qualitative user studies. Furthermore, our proposed phased framework of AAL acceptance can be applied and expanded on to explain the process of technology acceptance over time, across many different fields and contexts.

8.2 WHERE DO WE GO FROM HERE: SOME LIMITATIONS AND IMPLICATIONS FOR THE FUTURE OF AAL RESEARCH

Where do we go from here? This dissertation has provided a valuable contribution to the understanding of the acceptance of AAL technologies among older adults and their caregivers. However, as in every research, there are several limitations and unanswered questions on the road ahead. The methodological weaknesses of each study have been discussed in more detail in the respective chapters. This section focuses on the overall limitations and describes interesting avenues for future research.

A central contribution of this dissertation is the validated model of AAL acceptance. To the best of our knowledge, this model is one of the first theory-driven quantitative frameworks for understanding AAL acceptance that has been validated with a representative sample of the target population. However, this also means that this model is a first approximation to explaining AAL acceptance. Further cross-validation and refinement is needed to ensure that this model remains stable and valid across different populations and contexts.

Although one of the explorative user studies included older adults and caregivers from the UK, France and Belgium, the main focus was on the Dutch population. As long-term care systems, the reliance on informal care, and attitudes towards caring for older adults differ among countries (Broadbent, Stafford, & MacDonald, 2009; Carrera, Pavolini, Ranci, & Sabbatini, 2013), future research should investigate the validity of the proposed model in a different cultural context. Moreover, the Dutch population of older adults and informal caregivers is relatively tech-savvy in comparison with other countries (Vorrink et al., 2017). This might have contributed to the overall positive view of AAL technologies and reinforces the need for future research in a broader geographical context.

Furthermore, not all factors that were derived from the literature review and the qualitative user studies were included in the model to create a parsimonious model that focuses on the most salient beliefs and is applicable to the general concept of AAL. However, some of these factors might still be relevant for future research and a different research context. For example, researchers who want to investigate the acceptance of AAL applications with a medical focus, might want to include health outcomes in the conceptual model. Similarly, researchers who develop AAL technologies with a clear social focus, are certainly interested in the expectations about social connectedness. Nevertheless, we believe that the identified drivers and barriers of safe and independent living, loss of human touch, loss of privacy, relief of family burden, caregiver influence, personal innovativeness, self-efficacy, and financial cost are meaningful and valid across different AAL applications and contexts.

The focus of this dissertation was on the early acceptance of AAL. More specifically, we were interested in the expectations and perceptions towards these technologies in terms of outcomes; consistency with personal and social norms; and personal and practical constrains *(consideration stage*). The focus on early acceptance was chosen, due to the relative novelty and general low maturity of AAL technologies (Liu et al., 2016). At this stage, users have none or limited knowledge and experience with AAL. Although we found that users had an initial positive intention to use AAL in the future, it was already pointed out that this initial intention might not transform into the actual decision to acquire and use AAL in the near future. Supporting this suggestion, Bagozzi (2007) argues that:

> *"intentions are made prior to taking action, and the gap in time can be large, with many intervening steps needed and obstacles occurring, often unanticipated; and because intentions are often ill-formed or incomplete or need to be adjusted over time, it is important to consider various psychological and instrumental steps that go on between intention formation and action initiation"* (p.245).

Hence, future research needs to deploy longitudinal designs that explore the later stages of acceptance (i.e., decision, initial use and continuous use). As the users become more familiar with a technology and start using the technology in their own home environment, their attitudes, intentions and needs are likely to change (Chiu & Eysenbach, 2010; De Graaf et al., 2016; Demiris, Oliver, Dickey, Skubic, & Rantz, 2008). Longitudinal studies will further contribute to the development of a theoretical discourse for understanding the long-term acceptance of AAL as well as the sustainability and effectiveness of these technologies. However, although use experience can be simulated with prototypes in laboratory settings and over time by means of in-home field trials, the ecological validity of this use experience is still low (e.g., users do not have to pay for the technology; technical assistance is provided in case of any malfunction; usually field trials have relatively short time frames of a few weeks or months). Therefore, the value of longitudinal designs for acceptance research will increase when AAL has more matured, and users have voluntarily acquired AAL. For now, our insights into early acceptance can shape the further implementation and regulation of AAL. These insights can help developers of AAL applications to make more informed design decisions, before applications are widely diffused into society. As Van Dijk et al. (2018) underline, without exploring these early stages of acceptance, we cannot know if a technology will fall on fertile ground and is actually needed and asked for by the potential users.

Another important stakeholder group in the AAL context are formal caregivers. Their care practices will be directly affected by the implementation of AAL technologies. Some applications even target formal caregivers as one of the primary user groups (Bossen et al., 2013). Moreover, formal caregivers are likely to be regarded as opinion leaders in the context of AAL and can therefore influence the perception of AAL. Similar to informal caregivers, they are likely to play important roles in signaling the care receiver's need for support and introducing AAL solutions into homecare practices. However, previous research has shown that formal caregivers also perceive barriers towards the acceptance of AAL (Bossen et al., 2013; Magnusson, Hanson, & Nolan, 2005; Novek et al., 2000). While formal caregivers were involved in one of the user studies of this dissertation, the primary focus was on older adults and informal caregivers. Hence, future research should further explore the perceptions and attitudes of formal caregivers towards AAL, as they are likely to play an important role for the future implementation of AAL. Providing care is a collaborative process and:

> *"such technologies do not just need to be adopted by individuals; they need to be incorporated into personal habits and collaborative routines (both lay and professional)"* (Shaw, Shaw, Wherton, Hughes, & Greenhalgh, 2017, p. 8)

While we believe that the focus on users (i.e., older adults, informal caregivers and formal caregivers) is vital to the successful implementation of AAL in the future, there are more stakeholders and interests involved in the successful and sustainable implementation of AAL. These stakeholders include managers of care organizations, technology industry and developers, researchers, insurance companies, policy makers and governments. These stakeholders differ greatly in their values, goals and priorities for the implementation of AAL. Greenhalgh, Procter, Wherton, Sugarhood, & Shaw (2012) have distinguished four discourses in this context: (1) modernist (technology focused, futuristic, utopian); (2) humanist (person centered, small scale, grounded in present reality); (3) political economy (critical, cautious) and (4) change management (recognizing complicatedness but not conflict). Future research in the field needs to work towards more collaborative approaches and create methods and tools to conceptualize these different perspectives, in order to bridge the gap between these parties and foster mutual awareness and understanding. The insights of the current dissertation can aid this process by providing a comprehensive understanding of the needs and priorities of the users as important stakeholders.

Consequently, these findings can be used to stimulate the dialogue on user-driven design and evaluation methods and inform and broaden current business models and implementation frameworks.

Although many challenges remain for future research, this dissertation contributes towards the development of a true user-centered perspective in the AAL field that moves beyond common stereotypes, encourages co-creation, and bridges the gap between users and other stakeholder groups.

8.3 FROM SCIENCE TO PRACTICE: IMPLICATIONS FOR THE DEVELOPMENT, IMPLEMENTATION AND POLICY DIRECTION OF AAL

The last section of the general discussion is dedicated to translating our findings into practical implications for the future development, implementation and policy direction of AAL. Thereby, answering the last research question (RQ 4):

> *What are the implications for the design, implementation and policy direction of AAL technologies that can be drawn from the insights on user acceptance?*

For the future of AAL, it is vital to know if these technologies will fall on fertile ground and will be accepted by the potential user groups. In other words: will the policy vision of AAL as solution to healthy and independent aging, active participation in society, a reduced workload for informal and formal caregivers, and savings on healthcare budget, become reality from the perspective of the potential users?

At first glance, our results show that Dutch older adults have an overall positive view on AAL and seem to be receptive to the idea of using AAL technology in the future. However, when looking at the qualitative results, there seems to be a gap between accepting AAL in theory and actually starting to use AAL in the near future. Our studies have identified several factors that are likely to hinder the future use of AAL. Hereafter, we will put forward some ideas on how to address these issues.

Create more awareness. Our findings showed that many older adults were not aware of the different possibilities of AAL and potential benefits were still somewhat abstract to them. Awareness is the first step in the acceptance process and with insufficient knowledge about the potential opportunities of AAL, older adults cannot start the consideration phase. Technology developers should seek opportunities to showcase their prototypes and solutions to the user.
Arrangements such as living labs (e.g., http://www.twentsezorgacademie.nl/) can provide opportunities to users to experience and learn about AAL and the potential benefits, without committing to buying the technology. At the same time, these encounters give developers the opportunity to talk to their future users and learn about their needs and concerns at first hand. Older adults that are already technology minded (high level of personal innovativeness) and have confidence in their own technical skills (high level of self-efficacy), will be most receptive to learn more about AAL - not necessarily the older adults with the highest objective need for support. Moreover, awareness efforts should not just be directed at the older adults themselves but also at informal caregivers and formal caregivers. Our results showed that informal caregivers play an important role in care-related decision making and are somewhat more positive towards the idea of using AAL. Moreover, we discovered that older adults are receptive to the opinion of their informal caregivers and take their needs into account. Like informal caregivers, formal caregivers are likely to play an important part in informing older adults about the support possibilities of AAL and introducing AAL solutions into homecare practices.

Rethink value propositions. Earlier research and our own user studies showed that there might be a discrepancy between the older adults' objective need for support and the older adults' subjective need experience. A similar suggestion was proposed by McCreadie & Tinker (2005). The lack of subjective need for AAL can partially be explained by the fact that the benefits of AAL are still somewhat abstract, and users need to be given more opportunities to learn about, try out and experience AAL. The results of the AAL acceptance survey stress that benefits such as safe and independent living and relief of the caregivers' physical and emotional burden are important to older adults, and should be emphasized when promoting AAL solutions. While these value propositions are certainly very important to older adults, they can also be associated with loss of function, frailty and being a burden to others. Therefore, these value propositions might threaten older adults' self-identity as capable, active and self-reliant members of society. In consequence, the use of these technologies might be postponed to some distant future. Hence, AAL developers should also pay attention to additional value propositions such as social connectedness with family and peers, education and information, and enjoyment and leisure benefits. Although these benefits were not included in the conceptual model of AAL acceptance, we still believe that these value propositions can appeal to older adults, especially when they feel no immediate need for support in their current situation.
This way older adults can familiarize themselves with these AAL technologies early on through social and leisure benefits, which can facilitate the acceptance of more care and health-related features later on, when their need for support increases (Fitzpatrick, Huldtgren, Malmborg, Harley, & IJssensteijn, 2015; Mahmood et al., 2008).

Modular and adaptive designs. Following up on the previous recommendation, value propositions of AAL technologies need to be flexible and adaptive to appeal to this highly diverse target group. We therefore agree with Fitzpatrick et al. (2015) and recommend that AAL implementations should be designed as *"modular infrastructures […] that can be adapted and repurposed"* (p.311). AAL systems cannot be designed in a 'one-size fits all' fashion, but have to be adaptive to different personal preferences, lifestyles, abilities, physical and social contexts and changing care needs. For example, for the conceptual SONOPA system (user study 1 and 3; Chapter 4) we envisioned offering SONOPA in different modes which can be scaled up according to changing preferences and support needs. One mode emphasized the social and leisure features and only included a few sensors. The other mode put more emphasis on support and safety features with a denser sensor installation. This recommendation is also in line with Greenhalgh et al., (2013) who demand AAL implementations that facilitate pragmatic re-design and customization ('bricolage'). An accompanying requirement for these modular design is striving towards more standardization and interoperability between different components and application of AAL.

Overcome stereotypes and foster agency and self-reliance. The vision of AAL is to promote independent and healthy aging, self-reliance, and active participation in society. Yet, many approaches in the AAL field are still routed in ageist stereotypes which frame older adults as passive actors and recipients of care, with needs that only evolve around deficits, frailty, dependence and loss. Older adults are framed as generally inept and disinterested in the use of technologies (Blackman et al., 2016; Peine et al., 2014).

These stereotypes often lead to an oversimplification and inadequate understanding of user needs and, consequently, to bad designs which are prone to be rejected by the intended user (Eisma et al., 2004; Östlund, 2005; Peine et al., 2014; Vines et al., 2015). Designers need to move away from these stereotypes, and realize that many older adults are active managers of their health and well-being. They are resourceful and creative and have complex needs and desires that will guide their choice for accepting or rejecting a technology (Fitzpatrick et al., 2015). Fitzpatrick et al. (2015) suggest several ways to incorporate agency and self-reliance into the design of AAL technologies. For example, older adults should not merely be passive subjects to monitoring, but be active managers of their health and activity data. This requires intuitive interfaces and accessible displays that invite older adults to manage and control their data. Other examples are social features that provide channels for sharing experience and knowledge with others (Wherton & Prendergast, 2009) and solutions that encourage peer-to-peer care (Riche & MacKay, 2010). This way older adults are not just passive receivers of care but actively contribute in a reciprocal manner.

Stimulate and not replace the human touch in care. The fear that technology will lead to less personal attention was a big concern to older adults and their caregiver. In our view, technology cannot and should not replace the human touch in care, but both should work in close symbiosis and support and enforce each other. For example, AAL technologies could take over functional tasks so that human caregivers, who often have to work on tight schedules, have more time to provide psychosocial support. There are several examples in the AAL field that introduced innovative ways how technology can facilitate social connectedness. For example, Lorenzen Huber et al. (2012) introduced a reciprocal monitoring system, where older adults are equal actors in the information exchange rather than just passive subjects to monitoring. Their results showed that the tested technology gave both older adults and their family members *"windows into each other's daily lives"* (p. 450). The system provided new topics of communication, while eliminating patronizing caregiving questions. Similarly, Family Window is a video communication and awareness tool that aims to foster feelings of connectedness between distant family members (Judge et al., 2010). Tovertafel is a collection of interactive serious games with light projections for older adults with dementia to improve social interaction and reduce feelings of anxiety and sadness (Anderiesen, 2017).

Respect the user's privacy. The loss of privacy is a well-known concern in the context of AAL, and our own findings reinforce this view. Hence, the user's privacy should be a focal point at every stage of the AAL development process (privacy-by-design) (Cavoukian, n.d.). One aspect of privacy is informational privacy. The sensor infrastructure of AAL systems collects an abundance of personal data, including sensitive data such as health data or visual material. This entails serious security issues which need to be addressed with advanced data protection techniques and security protocols. However, privacy goes beyond secure data processing and storage. Another aspect of privacy is personal space and territoriality. Therefore, the hardware of AAL has to blend seamlessly with the surroundings and not interfere with the user's sense of home environment (McCreadie & Tinker, 2005). Wearable devices have to be comfortable, lightweight and have good aesthetics. Reciprocal or self-monitoring approaches can counter feeling of inferiority and paternalism. Moreover, users have to be in control over the placement of sensors and over which data are shared and with whom. Many users also require an easy way to deactivate monitoring systems at their own control. Obviously, a high level of user control can affect the proper working and reliability of the technology and these issues should be clearly discussed with the users and caregivers. Although there are a lot of promising initiatives in computer vision for monitoring and fall-detection (Cardinaux et al., 2011), visual sensors are not likely to be embraced by the user, even when they are privacy-sensitive, such as low-resolution cameras. Hence, ambient and wearable sensors seem more promising for the future of AAL.

Usability and Training. While the AAL acceptance survey showed that the Dutch older adults had a relatively high level of self-efficacy, our qualitative work showed that older adults can still be concerned about their technical competence and ability to interact with AAL. Intuitive interfaces and user-friendly and accessible design are therefore imperative for AAL applications. Training programs can help older adults to familiarize themselves with AAL technologies and enhance their self-efficacy, thereby improving the overall acceptance. However, training efforts should also be directed at informal caregivers and formal caregivers as they have to integrate AAL into their care routine.
As future care professionals will play an important role in introducing AAL technologies into homecare practices, future professionals should be educated about the different possibilities of AAL, acceptance issues and potential implementation models. Care-related ICT knowledge has recently been incorporated in the Dutch Bachelor Nursing 2020. Likewise, for social workers new job competences related to ICT technology have been introduced. To prepare these professionals for the interaction with AAL, it is highly recommended to further expand this focus on technology when educating future care professionals. When designing new courses, educators should partner up with care organizations and industry partners to not lack behind the rapid development of technologies in the AAL field.

Work towards reimbursement schemes and flexible financing. One of the hurdles to the implementation and diffusion of AAL systems, is the uncertainty of their cost and the lack of reimbursement models (Rashidi & Mihailidis, 2013; Reeder et al., 2013; Vimarlund & Wass, 2014). Our findings showed that older adults expected AAL systems to be unaffordable, and they were unwilling to spend a lot of money on such technologies. Although different AAL stakeholders are working towards reimbursement schemes and exploring means to embed these technologies into the healthcare system (Manetti et al., 2017), it will probably take several more years and more evidence-based research before reimbursement schemes become reality. For now, AAL technologies have to be financed by the users themselves. Hence, developers have to keep in mind that AAL technologies have to be affordable to older adults with limited income. We also recommend flexible payment schemes and implementations where technologies can be rented instead of bought.

Co-creation, multidisciplinary approaches and keeping in touch with the user. In order to realize the recommendations above (create more awareness; rethink value propositions; modular and adaptive designs; overcome stereotypes and foster agency and self-reliance; stimulate and not replace the human touch in care; respect the user's privacy; reimbursement schemes and flexible financing), the needs of older adults and their caregivers have to be the focal point of AAL development and implementation. The intended users should be involved early on and throughout the development and implementation process. They should be treated as active co-creators and inspirers of

AAL solutions. Working in multidisciplinary teams, which are composed of different AAL stakeholders and end-user groups, will create mutual understanding of each other's needs and values and will help to bridge the gap between these different stakeholders.
In this dissertation, we have suggested that technology acceptance is a process over time, and it can take several months or even years before technologies are incorporated into our daily lives. Therefore, co-creation and multidisciplinary cooperation should continue after the implementation of AAL applications, as the continuous dialogue with end-users and other stakeholders will help to further improve and refine future implementations.

In conclusion, it will probably take several more years before AAL will be widely diffused in the homes and everyday lives of older adults and will be fully incorporated into care routines. As pointed out above, there are still many challenges to the acceptance and implementation of these technologies that need to be addressed. However, we believe that the implications that are routed in the findings of this dissertation can help stakeholders to work towards a more user-centered perspective in AAL that will lead to implementations that are embraced by older adults and their caregivers.

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Appendices

Appendix 1 Overview of the Measurements of the AAL Acceptance Survey

MEASUREMENT		SOURCE
Intention to Use AAL Technology Indication of person's readiness to use AAL technologies in the future (Ajzen, 2006)		2 items adapted from Ben Allouch et al. (2009)
ITEM EN	ITEM NL	ABBREV.
In the future, I plan to use AAL technology.	Ik ben van plan om AAL technologie in de toekomst te gebruiken.	ITU01
In the future, I expect to use AAL technology.	Ik verwacht dat ik AAL technologie in de toekomst ga gebruiken.	ITU02
In the future, I intend to use AAL technology.	Ik neem me voor om AAL technologie in de toekomst te gebruiken.	ITU03
I would recommend other people to use AAL technology.	Ik zal anderen aanraden om AAL technologie te gebruiken.	ITU04

MEASUREMENT		SOURCE
Attitude towards Using AAL Technology The degree to which using AAL technology is positively or negatively valued (Ajzen, 2006)		Adapted from Norman et al. (2000) Taylor and Todd (1995b) Ben Allouch et al. (2009)
ITEM EN	ITEM NL	ABBREV.
Using AAL technology is a (good/bad) idea.	Het is een (goed/slecht) idee om AAL technologie te gebruiken.	ATT01
Using AAL technology is (wise/ foolish).	Het gebruik van AAL technologie is (verstandig/onverstandig).	ATT02
Using AAL technology is (valuable/worthless).	Het gebruik van AAL technologie is (waardevol/waardeloos).	ATT03
I (like/dislike) the idea of using AAL technology.	Ik vind het idee om AAL technologie te gebruiken (leuk/niet leuk).	ATT04
Using AAL technology is (pleasant/unpleasant).	Het gebruik van AAL technologie is (prettig/onprettig).	ATT05
Using AAL technology is (enjoyable/unenjoyable).	Het gebruik van AAL technologie is (plezierig/onplezierig).	ATT06

MEASUREMENT		SOURCE
Social Norm Perceived social pressure to use AAL technology (Ajzen, 2006)		Adapted from Mathieson (1991) Taylor & Todd (1995b).
ITEM EN	ITEM NL	ABBREV.
Most people who influence me would have a positive opinion towards my use of AAL technology.	De meeste mensen die invloed op me hebben, zullen een positieve opvatting hebben over mijn AAL technologie gebruik.	SN01
Most people who are important to me would have a positive opinion towards my use of AAL technology.	De meeste mensen die belangrijk voor mij zijn, zullen een positieve kijk hebben op mijn AAL technologie gebruik.	SN02
Most people whose opinion I value would think positively about my use of AAL technology.	De meeste mensen wiens mening ik waardeer, zullen positief denken over mijn AAL technologie gebruik.	SN03

MEASUREMENT	SOURCE
Personal Norm People's self-based standards or expectations for AAL use that flow from one's internalized values (Adapted from Schwarz, 1977).	Adapted from Y. Lee, Lee, and Lee (2006) and Sparks and Shepherd (1992).

ITEM EN	ITEM NL	ABBREV.
I view myself as a user of technology for my health and well-being.	Ik zie mezelf als iemand die technologie gebruikt voor mijn gezondheid en welzijn.	PSN01
I think of myself as someone who is very interested in technology for health and well-being.	Ik ben iemand die zeer geïnteresseerd is in technologie voor gezondheid en welzijn.	PSN02
I am not the type of person oriented to use technology for my health and well-being (-).	Ik ben niet het type persoon dat technologie gebruikt voor mijn gezondheid en welzijn(-).	PSN03 (-)

MEASUREMENT	SOURCE
Perceived Behavioral Control People's perception of the extent to which they have control over using AAL technologies (Ajzen and Fishbein, 2005).	Adapted from Taylor & Todd (1995b).

ITEM EN	ITEM NL	ABBREV.
I would be able to use AAL technology.	Ik denk dat ik in staat ben om AAL technologie te gebruiken.	PBC01
Using AAL technology is entirely in my control.	Ik denk dat ik het gebruik van AAL technologie volledig in de hand heb.	PBC02
I have the resources and opportunities it takes to make use of AAL technology.	Ik heb de middelen en mogelijkheden die nodig zijn om AAL technologie te gebruiken.	PBC03
I have the knowledge it takes to make use of AAL technology.	Ik heb de kennis die nodig is om AAL technologie te gebruiken.	PBC04

MEASUREMENT	SOURCE
Safe and Independent Living **(merged into one construct after pilot study)** People's judgement of the likelihood that using AAL technology will lead to an enhanced sense of safety and security, faster detection of and response to harmful situations in the home environment, and allow them to age independently in their own home environment.	3(4) items inspired by Roelands et al. (2002)

ITEM EN	ITEM NL	ABBREV.	
Using AAL technology will give me a sense of security.	Het gebruik van AAL technologie zal me een gevoel van veiligheid geven.	SAF01	
If I use AAL technology, I will feel safer in my home.	Als ik AAL technologie gebruik, zal ik me thuis veiliger voelen.	SAF02	
If I use AAL technology, accidents at home will be noticed immediately.	Als ik AAL technologie gebruik, zullen ongevallen thuis direct opgemerkt worden.	SAF03	
With the help of AAL technology, I will receive immediate help in case of emergencies.	Met behulp van AAL technologie, zal ik in nood direct hulp krijgen.	SAF04	
Using AAL technology will prevent accidents at home.	Door AAL technologie, kunnen ongelukken thuis worden voorkomen.	SAF05	Removed after pilot study
With the help of AAL technology, dangerous situations at home can be avoided.	Gevaarlijke situaties thuis kunnen worden vermeden met behulp van AAL technologie.	SAF06	Removed in main study
Using AAL technology will allow me to age in my home environment.	Door AAL technologie zal ik in staat zijn om thuis oud te worden.	IDEP01	
Using AAL will make me less dependent on assistance by other people.	AAL technologie zal me minder afhankelijk maken van hulp van anderen.	IDEP02	Removed in main study
If I use AAL technology I can keep doing things on my own.	Als ik AAL technologie gebruik, kan ik dingen zelf blijven doen.	IDEP03	
If I use AAL technology I can do things independently.	Als ik AAL technologie gebruik, kan ik dingen zelfstandig doen.	IDEP04	

MEASUREMENT	SOURCE
Relief of Family Burden People's judgement of the likelihood that using AAL technology will reduce family caregivers' emotional and physical burden.	1(2) items inspired by Bedard et al. (2001)

ITEM EN	ITEM NL	ABBREV.	
My use of AAL technology, will give my family members peace of mind.	Mijn gebruik van AAL technologie zal mijn familie gerust stellen.	FB01	
If I use AAL technology, my family members will be less concerned.	Als ik AAL technologie gebruik, zal mijn familie minder bezorgd zijn.	FB02	
If I use AAL technology, my family members will have more time for themselves.	Als ik AAL technologie gebruik, zal mijn familie meer tijd voor zich zelf hebben.	FB03	
If I use AAL technology, my family members will feel less strained around me.	Als ik AAL technologie gebruik, zal de band met mijn familie verbeteren.	FB04	Removed after pilot study
My use of AAL technology will ~~put a burden on~~ relieve the burden on my family members.	Door mijn gebruik van AAL technologie zal mijn familie **minder** belast worden.	FB05	Positively rephrased after pilot study
Using AAL technology will give my family members more responsibilities (-).	Mijn gebruik van AAL technologie zal mijn familie meer taken geven (-).	FB06 (-)	Removed after pilot study

MEASUREMENT		SOURCE	
Loss of Privacy People's judgement of the likelihood that using AAL technology will compromise their physical, psychological, social and informational privacy'.		1 item inspired by Boise et al. (2013) 2 items inspired by Kirchbuchner et al. (2015)	
ITEM EN	**ITEM NL**	**ABBREV.**	
If I use AAL technology, I am concerned that others might use my personal information to harm me.	Als ik AAL technologie gebruik, ben ik bang dat anderen misbruik maken van mijn persoonlijke gegevens.	LP01	
If I use AAL technology, I worry that my personal information might be shared with others without my permission.	Als ik AAL technologie gebruik, maak ik me zorgen dat mijn persoonlijke gegevens zonder mijn toestemming met anderen worden gedeeld.	LP02	
If I use AAL technology, I worry to be constantly monitored.	Als ik AAL technologie gebruik, ben ik bang dat ik constant in de gaten wordt gehouden.	LP03	
If I use AAL technology, I am concerned that my social interactions will be monitored.	Als ik AAL technologie gebruik, ben ik bezorgd dat mijn gesprekken in de gaten worden gehouden.	LP04	
Using AAL technology will feel like an invasion into my personal space.	Het gebruik van AAL technologie, zal voelen als een inbreuk in mijn persoonlijke ruimte.	LP05	
If I use AAL technology, I am concerned that intimate situation will be monitored.	Als ik AAL technologie gebruik, ben ik bang dat intieme situaties gevolgd worden.	LP06	

MEASUREMENT		SOURCE	
Loss of Human Touch People's judgement of the likelihood that using AAL technology will decrease the human touch in care and face-to-face interaction.		1(2) items inspired by Roelands et al. (2002)	
ITEM EN	**ITEM NL**	**ABBREV.**	
Using AAL technology will foster loneliness.	AAL technologie zal eenzaamheid versterken.	LHT01	Removed in main study
Using AAL technology will replace personal assistance	AAL technologie zal zorg door mensen vervangen.	LHT02	Removed after pilot study
If I use AAL technology, people will visit me less often.	Als ik AAL technologie gebruik, ontvang ik minder bezoek.	LHT03	
If I use AAL technology, I will receive less personal care.	Als ik AAL technologie gebruik, ontvang ik minder zorg door mensen.	LHT04	
Using AAL technology, I will have get less personal attention.	Door het gebruik van AAL technologie zal ik minder persoonlijke aandacht krijgen.	LHT05	
Using AAL technology will replace human contact.	Het gebruik van AAL technologie zal het menselijke contact vervangen.	LHT06	

MEASUREMENT		SOURCE	
Social Stigma People's perception that important others will think they are old, frail and dependent when using AAL technology		2 items inspired by Roelands et al. (2002) Construct was removed in the main study	
ITEM EN	**ITEM NL**	**ABBREV.**	
If I use AAL technology, others will think I am dependent	Als ik AAL technologie gebruik, zullen andere mensen denken dat ik afhankelijk ben.	STG01	
If I use AAL technology, others will think I am old	Als ik AAL technologie gebruik, zullen andere mensen denken dat ik oud ben.	STG02	
If I use AAL technology, I am concerned that the technology will be visible to others	Als ik AAL technologie gebruik, ben ik bang dat de technologie te veel opvalt voor anderen	STG03	
If I use AAL technology, I would want to hide the technology from others	Als ik AAL technologie gebruik, zal ik deze technologie voor andere mensen verbergen.	STG04	

MEASUREMENT		SOURCE	
Caregiver Influence People's perception that caregivers would encourage their use of AAL technology.		Adapted from Ajzen, 2006a Taylor and Todd (1995b)	
ITEM EN	**ITEM NL**	**ABBREV.**	
My caregivers would have a positive opinion towards my use of AAL technology.	Mensen die mij zorg verlenen, zullen een positieve opvatting hebben over mijn AAL technologie gebruik.	CI01	
My caregivers would think I should use AAL technology	Mensen die mij zorg verlenen, zullen vinden dat ik AAL technologie moet gebruiken.	CI02	Removed in main study
My caregivers would have a positive view on my use of AAL technology.	Mensen die mij zorg verlenen, zullen een positieve kijk hebben op mijn AAL technologie gebruik.	CI03	
My caregivers would value my use of AAL technology.	Mensen die mij zorg verlenen, zullen het waarderen als ik AAL technologie gebruik	CI04	Added after pilot study

MEASUREMENT		SOURCE	
Human Touch Norm People's judgement of the importance of the human touch in care and face-to-face interaction.		Adapted from Dabholkar (1996) Phang yet al. (2006)	
ITEM EN	**ITEM NL**	**ABBREV.**	
Human contact is more enjoyable than contact via AAL technology.	Menselijk contact is plezieriger dan contact via AAL technologie.	HTN01	
I Like interacting with humans more than interacting via AAL technology.	Ik vind de interactie met mensen leuker dan de interactie via AAL technologie.	HTN02	
Personal attention is more important than attention via AAL technology	Persoonlijke aandacht is belangrijker dan aandacht via AAL technologie.	HTN03	
I prefer personal care over care via AAL technology.	Ik geef voorkeur aan zorg door mensen ten opzichte van zorg via AAL technologie.	HTN04	

MEASUREMENT		SOURCE	
Privacy Norm People's judgement of the importance of privacy and data security when using AAL technology.		3 items adapted from Yao et al. (2007) 2 items inspired by Angst and Argarwal (2009) Construct was removed in the main study	
ITEM EN	**ITEM NL**	**ABBREV.**	
I think that people have the right to be left alone	Ik vind dat mensen het recht hebben om met rust gelaten te worden	PN01	
I think that AAL technology should not invade my private life.	Ik vind dat AAL technologie niet in mijn privé leven mag indringen.	PN02	Removed after pilot study
AAL technology may not share personal information without my consent.	AAL technologie mag geen persoonlijke informatie doorgeven zonder mijn toestemming.	PN03	
I think I have the right to control my personal information in AAL.	Ik vind dat ik het recht heb om te beslissen over mijn persoonlijke informatie in AAL.	PN04	
It would bother me to share personal information with informal and formal caregivers.	Het zou me storen om persoonlijke gegevens met mantelzorgers en andere zorgverleners te delen.	PN05	Removed after pilot study
AAL databases should be protected from unauthorized access no matter how much it costs.	Mijn persoonlijke gegevens in AAL moeten beschermd worden tegen toegang door onbevoegden.	PN06	

MEASUREMENT		SOURCE	
Personal Innovativeness People's willingness to try out any new information technology (Agarwal & Prasad, 1998).		Adapted from Agarwal and Prasad (1998)	
ITEM EN	**ITEM NL**	**ABBREV.**	
If I heard about a new information technology, I would look for ways to experiment with it.	Als ik over een nieuwe technologie hoor, wil ik die graag uitproberen.	PI01	
In general I am hesitant to try out new information technologies (-).	In het algemeen ben ik terughoudend in het uitproberen van nieuwe technologieen (-).	PI02 (-)	
Among my peers, I am usually the first to try out new information technologies.	Van mijn vrienden ben ik meestal de eerste die nieuwe technologie uitprobeert.	PI03	
I like to experiment with new information technologies.	Ik vind het leuk om nieuwe technologie uit te proberen.	PI04	

MEASUREMENT		SOURCE	
Self-Efficacy People's judgment of their capabilities to organize and execute courses of action required to use AAL technology (Bandura, 1986).		3(4) items adapted from LaRose et al. (2012) 2(3) items adapted from Meuter et al. (2003)	
ITEM EN	**ITEM NL**	**ABBREV.**	
I feel confident about using AAL technology.	Ik heb er vertrouwen in dat ik AAL technologie kan gebruiken.	SEF01	
I feel confident I know how to learn advanced skills related to using AAL technology.	Ik heb er vertrouwen in dat ik de vaardigheden kan leren om AAL technologie te gebruiken.	SEF02	
I feel confident understanding terms/words relating to AAL technology.	Ik heb er vertrouwen in dat ik de termen van AAL technologie kan begrijpen.	SEF03	
If I had problems relating to using AAL technology I know I could work them out.	Mocht ik problemen bij het gebruik van AAL technologie ervaren, dan weet ik dat ik ze op kan lossen.	SEF04	Removed in main study
When given the opportunity to use AAL technology, I fear I might damage it in some way (-).	Als ik de kans krijg om AAL technologie te gebruiken, ben ik bang om deze te beschadigen (-).	SEF05 (-)	Removed after pilot study
I would avoid AAL technology because it is unfamiliar to me (-).	Ik zal AAL technologie vermijden omdat deze onbekend voor mij is (-).	SEF06 (-)	
I hesitate to use AAL technology for fear of making mistakes I cannot correct (-).	Ik ben huiverig om AAL technologie te gebruiken, omdat ik bang ben fouten te maken die ik niet kan corrigeren (-).	SEF07 (-)	

MEASUREMENT	SOURCE
User Control People's perceived sense of control over the interaction with AAL technology (Trevino and Webster, 1992).	Adapted from Trevino and Webster (1992) Construct was removed in the pilot study

ITEM EN	ITEM NL	ABBREV.
I think that I will feel in control, when using AAL technology	Ik denk dat ik het voor het zeggen heb, als ik AAL technologie ga gebruiken.	CTR01
I think that AAL technology will allow me to control my interaction with the technology	Ik denk dat ik grip heb op de bediening van de AAL technologie.	CTR02
I think that I will have no control over my interaction with the AAL technology (-)	Ik denk dat ik geen regie heb over de bediening van de AAL technologie (-).	CTR03 (-)

MEASUREMENT	SOURCE
Reliability People's belief that AAL technology will consistently operate properly (McKnight et al. 2011).	Adapted from Mcknight et al. (2011)

ITEM EN	ITEM NL	ABBREV.	
I think that AAL technology is reliable	Ik denk dat AAL technologie betrouwbaar is.	REL01	
I think that AAL technology wil not fail me	Ik denk dat AAL technologie mij niet in de steek laat.	REL02	
I think that AAL technology is ~~extremely~~ undependable (-)	Ik denk dat je ~~absoluut~~ niet kan rekenen op AAL technologie(-)	REL03 (-)	Rephrased after pilot study. Removed in main study
I think that AAL technology does not malfunction for me.	Ik denk dat AAL technologie zonder storingen werkt.	REL04	

MEASUREMENT	SOURCE
Financial Cost People's belief that AAL technology use is associated with high financial expenses	2 items adapted from Luarn & Lin (2005)

ITEM EN	ITEM NL	ABBREV.
It will cost a lot to use AAL technology	Het zal veel geld kosten om AAL technologie te gebruiken.	C01
There are financial barriers to my use of AAL technology	De financiele kosten zijn voor mij een belemmering om AAL technologie te gebruiken.	C02
I think that using AAL technology will be expensive.	Ik denk dat het gebruik van AAL technologie duur zal zijn.	C03

Related Publications

2018

Jaschinski, C., & Ben Allouch, S. (2018). Listening to the ones who care: exploring the perceptions of informal caregivers towards ambient assisted living applications. *Journal of Ambient Intelligence and Humanized Computing*, 1-18. https://doi.org/10.1007/s12652-018-0856-6

Van Dijk, J. A. G. M., Ben Allouch, S., Graaf, M. M. A., & **Jaschinski, C**. (2018). Toward a Process Model for Selection of Theories of Technology Acceptance. Paper presented at the *2018 Annual International Communication Association Conference.* Prague, Czech Republic.

2017

Jaschinski, C., & Ben Allouch, S. (2017). Voices and Views of Informal Caregivers: Investigating Ambient Assisted Living Technologies. In A. Braun, R. Wichert, & A. Maña (Eds.), *Ambient Intelligence. AmI 2017, LNCS* (Vol. 10217, pp. 110–123). Springer International Publishing. http://doi.org/10.1007/978-3-319-56997-0_8

2016

Ben Allouch, S., **Jaschinski, C.**, Deboeverie, F., & Aghajan, H., Philips, W. (2016). Lessons learned from SONOPA (SOcial Networks for Older adults to Promote an Active life). *Gerontechnology, 15*(0), 71-71. http://dx.doi.org/10.4017/gt.2016.15.s.854.00

2015

Jaschinski, C., & Ben Allouch, S. (2015). An Extended View on Benefits and Barriers of Ambient Assisted Living Solutions. *International Journal on Advances in Life Sciences, 7*(1&2), 40–53.

Jaschinski, C., & Ben Allouch, S. (2015). Why Should I Use This? Identifying Incentives for Using AAL Technologies. In B. de Ruyter, A. Kameas, P. Chatzimisios, & I. Mavrommati (Eds.), *Ambient Intelligence, AmI 2015, LNCS* (Vol. 9425, pp. 155–170). Springer International Publishing. http://doi.org/10.1007/978-3-319-26005-1_11

Jaschinski, C., & Ben Allouch, S. (2015). Understanding the User's Acceptance of a Sensor-Based Ambient Assisted Living Application. In A. A. Salah, B. J. A. Kröse, & D. J. Cook (Eds.), *Human Behavior Understanding (HBU 2015), LNCS* (Vol. 9277, pp. 13–25). Springer International Publishing. http://doi.org/10.1007/978-3-319-24195-1_2

2014

Jaschinski, C., (2014). Ambient Assisted Living: Towards a Model of Technology Adoption and Use Among Elderly Users. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing Adjunct Publication - UbiComp '14 Adjunct* (pp. 319–324). New York, New York, USA: ACM Press. http://doi.org/10.1145/2638728.2638838

Jaschinski, C., & Ben Allouch, S. (2014). Ambient Assisted Living : Benefits and Barriers From a User-Centered Perspective. In *AMBIENT 2014, The Fourth International Conference on Ambient Computing, Applications, Services and Technologies* (pp. 56–64).

Summary

Who takes care of our older adults? According to the European Union, smart technologies that support independent living and active aging, introduced as 'Ambient Assisted Living' (AAL), are the future for our aging population. Promises of AAL include saving long-term care costs, improving the quality of care, unburdening family caregivers, and increasing the older adults' independence and overall quality of life. While the policy enthusiasm for AAL technology is high, it is unclear if the potential users of AAL are willing to embrace AAL technologies in their daily lives.

Hence, the research question central to this dissertation is:

> *Which factors determine the acceptance of AAL technologies among older adults (primary focus) and their caregivers (secondary focus)?*

Chapter 1 gives a general introduction to the context and focus of this research. The chapter starts with an overview of the demographic developments in Europe and the challenges associated with the aging population. Furthermore, the changes in long-term care policies and the increasing interest in smart technologies to support independent living and active ageing (AAL) are discussed. It is emphasized that currently AAL research is mainly technology-driven, rather than user-driven (Chan, Campo, Estève, & Fourniols, 2009; Queirós, Silva, Alvarelhão, Rocha, & Teixeira, 2015). The field lacks a theoretically grounded understanding of how and why users will accept or reject AAL technologies (Liu, Stroulia, Nikolaidis, Miguel-Cruz, & Rios Rincon, 2016; Peek et al., 2014).

Before turning to the acceptance of AAL, we first looked into the definition of AAL. Ambient Assisted Living is still a relatively new and emerging research area that encompasses several types of technologies (e.g., smart home, mobile and wearable technology, assistive robotics) as well as a broad range of application domains (e.g. health and rehabilitation, safety and social inclusion). Due to this broadness and its interdisciplinary nature there is no common understanding among researchers on how AAL should be defined. Therefore, **Chapter 2** introduces the following definition for AAL:

> *State-of-the-art ICT-based solutions that build on the principles of ambient intelligence to create intelligent environments that provide all-encompassing, non-invasive, and pro-active support to older adults and have the ultimate goal to maintain their independence, enhance their overall quality of life, and support their caregivers.*

Furthermore, the different application domains, tools and techniques of AAL are presented. The chapter concludes with a description of the current challenges in this research area. These challenges concern the technical feasibility and overall implementation of AAL, the user acceptance, the lack of large-scale quantitative and evidence-based research, and a missing theoretical discourse.

This dissertation addresses some of the challenges by (1) focusing on the user; (2) identifying potential drivers and barriers for AAL acceptance; (3) developing a theoretical understanding of the underlying social, psychological, and behavioral mechanisms in the acceptance process; (4) model the underlying relationships between acceptance factors and (5) deploying a large-scale quantitative survey to test and validate these factors and make statistically grounded inferences about their relative importance. In extension, these insights will contribute to the development of a theoretical discourse in the AAL field that provides guidance to developers and policy makers to improve AAL designs, recognize and address ethical dilemmas, and explore and establish structured regulations.

In order to identify important factors that might influence the acceptance process, a literature review was conducted (**Chapter 3**). This literature review intended to accumulate and compare the results from earlier AAL user studies to reach some consensus about important drivers and barriers of AAL acceptance. In addition, the results provided insights into the underlying aspects, meanings and perceptions associated with the acceptance factors. Therefore, the literature review provided part of the groundwork for the development of the acceptance model.

After analyzing 22 user studies, eight drivers and nine barriers of AAL acceptance could be identified. The most common drivers were health and safety; support and unburden caregivers and provide peace of mind; social connectedness; and independent living and aging in place. Other drivers that were less prevalent included enjoyment and leisure; support with daily activities; self-confidence and status; and education and information. The most common barriers were privacy, intrusiveness and control; loss of human touch; self-efficacy, technology experience and usability; and the absence of perceived need and perceived value. Other barriers that were less prevalent included financial cost; social stigma and pride; reliability and trust in technology; health concerns and burdening caregivers.

To further validate the identified factors, three qualitative user studies were conducted (**Chapter 4**). The first study was conducted within the framework of the European research project SONOPA (SOcial Networks for Older adults to Promote and Active life). The user groups included older adults from France and the United Kingdom and older adults and professional caregivers from Belgium. The second user study was conducted with informal caregivers from the Netherlands. In this second study, several examples of AAL technologies were presented to the participants. The third user study was conducted with couples of older adults and their caregivers. A later iteration of the SONOPA prototype was evaluated within this third user study.

In the user studies, most of the drivers and barriers from the literature review could be validated. The results also showed that informal caregivers play an important role in care-related decision making. They are often the initiators of discussions on care-related topics. Their influence varies from a cautious suggestion, to a strong advisory role, to making decisions for the user.
Finally, it appeared that older adults and their caregivers are generally open to the idea of AAL technology. However, it should be noted that participants often felt no need to use AAL in their current situation. Instead, they often talked about potential future use or other older adults who might benefit from AAL.

Chapter 5 takes a critical look at some of the popular theories and models of technology acceptance research. The aim was to develop a well-grounded understanding of the user's acceptance process and to integrate the identified acceptance factors into a theoretical framework. The chapter starts with a description of the different stages of technology acceptance, namely: awareness, consideration, decision, initial use and continuous use. This dissertation focuses on the early stages of the acceptance process, in particular the consideration phase.
Due to its novelty and the low technological readiness (mainly pilot phase) (Liu et al., 2016), it is suspected that most users have limited knowledge and experience with AAL technologies. Nevertheless, it is crucial to get an early insight into the users' expectations towards AAL.

After critical consideration of several theories (diffusion of innovations, technology acceptance model, unified theory of acceptance and use of technology, social cognitive theory and theory of planned behavior), it was decided to use the theory of planned behavior (TPB) (Ajzen, 1991) as a theoretical starting point. TPB was chosen because of its theoretical strengths, its empirical robustness, its proven effectiveness in related research areas and especially its adequateness for explaining the early stages of the acceptance process. Using TPB as a starting point, the factors from the literature review and the qualitative user studies were integrated into a conceptual model for AAL acceptance.

Following TPB, the conceptual model of AAL acceptance suggested that intention to use AAL technology can be explained by the attitude towards AAL use, the perceived social pressure to use AAL (social norm), the perceived fit with personal norms and values (personal norm), and the perceived overall control over using AAL (perceived behavioral control). Personal norm was added to the original TPB to address earlier criticism regarding the neglect of personal normative mechanisms (Armitage & Conner, 2001; Godin & Kok, 1996). Following Taylor and Todd (1995b) and other researchers (De Graaf et al., 2017; Hsieh et al., 2008; Pavloe & Fygenson, 2006), TBP's underlying belief structure was decomposed into separate multi-dimensional belief constructs. It was hypothesized that attitude was positively influenced by beliefs about safety, independence, and relief of family burden, but negatively influenced by beliefs about loss of privacy and loss of human touch (behavioral beliefs). The overall social norm was hypothesized to be positively affected by caregiver influence, but negatively affected by beliefs about social stigma (social normative beliefs). The overall personal norm was hypothesized to be positively affected by one's personal innovativeness, but negatively influenced by one's human touch norm and privacy norm. Finally, perceived behavioral control was expected to be positively affected by self-efficacy beliefs, beliefs about the technology's reliability, and beliefs about the sense of user control during interaction, but negatively affected by the expected financial cost (control beliefs).

Chapter 6 and **Chapter 7** describe the online survey of AAL acceptance which was conducted among a representative sample of Dutch older adults. The data from these studies were used to validate the conceptual model using structural equation modeling.

Chapter 6 presents the scope and design of the AAL acceptance survey and the development of the measurements. The second part of the chapter describes the results of the first pilot study that was conducted with 320 Dutch older adults. A confirmatory factor analysis (CFA) was used to investigate the psychometric properties of the scales.
The construct user control was removed due to poor psychometric properties and the constructs safety and independence were merged into the construct safe and independent living. The pilot study resulted in refined measurements and an adapted conceptual model of AAL acceptance.

Chapter 7 describes the results of the main study that was conducted with a larger sample of 1296 Dutch older adults. Structural equation modeling was used to further validate the modified conceptual model.
After a second CFA, the constructs social stigma and privacy norm were removed due to poor psychometric properties.

The overall intention to use AAL technologies was moderately positive across both independent samples. This means that Dutch older adults are relatively open to the idea of using AAL technologies in the future. We found no difference in use intention between age groups, gender groups, people with different subjective health rating, and people with different expected support need. The only significant difference was found between older adults with low education level and older adults with high education level. However, the effect size of this difference was very small.

The results of the acceptance survey indicated that the adapted model of AAL acceptance showed adequate model fit for the observed data (normed chi-square (3.06), RMSEA (.040), SRMR (.06), CFI (.93) and TLI (.92)) and explained 69% of the variance in intention to use. All hypothesized paths were significant, except for the path between human touch norm and personal norm, and the path between reliability and perceived behavior control. The hypothesized behavioral belief constructs explained 71% of the variance in attitude; the hypothesized social normative belief constructs accounted for 94% in variance of social norm; the personal normative belief constructs accounted for 67% in variance of personal norm; and the control belief constructs explained 71% of the variance in perceived behavioral control.
Hence, it can be concluded that our established theoretical model provides a valuable framework for understanding and explaining older adults' acceptance of AAL technologies in an early acceptance stage (*consideration*).

The dissertation concludes with a general discussion (**Chapter 8**). Besides a description of the most important results, limitations and possible directions for future research, the following recommendations are given for the future development, implementation and policy direction of AAL:

1. Create more awareness for AAL among the intended users.

2. Reconsider the value propositions of AAL applications.

3. Design applications that are modular and adaptive.

4. Foster agency and self-reliance.

5. Stimulate and not replace the human touch in care

6. Respect the user's privacy.

7. Improve the user-friendliness of AAL applications and offer training courses.

8. Work towards reimbursement schemes and flexible financing

9. Use co-creation, work in multidisciplinary teams and keep in touch with the intended users.

In conclusion, it will probably take several more years before AAL will be widely diffused in the homes and everyday lives of older adults and will be fully incorporated into care routines. There are still many challenges to the acceptance and implementation of these technologies that need to be addressed. However, we believe that the implications that are routed in the findings of this dissertation can help stakeholders to work towards a more user-centered perspective in AAL that will lead to implementations that are embraced by older adults and their caregivers.

Dutch Summary

Wie gaat voor onze ouderen zorgen? Volgens de Europese beleidsmakers zijn slimme technologieën ter ondersteuning van zelfstandig wonen en actief ouder worden, geïntroduceerd als 'Ambient Assisted Living' (AAL), de toekomst voor onze vergrijzende bevolking. Beloften van AAL zijn onder meer het besparen van kosten voor langdurige zorg, het verbeteren van de kwaliteit van de zorg, het ontlasten van mantelzorgers en het vergroten van de zelfstandigheid en de algehele kwaliteit van leven van ouderen. Hoewel het enthousiasme voor AAL technologie onder beleidsmakers groot is, is het onduidelijk of de potentiële gebruikers van AAL bereid zijn AAL technologieën in hun dagelijks leven te integreren.

In dit proefschrift staat daarom het volgende vraagstuk centraal:

> *Welke factoren bepalen de acceptatie van AAL technologieën bij oudere volwassenen (primaire focus) en hun zorgverleners (secundaire focus)?*

Hoofdstuk 1 geeft een algemene introductie van de context en focus van dit onderzoek. Het hoofdstuk begint met een beschrijving van de demografische ontwikkelingen van de vergrijzende bevolking in Europa en de gevolgen daarvan. Tevens wordt er ingegaan op de politieke veranderingen met betrekking tot de langdurige zorg en de toenemende belangstelling voor slimme technologieën ter ondersteuning van zelfstandig wonen en actief ouder worden, ofwel AAL technologie. Er wordt ook geschetst dat AAL onderzoek op dit moment vooral technologiegedreven is, in plaats van gebruikersgedreven (Chan, Campo, Estève, & Fourniols, 2009; Queirós, Silva, Alvarelhão, Rocha, & Teixeira, 2015). Het ontbreekt aan een theoretisch onderbouwd inzicht in waarom gebruikers AAL technologieën zullen accepteren of afwijzen (Liu, Stroulia, Nikolaidis, Miguel-Cruz, & Rios Rincon, 2016; Peek et al., 2014).

Alvorens de acceptatie van AAL technologie verder te bestuderen, is er gekeken naar de definitie van AAL. Ambient Assisted Living is een relatief nieuw en opkomend onderzoeksgebied. AAL kent verschillende soorten nieuwe technologieën (b.v., smart homes, robotica, draagbare en mobiele sensoren) en een breed scala aan toepassingsgebieden (b.v., gezondheid en rehabilitatie, veiligheid en sociale verbondenheid). Door de verschillende toepassingsgebieden en het interdisciplinaire karakter van AAL onderzoek is er weinig overeenstemming onder onderzoekers over de definitie van AAL. **Hoofdstuk 2** introduceert daarom de volgende definitie voor AAL:

> *Geavanceerde, op ICT-gebaseerde oplossingen die voortbouwen op ambient intelligence om intelligente omgevingen te creëren die allesomvattende, niet-invasieve en proactieve ondersteuning bieden aan oudere volwassenen en het uiteindelijke doel hebben om hun onafhankelijkheid te behouden, hun algemene levenskwaliteit te verbeteren en hun zorgverleners te ondersteunen.*

Verder wordt in dit hoofdstuk meer licht geworpen op de verschillende toepassingsgebieden, technologieën en technieken van AAL. Het hoofdstuk sluit af met een beschrijving van de actuele uitdagingen op dit onderzoeksgebied. Deze uitdagingen betreffen de technische haalbaarheid en implementatie van AAL, de acceptatie door de gebruiker, het gebrek aan grootschalig kwantitatief en empirisch onderbouwd onderzoek, en een ontbrekend theoretisch discours.

Het proefschrift gaat in op een aantal van deze uitdagingen door (1) de gebruiker centraal te stellen; (2) potentiële drijfveren en barrières voor AAL acceptatie te identificeren; (3) theoretisch begrip van de onderliggende sociale-, psychologische- en gedrags-mechanismen te ontwikkelen en (4) onderliggende relaties tussen acceptatiefactoren te onderzoeken middels een grootschalige kwantitatieve survey onder Nederlandse ouderen. In het verlengde daarvan dragen deze inzichten bij aan de ontwikkeling van een theoretisch discours in AAL onderzoek. Daarnaast kunnen deze inzichten ontwikkelaars en beleidsmakers helpen om AAL toepassingen te verbeteren, ethische dilemma's te herkennen, en gestructureerde regelgeving rondom AAL vast te stellen.

Om factoren in kaart te brengen die invloed kunnen hebben op het acceptatieproces is er als eerste een literatuuronderzoek uitgevoerd (**Hoofdstuk 3**). Het doel van dit onderzoek was om eerder gebruikersonderzoek naar AAL te analyseren en consensus te bereiken over belangrijke drijfveren en barrières voor de acceptatie van AAL. Daarnaast geven de resultaten inzicht in de onderliggende aspecten, betekenissen en percepties die met deze factoren samenhangen. Deze literatuurstudie is één van de uitgangpunten voor de ontwikkeling van het acceptatiemodel.

Na het analyseren van 22 studies zijn er, acht drijfveren en negen barrières voor de acceptatie van AAL geïdentificeerd. De meest voorkomende drijfveren zijn gezondheid en veiligheid, ondersteuning en ontlasting van zorgverleners en verhoogde gemoedsrust, sociale verbondenheid en zelfstandig wonen. Andere drijfveren die wat minder sterk naar voren kwamen zijn plezier en recreatie, ondersteuning bij dagelijkse activiteiten, zelfvertrouwen en status, en voorlichting en informatie. De meest voorkomende barrières zijn privacy, opdringerigheid en controle, verlies van menselijk contact, gebrek aan technologische ervaring en gebruikersvriendelijkheid, en het ontbreken van behoefte. Andere barrières die wat minder sterk naar voren kwamen zijn financiële kosten, stigmatisering en trots, betrouwbaarheid en vertrouwen in technologie, gezondheidsrisico's en zorgverleners belasten.

Om de geïdentificeerde factoren verder de valideren is er een drietal kwalitatieve gebruikerstudies uitgevoerd (**Hoofdstuk 4**). De eerste studie werd uitgevoerd in het kader van het Europese onderzoeksproject SONOPA (SOcial Networks for Older adults to Promote and Active life). Tot de gebruikersgroepen behoorden oudere volwassenen uit Frankrijk en het Verenigd Koninkrijk en oudere volwassenen en professionele zorgverleners uit België. De tweede gebruikersstudie werd uitgevoerd met mantelzorgers uit Nederland. In deze tweede studie werden verschillende voorbeelden van AAL technologieën getoond aan de proefpersonen. De derde gebruikers-studie werd uitgevoerd met koppels van oudere volwassenen en hun mantelzorgers. Een latere iteratie van het SONOPA prototype werd geëvalueerd binnen deze derde gebruikersstudie.

In de gebruikerstudies konden de meeste drijfveren en barrières uit het literatuuronderzoek gevalideerd worden. De resultaten lieten ook zien dat mantelzorgers een belangrijke rol spelen in het nemen van zorggerelateerde beslissingen. Zij zijn vaak de initiatiefnemers van discussies over zorggerelateerde onderwerpen. Hun invloed varieert van een voorzichtige suggestie tot een sterke adviserende rol, tot het nemen van beslissingen voor de zorgvrager. Tot slot bleek dat oudere volwassenen en hun zorgverleners over het algemeen open staan voor AAL technologie. Een kanttekening hierbij is dat zij zelf vaak geen behoefte hebben om AAL in hun huidige situatie te gebruiken. Ze praten dan ook vaak over mogelijk toekomstig gebruik of andere oudere volwassenen die baat kunnen hebben bij AAL.

In **Hoofdstuk 5** wordt kritisch gekeken naar relevante theorieën over het acceptatiegedrag van technologie. Het doel was om een gefundeerd begrip van het acceptatieproces te ontwikkelen en de geïdentificeerde factoren te integreren in een theoretisch raamwerk. Het hoofdstuk begint met een beschrijving van de verschillende fases in het acceptatieproces, te weten: *awareness* (bewustwording), *consideration* (afweging), *decision* (beslissing), *initial use* (eerste gebruik) en *continious use* (aanhoudend gebruik). Het proefschrift richt zich op de vroege stadia van het acceptatieproces, in het bijzonder de afwegingsfase (consideration). Vanwege de nieuwheid en de lage technologische gereedheid (meestal pilotfase) (Liu et al., 2016), vermoeden wij dat de meeste gebruikers beperkte kennis en ervaring hebben met AAL technologieën. Desalniettemin is het van cruciaal belang om in een vroeg stadium inzicht te krijgen in de verwachtingen van de gebruikers ten aanzien van AAL.

Na de kritische beschouwing van meerdere theorieën (diffusion of innovations, technology acceptance model, unified theory of acceptance and use of technology, social cognitive theory en theory of planned behavior) is er gekozen om de theory of planned behavior (TPB) (Ajzen, 1991) als theoretisch uitgangspunt te gebruiken. TPB werd gekozen vanwege de sterke theoretische basis, de empirische robuustheid, de bewezen effectiviteit in gerelateerde onderzoeksgebieden en vooral vanwege de geschiktheid voor het verklaren van de vroege stadia in het acceptatieproces. Met TPB als uitgangspunt zijn de geïdentificeerde factoren uit het literatuuronderzoek en de kwalitatieve studies vertaald naar een conceptueel model voor AAL acceptatie.

In overeenkomst met TPB stelt het conceptueel model dat de intentie om AAL technologie te gebruiken verklaard kan worden door de houding ten opzichte van AAL gebruik (*attitude*), de waargenomen sociale druk om AAL te gebruiken (*social norm*), de waargenomen fit met persoonlijke normen en waarden *(personal norm*), en de waargenomen controle over het gebruik van AAL (*perceived behavior control*). Het construct personal norm werd toegevoegd om eerdere kritiek op de verwaarlozing van persoonlijke normatieve mechanismen op te volgen (Armitage & Conner, 2001; Godin & Kok, 1996).

In navolging op Taylor en Todd (1995b) en andere onderzoekers (De Graaf et al., 2017; Hsieh et al., 2008; Pavloe & Fygenson, 2006), werd de onderliggende belief structuur van TBP ontleed in afzonderlijke multidimensionale belief constructen. Het model stelt dat attitude positief beïnvloed wordt door verwachtingen (*behavioral beliefs*) over veiligheid (*safety*), zelfstandigheid (*independence*) en het ontlasten van de familie (*relief of family burden*), maar negatief beïnvloed wordt door verwachtingen over het verlies van privacy (*loss of privacy*) en het verlies van menselijk contact (*loss of human touch*). *Social norm* wordt volgens het conceptueel model positief beïnvloed door de verwachtingen (*social normative beliefs*) over de mening van de zorgverlener (*caregiver influence*), maar negatief beïnvloed door verwachtingen over stigmatisering (*social stigma*). Personal norm wordt volgens het conceptuele model positief beïnvloed door iemands innovativiteit (*personal innovativeness*), maar negatief beïnvloed door iemands normatieve overtuigingen (*personal normative beliefs*) over het belang van menselijk contact *(human touch norm*) en privacy (*privacy norm*). Tot slot wordt verwacht dat perceived behavior control positief beïnvloed wordt door iemands vertrouwen (*control beliefs*) in zijn vaardigheden (*self- efficacy*), verwachtingen over de betrouwbaarheid van de technologie (*reliability*), en het verwachte gevoel van controle tijdens de interactie met AAL (*user control*), maar negatief beïnvloed wordt door de verwachte financiële kosten *(financial cost*).

In **Hoofdstuk 6** en **Hoofdstuk 7** wordt de online survey over AAL acceptatie beschreven die is uitgevoerd onder een representatieve steekproef van Nederlandse ouderen. De data van deze studies zijn gebruikt om het conceptueel model middels *structural equation* modeling te valideren.

Hoofdstuk 6 presenteert de opzet van het onderzoek en de ontwikkeling van de meetinstrumenten. Het tweede deel van het hoofdstuk beschrijft de resultaten van de eerste pilot studie die is uitgevoerd met 320 Nederlandse ouderen. Er is gebruik gemaakt van een *confirmatory factor analysis (CFA)* om de psychometrische eigenschappen van de meetinstrumenten te onderzoeken en een eerste bewijs te leveren voor het voorgestelde conceptueel model van AAL acceptatie. Hierbij is het construct *user control,* vanwege slechte psychometrische eigenschappen verwijderd en zijn de constructen safety en independence samengevoegd tot het construct *safe en independent* living. De pilotstudie resulteerde in verfijnde meetinstrumenten en een aangepast conceptueel model van AAL acceptatie.

Hoofdstuk 7 beschrijft de resultaten van het hoofdonderzoek dat is uitgevoerd met een grotere steekproef van 1296 Nederlandse ouderen. Er is gebruik gemaakt van *structural equation modeling* om het aangepaste conceptuele model verder te valideren. Hierbij zijn na een tweede CFA de constructen *social stigma* en *privacy norm,* vanwege slechte psychometrische eigenschappen, verwijderd.

Uit de resultaten bleek dat Nederlandse ouderen een licht positieve intentie hebben om AAL in de toekomst te gebruiken. Er zijn voor deze vroege acceptatiefase geen verschillen gevonden in de gebruiksintentie tussen leeftijdsgroepen, geslachtsgroepen, mensen met verschillende waargenomen gezondheid en mensen met verschillende behoefte aan ondersteuning. Het enige significante verschil werd gevonden tussen oudere volwassenen met een laag opleidingsniveau en oudere volwassenen met een hoog opleidingsniveau. Het effect van dit verschil was echter zeer klein.

Het aangepaste model van AAL acceptatie toonde voldoende model fit met de geobserveerde data (normed chi-square (3.06), RMSEA (.04), SRMR (.06), CFI (.93) en TLI (.92)). Uit de resultaten bleek verder dat het model 69% van de variantie in intentie tot gebruik kon verklaren. Alle veronderstelde paden waren significant, behalve het pad tussen *human touch norm en personal norm,* en het pad tussen *reliability* en *perceived behavior control.* De veronderstelde behavioral beliefs verklaarden 71% van de variantie in attitude; de veronderstelde *social normative beliefs* namen 94% van de variantie van social norm voor hun rekening; *de personal normative belief*s verklaarden 67% van de variantie van *personal norm;* en de control beliefs verklaarden 71% van de variantie in *perceived behavior control.* Daarom kan geconcludeerd worden dat ons gevalideerd model een waardevol kader biedt voor het begrijpen en verklaren van de acceptatie van AAL technologieën in een vroeg stadium van acceptatie *(consideration).*

Het proefschrift sluit af met een algemene discussie (**Hoofdstuk 8**). Naast een beschrijving van de belangrijkste resultaten, beperkingen en mogelijke richtingen voor toekomstig onderzoek, worden de volgende aanbevelingen gegeven voor de toekomstige ontwikkeling, implementatie en beleid rondom AAL:

1. Creëer meer bewustzijn voor AAL onder de beoogde gebruikers.

2. Heroverweeg de waarde proposities van AAL toepassingen.

3. Ontwerp toepassingen die modulair en adaptief zijn.

4. Stimuleer eigen regie en zelfredzaamheid.

5. Stimuleer menselijk contact in plaats van menselijk contact te vervangen.

6. Respecteer de privacy van de gebruiker.

7. Verbeter de gebruiksvriendelijkheid en bied trainingen aan.

8. Implementeer terugbetalingsregelingen en flexibele financiering.

9. Gebruik co-creatie, werk in multidisciplinaire teams en houd voortdurend contact met de beoogde gebruikers.

Concluderend kan worden gesteld dat het waarschijnlijk nog enkele jaren zal duren voordat AAL op grote schaal zal worden gebruikt door ouderen en volledig zal worden geïntegreerd in de zorgroutines. Er zijn nog veel uitdagingen voor de acceptatie en implementatie van deze technologieën. De bevindingen van dit proefschrift kunnen gebruikt worden om te werken aan een meer gebruikersgericht perspectief dat zal leiden tot AAL toepassingen die door ouderen en hun zorgverleners worden omarmd.

Acknowledgements

In augustus 2007 kwam ik naar Enschede om aan de Universiteit Twente communicatiewetenschap te studeren. Nu, ruim 11 jaar later, voelt Enschede als mijn thuis. Ik kan me herinneren dat ik het raar vond wanneer mensen na hun studie ook nog wilden promoveren. Ook had ik nooit van een carrière als onderzoeker gedroomd.
Maar toen Somaya mij in 2013 attendeerde op het promotietraject, was ik er stiekem toch snel enthousiast over. Nu 5 jaar later kunnen we concluderen dat ik of een beetje raar ben, of dat promoveren toch niet zo raar is.
Wel is het duidelijk dat ik niet op dit punt heb kunnen komen zonder de ondersteuning van heel veel lieve mensen die ik dan ook graag wil bedanken:

Allereerst wil ik mijn promotor Jan van Dijk en mijn co-promoter Somaya Ben Allouch bedanken. Beste Jan, bedankt voor al het waardevolle advies, de scherpe inzichten en kritische discussies. Je deur stond altijd open en zelfs na je officiële afscheid heb je nog steeds de moeite genomen om regelmatig naar de UT te komen om je over mijn stukken te buigen. Ik ben erg dankbaar dat je mij de kans hebt gegeven om dit onderzoek uit te voeren.

Somaya, jij bent een fantastische co-promoter, een inspirerende leidinggevende en vooral een hele leuke collega en kamergenoot. Ik ga je dan ook erg missen als je binnenkort naar Amsterdam vertrekt. Bedankt dat je mij vanaf het begin het vertrouwen en de vrijheid hebt gegeven om dit onderzoek vorm te geven en te groeien als onderzoeker. Ik kon altijd bij jou terecht voor vragen en advies en je hebt de nodige ruimte voor mij gecreëerd om mijn onderzoek af te kunnen ronden. Op de momenten dat het minder goed ging wist je me gerust te stellen en te motiveren om door te gaan. Je inzichten, advies en commentaar waren van onschatbare waarde voor dit proefschrift. Bedankt voor je fantastische begeleiding, je vertrouwen en je aanstekelijke enthousiasme. Ik weet zeker dat we ook in de toekomst nog veel samen gaan werken (of gewoon koffie gaan drinken in Amsterdam :-)).

Oscar, je bent halverwege mijn promotie een derde begeleider voor mij geworden. Bedankt voor al je theoretische en vooral statistische advies. Fijn dat je zoveel tijd en moeite hebt genomen om mij te ondersteunen.

Beste leden van de promotiecommissie: prof. dr. Lisette van Gemert-Pijnen, prof. dr. ir. Peter-Paul Verbeek, prof. dr. ir. Ben Kröse, prof. dr. Boris de Ruyter en prof. dr. Britt Östlund. Ik voel me vereerd dat jullie zitting hebben genomen in mijn commissie.

Lieve Saxion collega's, vooral mijn fantastische collega's van het lectoraat TH&C: Niek, Judith, Melissa, Richard, Lutz, Ingrid, Josca, Marloes, Mijke, Michael, José, Janet en oud collega Margreet. Wat is het fijn om met jullie samen te werken. Bedankt voor alle uitwisseling, ondersteuning en gezelligheid. Jullie zijn een topteam! Bijzonder dank ook aan het team van de master HC&SW. Ik ben er trots op dat we samen mooi onderwijs maken.
Leon, fijn dat ik ook na je vertrek bij TH&C nog steeds kon bellen om te sparren over mijn onderzoek. Hans, mijn oud directeur, bedankt voor je vertrouwen in mijn werk en dat je je sterk hebt gemaakt voor mijn positie bij Saxion.

Naast mijn Saxion collega's wil ik ook mijn UT collega's bedanken, want daar is het allemaal begonnen. Nadine, jij hebt mede ervoor gezorgd dat ik dit avontuur ben aangegaan en dat ik altijd een gezellig klets- en koffiemoment had na mijn UT afspraken. Yvon en Maartje, jullie hebben mijn start als promovenda stukken gezelliger gemaakt en mij destijds veel nuttig advies gegeven, waar ik jaren later nog veel aan heb gehad. Alexander, ook jou wil ik bedanken voor het meedenken in de laatste fase van mijn onderzoek. Pauline en Alice, dank voor jullie fantastische ondersteuning met alle 'regeldingen'.

Verder wil ik ook mijn studenten bedanken. Jullie nieuwsgierigheid en enthousiasme over dit onderwerp bevestigen voor mij telkens weer de waarde van dit onderzoek. Dit geldt uiteraard ook voor alle proefpersonen die mij verwelkomden in hun huis.

Ook buiten Saxion en de UT zijn er meerdere mensen waaraan ik mijn dank wil uitspreken. Lex, erg bedankt voor het proeflezen van sommige hoofdstukken. Mocht je ooit nog iemand nodig hebben voor een Duitse focusgroep, weet je mij te vinden :). Joey, wat hebben we een fijne samenwerking in het EyeBeacons project. Bedankt dat je me binnen dit project de ruimte hebt gegeven om mijn proefschrift af te kunnen ronden. Ricardo, my friend, thank you for taking the time to introduce me to the wonders of the program 'R'. Finally, I am grateful to all SONOPA colleagues for the productive collaboration.

Robert en Marloes, de creatieve krachtpatsers van Beeldgeneratie. Bedankt dat jullie mijn verhaal vertaald hebben in een prachtig design. Morlay, je hebt mijn ideeën in beeld gebracht in de AAL animatie video. Mijn dank hiervoor.

In het bijzonder wil ik ook mijn vrienden en familie bedanken. Zonder jullie ondersteuning was het niet gelukt:

Meine fantastischen Perlen, ihr steht seit Beginn meines Studiums an meiner Seite. Schön, dass ihr mir auch bei meiner Promotion wieder den Rücken stärkt.
Zwei von Euch, Lisa und Julia tun dies buchstäblich als meine Paranimfen.
Danke euch beiden, dass ihr diese Rolle auf euch genommen habt.

Meine liebe Doro, seit vielen Jahren unterstützt du mich bei allen wichtigen Momenten in meinem Leben, so auch bei meiner Promotion. Danke, dass du meine beste Freundin bist und ich immer auf dich zählen kann.

Lieve 'Enschede gang', vooral het 'theekransje', bedankt voor alle afleiding, ondersteuning en gezelligheid. Dankzij jullie heb ik ook in de moeilijke en stressvolle tijden kunnen ontspannen. Fijn dat jullie mijn vrienden zijn.

Aan mijn schoonfamilie en in het bijzonder mijn lieve schoonmoeder: heel erg bedankt dat jullie zoveel belangstelling tonen in mijn onderzoek. Fijn dat jullie mij hebben verwelkomd in jullie fantastische familie.

Mama, du bist großartig! Danke dass du mich zu der Person gemacht hast, die ich heute bin. Tobi und Marija, danke auch euch für eure Unterstützung aus dem fernen China. Ich freue mich schon sehr auf meinen kleinen Neffen. Papa, auch wenn du nicht mehr bei uns bist, weiß ich, dass du stolz auf mich bist. In den besonders stressvollen Momenten, hast du mir die Kraft gegeben durchzuhalten. Ich bin stolz deine Tochter zu sein.

Ten slotte wil ik de meest belangrijke persoon in mijn leven bedanken. Gerrald, zonder jou had ik dit proces niet kunnen afronden. Je hebt me op alle mogelijke vlakken ondersteund bij dit avontuur. Samen hebben wij mijn successen gevierd en op de minder leuke momenten was jij het die me hielp er weer bovenop te komen. Je voelde telkens precies aan wat ik nodig had en het is niet in woorden uit te drukken hoe dankbaar ik ben. Samen met jou kan ik alle uitdagingen aan. En een van de leukste uitdagingen staat al op ons te wachten…

Aan mijn kleine zoon: Je hebt besloten dat je mij op de laatste meters van deze reis wil vergezellen. Ik kan niet wachten om je straks in mijn armen te houden.

Curriculum Vitae

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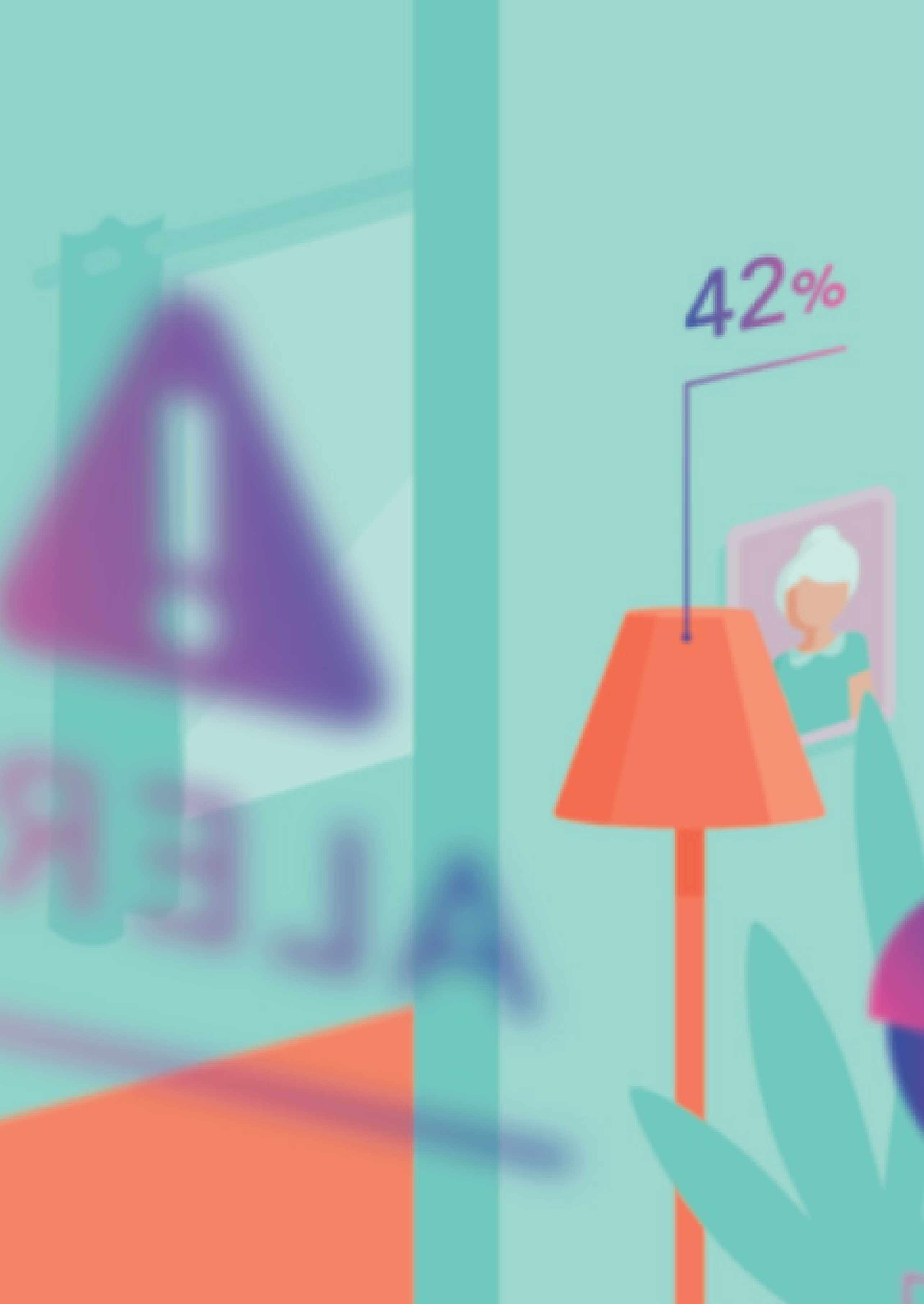
Christina Jaschinski was born on May 22nd, 1987 in Herten, Germany. In 2007 she moved to the Netherlands to pursue her studies at the University of Twente (UT). In 2012 she graduated with honors and received a Master of Science in Communication Studies.

Shortly after, she started her PhD research at the University of Twente, Faculty of Behavioral, Management and Social Sciences under the supervision of prof. dr. J.A.G.M Van Dijk and dr. Somaya Ben Allouch. In 2014 she joined her co-promoter dr. Somaya Ben Allouch at Saxion University of Applied Sciences where she continued to work on her PhD. Part of her doctoral research was conducted within the European AAL project SONOPA.

Currently, Christina Jaschinski works as a researcher and lecturer at the Saxion Research Group Technology Health & Care where she is involved in different research projects and education programs.
Her research interests are in the adoption and acceptance of new technologies in the field of health and well-being.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