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User-Centered Development of sensor-based Systems for Older People

DISSERTATION

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by

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Wien, 27. September 2017

Jean D. Hallewell Haslwanter

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Abstract

Europe is aging - people are living longer and fewer babies are being born. This has important implications long term, as there are fewer people to care for older people, and also fewer people working to finance their care. One solution that has been proposed is Ambient Assisted Living (AAL) - new technology that allows people to stay in their own homes longer and may also support carers, thereby reducing the economic impact on society. Despite extensive funding in Europe to support the development of AAL systems starting in 2008, there are not many systems on the market, making it interesting to understand why.

This research studied the development of these systems, as this is where decisions about functionality and design are made that can affect user acceptance and success on the market later. The goal was to identify issues teams face and to gain understanding of these. The approach of studying development processes has been successfully applied previously in other research areas to gain insight. Taking a Human-Computer Interaction perspective, a key focus here was the way in which the needs of the people who will use the system were gathered and taken into account during the development process, but it was also open to wider issues.

Qualitative methods were applied to explore this topic. Two large case studies of projects developing AAL systems were conducted. The first involved a tablet based system that was studied during the development itself. The second case study considered a project that developed a more comprehensive smart home system in retrospect. Both projects aimed to combine monitoring features to increase security in private homes with interactive services to support older people. These case studies provide detailed accounts about what occurred during these projects, which started out user-centered and yet did not reach their goal of having a successful product.

To expand on these results and check whether these issues have also been experienced by others, a series of studies was conducted that included a wider group of people with experience developing AAL systems. For this purpose, interviews, workshops and an interactive poster were done. These supported finding further issues, but also getting suggestions about how to address some of these.

The findings point to issues around the complexity of the term 'user' in these types of systems, how sensors frame notions of the user, the hidden effort to get systems working, and the impact of funding arrangements on projects. While some of the issues found are intrinsic to the problem space, others are within the control of teams and can be addressed with available methods and good project management. Yet others point to

problems that warrant further study, both to gain further understanding and to develop appropriate solutions. AAL is an important area for the future. The results provide a basis on which to build more successful systems, that are both reliable and usable, in the future.

Kurzfassung

Unsere Gesellschaft wird älter - Männer und Frauen leben länger, und gleichzeitig werden immer weniger Kinder geboren. Das hat wichtige, langfristige Konsequenzen, weil es weniger Pflegekräfte für immer mehr alte Leute gibt - und gleichzeitig weniger Arbeitskräfte, welche für die anfallenden Kosten aufkommen können. Ein Ansatz, um dieses Problem zu lösen und die wirtschaftlichen Auswirkungen dieser Änderungen abzufangen, ist „Ambient Assisted Living“ (AAL) - neue Technologien, welche es älteren Personen erlauben länger zuhause zu leben, und welche bei Bedarf auch die Pflegekräfte unterstützen können. Obwohl es seit 2008 ausgiebige Forschungsförderungen für AAL Systeme gibt, haben es bisher nur wenige Systeme auf den Markt geschafft. Daher wurde auch das wichtigste europäische Förderungsprogramm, das AAL Programme 2014 weiter verlängert, um mehr Systeme auf den Markt zu bringen.

Die vorliegende Forschungsarbeit untersucht die Entwicklung von AAL Systemen, um herauszufinden, wie die relevanten Entscheidungen über Funktionalität und Design getroffen werden, welche in weiterer Folge die User Akzeptanz und den Markterfolg entscheiden. Ziel war es, die Probleme vor denen Entwicklungsteams stehen zu identifizieren, und zu verstehen, wie diese Probleme miteinander zusammenhängen. Diese Vorgehensweise wurde mit Erfolg bereits in anderen Anwendungsbereichen angewendet. Dabei wurden die Fragestellungen hier aus der Perspektive der Human-Computer-Interaction betrachtet: Wie wurden bei der Entwicklung die Bedürfnisse der Benutzer erfasst? Und wie wurden diese dann weiter berücksichtigt?

Um herauszufinden welche Probleme in der Praxis auftreten, und um diese zu verstehen, wurden qualitative Untersuchungsmethoden eingesetzt. Dabei wurden zuerst zwei grosse Fallstudien zu Entwicklungsprojekten von AAL-Systemen durchgeführt. Die erste war eine begleitende Studie zur Entwicklung eines Tablet-basierten Systems. Die zweite Studie untersuchte retrospektiv die Durchführung eines grösseren, ambitionierten „Smart Home“ Projektes. Bei beiden Projekten wurde versucht, Telemonitoring-Optionen zur Erhöhung der Sicherheit älterer Personen in deren Wohnungen mit interaktiven Dienstleistungen zu kombinieren. Die Ergebnisse liefern einen detaillierten Bericht über die Entwicklung der beiden Projekte. Beide starteten mit einem nutzerzentrierten Ansatz, konnten aber trotzdem nicht erfolgreich am Markt etabliert werden. Die Ergebnisse der vorliegenden Untersuchungen zeigen, dass die Ansicht, wer der eigentliche System-Benutzer ist, bei der Entwicklung eine kritische Rolle spielen, und dass die Strukturen der Forschungsförderungsprogramme zusätzliche Hürden schaffen.

Zur Untermauerung und Erweiterung der Resultate der beiden Fallstudien wurden Forscher und Entwickler mit Erfahrung in der Entwicklung von AAL-Systemen konsultiert. Dafür wurden Interviews, Workshops, und die Methode eines „Interaktiven Posters“ angewendet. Die Ergebnisse unterstützen nicht nur die Resultate der Fallstudien, sondern zeigen auch zusätzliche Problemquellen auf. Die Experten haben auch Lösungsmöglichkeiten aufgezeigt.

Einige der aufgezeigten Problemursachen sind der Aufgabenstellung immanent: „Ältere Personen“ stellt eine sehr diverse Gruppe dar, und die beteiligten Interessengruppen verfolgen oft divergente Ziele. Andere Ursachen hingegen können von den Entwicklerteams beeinflusst werden, und durch existierende Methoden zum Projektmanagement und zur Softwareentwicklung unter Kontrolle gebracht werden. Darüber hinaus gibt es Aspekte, wie zum Beispiel die Rolle von Messsensoren bei der Entwicklung von anwenderorientierten Applikationen, welche zum aktuellen Zeitpunkt noch unzureichend verstanden sind.

AAL ist ein wichtiges Thema für die Zukunft unserer Gesellschaft. Die vorliegenden Ergebnisse bieten eine bessere Basis zur Entwicklung erfolgreicher Anwendungen, welche unsere Zukunft zuverlässig und hilfreich erleichtern sollen.

Contents

List of Figures

List of Tables

Part I

Introductory Chapters

CHAPTER 1

Introduction

The age pyramid in Europe is shifting – people are living longer and fewer are being born (European Commission, 2006). This causes practical problems, as there will be fewer young people to care for the older, but also financial problems, since there will be fewer people to pay into pension- and health systems used by older people (European Commission, 2009). One way way of tackling this problem, is the use of technology, often called Ambient Assisted Living, or more recently Active and Assisted Living (AAL):

> *"The concept of Ambient Assisted Living is understood as:*
> ** extending the time people can live in their preferred environment by increasing their autonomy, self-confidence and mobility;*
> ** supporting the preservation of health and functional capabilities of the elderly,*
> ** promoting a better and healthier lifestyle for individuals at risk;*
> ** enhancing security, preventing social isolation and supporting the preservation of the multifunctional network around the individual;*
> ** supporting carers, families and care organisations;*
> ** increasing the efficiency and productivity of used resources in the ageing societies"(AAL Joint Programme, 2017)*

This includes a broad range of possibilities, such as, helping assure that older people living alone take their medicine correctly, or generating an alarm if an older person falls and consequently may need assistance. To some degree the concept is technology driven, as technological solutions are put in the foreground. It is in part financially motivated, reducing the costs of caring for the growing older population. But in the end, these solutions also address human needs - they may allow people to age with more dignity and more enjoyment, as well as allow people to live at home longer, a wish expressed by many older people (Keenan, 2010). Apparently, older people may even be willing to accept some loss of privacy, something they generally value highly (Sallinen et al., 2015), in order to stay in their own homes (Wagner et al., 2012).

Due to the perceived importance, there are a number of funding programmes that support the development of these types of systems. These include national funding programmes, and the Active and Assisted Living Programme of EU (funding), formerly Ambient Assisted Living Joint Programme (AAL Programme) of the European Union (EU) which was founded in 2008. The AAL Programme aimed to encourage small or medium size enterprises (SMEs) to invest in the area and to develop projects with a two to three year horizon to market. Although 130 projects were funded between 2008 and 2013 (Busquin et al., 2013), there were not many systems on the market when the first phase ended in 2013. According to the evaluation report, the technologies were restricted to "specific market niches" and not the mainstream (Busquin et al., 2013, p. 3). In 2015, the AAL Programme celebrated ten projects that *had* made it to market in some way, acknowledging that the "road is tough" and there is still a way to go (AAL Programme, 2015, p. 3). The programme was extended in 2014 with an increased focus on getting to market (Busquin et al., 2013), so that there is still time to attempt to address issues with these systems and their development while funding remains available.

There are many challenges involved in developing AAL technologies. Identifying some of these, and gaining more information about them, may aid in understanding why there are not more systems on the market. Security features, such as fall sensors and monitoring whether people are still moving in their homes, involve cutting edge technology and demand a high level of reliability. Furthermore there is a diverse user group, from healthy people who have experience using computers, to people with physical or cognitive limitations and almost no experience with computers. Here, age is not the best indicator, as there are 75 year olds on both end of these dimensions. Moreover, there are numerous stakeholders. For instance, with the aforementioned security systems, there may be relatives who care for the older people part of the day, professional carers responsible at another time and ambulance services that are needed for serious incidents.

In order to understand why these systems are not more widespread, various perspectives have been taken. Some people have studied user acceptance: what is it that makes it hard for people to use these systems or makes them not want to use them. Some aspects include insufficient usability, fear of costs, but also a concern that carers may come by less frequently (Yusif et al., 2016; Sanders et al., 2012). Others have looked at methods which can be used to include older users and get direct input from them (e.g. Lindsay et al., 2012; Subasi and Fitzpatrick, 2012). Yet others have looked at the effectiveness and benefit these types of systems have (e.g. Barlow et al., 2007). Like this research, some of these have taken the perspective of Human-Computer Interaction (HCI) (e.g. Lindsay et al., 2012; Subasi and Fitzpatrick, 2012), looking at the design of computer systems and the way people interact with them. Prior to this research, no one had looked at the development process of AAL itself to understand where the problems are, but instead had focused on the outcome.

In this research, the focus was put on studying development processes aimed at addressing the needs of the users, to gather information about the issues developers face and gain insight into these. For example, is it difficult to communicate with older people about these systems, or is it difficult to find people to involve? Which users are

included in practice? On what basis are decisions made? This is important, because it is during the development itself, that the decisions are made about the functionality and the design, both of which can later affect the acceptance, but also the effectiveness and reliability of solutions that have been investigated by others.

Studying the development process to understand why systems are successful or not is supported by previous research: Design decisions can be a decisive factor in deciding whether products are a commercial success, even with systems from the same company like Windows XP™ or Microsoft BOB™ (Hassard et al., 2009). According to existing models, usefulness and usability contribute to the acceptance of technologies. They are also a concern of older people prior to installing systems that support staying in their own homes longer (Peek et al., 2014), and hence could impact market success. It is during the design process itself that developers choose the functions to include that affect the usefulness, but also decide between focusing on the functionality or usability, or even reliability or privacy, which affects the acceptance and success of the product (Whitworth et al., 2006). It has been demonstrated that even more technical design decisions impact qualities of systems that are crucial to success (Falessi et al., 2011). The issues developers face during the development, such as time constraints, can also influence the decisions made (Falessi et al., 2011, p. 33:4). Through studying a project, important details can be uncovered about decisions; for example, which users or personas considered at the outset were really used as a basis for decisions (Friess, 2012). Finally, since during the development HCI knowledge can help ensure the usability and acceptability of the resulting systems (Blythe et al., 2005, p. 687), it makes sense to take the perspective of HCI.

The goal was to explore the development of AAL systems with the aim of identifying and understanding the issues teams face that could affect their success. The focus was placed on sensor-based systems developed by companies with the intention of bringing a product to market. Thus, the aspects being investigated are related to, but not restricted to the *users* of these systems, the *technology* behind them and the *development processes*. The guiding Research Question (RQ) were:

- RQ 1: How are stakeholders, including older people, considered and included in the process?
- RQ 2: How does using sensor technology affect the development?
- RQ 3: How is the development done in practice?
  - RQ 3.1: Which user-centered methods and techniques are used?
  - RQ 3.2: How are decisions made during the development about which features to include?
- RQ 4: What other issues arise that could potentially affect the success?

To support the goals, qualitative methods were applied. Case studies of two projects developing AAL technology were conducted. In the next step, interviews, workshops and

an interactive poster were used to get input from a wider group of people with experience in the development of these technologies.

The focus was put on companies in Europe, and on monitoring systems. These systems use sensors to monitor the activities of people; for instance, to determine if they have fallen or if they have been inactive for a suspicious amount of time and hence may need assistance. If problems are detected an alarm is sent; for example, to a family member, professional carer or emergencies service. These systems provide security and can give people peace of mind, both the older people who have them installed (Turner and McGee-Lennon, 2013, p. 24) and their family members (Mynatt et al., 2000, p. 69), but require extensive testing to ensure they have the needed reliability and usability (Wagner et al., 2012, p. 32-33). Monitoring features may also be incorporated into more comprehensive solutions, which also offer additional features.

This topic was chosen, because I was interested in learning more about the difficulties confronting developers in this exciting new area of technology, aware that I one day may find myself dependent on these types of systems. Based on my experience with methods to include users (e.g. Muller et al., 1997), thirteen years of experience working as a developer of technical software in various countries and now as a lecturer, I saw many challenges. I had experienced the time constraints at companies that limit including users, and watched engineering students struggle to understand user needs. Ultimately, I hoped to apply the knowledge professionally to support more success and better systems for the users in the future through my work with students and companies. Through my position as a lecturer at a university of applied science, I also have had substantial contact with companies doing software development. This proved quite useful during the research.

This topic is relevant now. The problems of financing an aging population are still much in discussion. Despite national and Europe-wide funding schemes, companies are still not having success in bringing viable products to market. As a result, even during the time the research was being done, some of these programmes were extended. This means that the results could be published in time to support developers and researchers working in this area.

1.1 Structure of the thesis

The thesis is structured in three parts: the introductory chapters, the empirical results and the discussion.

The first part presents relevant background information and information about the research methodology. It starts with the results of a literature review on areas relevant to the subject of the thesis.

- Chapter 2 describes the context of the application area being studied. Fitting with the tradition of HCI, but also the research questions, it first looks at aspects relating to the *people* who are intended to use these systems, in this case older

people, and then gives an overview of *technology* to support older people, i.e. AAL systems, while still taking a more human-centered view.

- Since the research focuses on the development processes, Chapter 3 takes a more technical view and describes relevant aspects of software *development processes*, which are largely independent of the application area. It includes the more traditional software development methods, human-centered methods and participatory methods. It closes with a description of related research.

- Chapter 4 describes the research methodology applied, including the research approach taken, and the methods of data collection and analysis chosen.

The second part presents the empirical results:

- Case Study 1 explores the early phases of the development. It is described in Chapter 5. The focus of this study was to gain insight into the development processes in more depth; for example, how methods were applied in detail and how decisions were made. For this, an ethnographic study was done as a participant observer, taking part in the project meetings. This was supplemented by interviews with team members and examining project documents and artifacts.

- Case Study 2 explores an entire development project from conception to roll-out. It is presented in Chapter 6. For this, a retrospective study was done of a project that was not entirely successful. The focus of this study was to gather information about issues related to the larger context, including the introduction of the system. This case study examined the development of a larger system that lasted several years and included multiple phases. It is based primarily on documents and interviews with key team members.

- The supplementary studies to extend the results are described in Chapter 7. The goal was to get input from other people developing AAL technologies, in order to identify further issues and to check whether the issues identified in previous studies had also been faced by others. In addition to going back to the literature, a series of empirical studies was conducted to get input from more people who had been involved in projects developing AAL systems. This was done through an interview study, workshops and also an interactive poster. These supplementary studies enabled experiences from other countries to be included. Altogether these studies allowed participants to rate how important the issues were, and to give suggestions and recommendations for addressing some of them.

The third and final part, discusses the results and puts them in context:

- The discussion in Chapter 8 synthesizes and elaborates the results, puts them in context of previous research, describes the contribution of the research, and offers suggestions both for future development projects and future research in the area of AAL.

- Finally, the conclusion in Chapter 9 summarizes the thesis.

1.2 Contributions

The thesis has a number of original empirical contributions. First of all, it takes a new perspective on AAL by looking at the development process. The thesis also provides a rich description of two case studies giving insight into what happened during the development of AAL systems incorporating monitoring. This level of access is difficult to gain. In combination with the results from the interviews, workshops and interactive poster, a number of issues others have faced could be identified. These issues, in combination with more detailed information from the case studies and interviews, supported developing a description of many interconnected issues that make developing AAL systems complex. The connections between the issues are an important result of the thesis, and provide a basis for finding solutions.

The results contribute to an understanding of the issues developers face that can affect the success. The issues identified are very broad. Based on input from workshop participants these can be grouped into five categories: *Users, Financing, Marketing, Product* and *Project*. Through the case studies it is possible to understand better what happens. One important example is understanding why teams who started out user-centered lost that focus. In one case study, older people were included early in the development, but for financial reasons the target was changed to assisted living facilities, changing also the customer and needed functionality. In the other case study, difficulties finding users to participate, technical difficulties attaining the needed reliability in the short time the funding lasted and using sensors which relegated the original users to mere signal generators led to a more technical focus. These issues further demonstrate the influence of financial issues that are often out of the control of development teams. The situation is complex, thus precluding simple solutions. Nonetheless, the results offer suggestions as to how some of the issues identified can be addressed, thus they may enable more successful development of AAL systems in the future. The results can be of use to researchers, funding agencies and people developing AAL technologies.

1.3 Publications related to the thesis

- Full paper at the British HCI conference (Hallewell Haslwanter and Fitzpatrick, 2013),

- Full paper in *Universal Access in the Information Society*, a journal specialized on accessibility and HCI (Hallewell Haslwanter and Fitzpatrick, 2017b),

- Full paper at PETRA, a conference on pervasive technologies related to assistive technology (Hallewell Haslwanter and Fitzpatrick, 2017a),

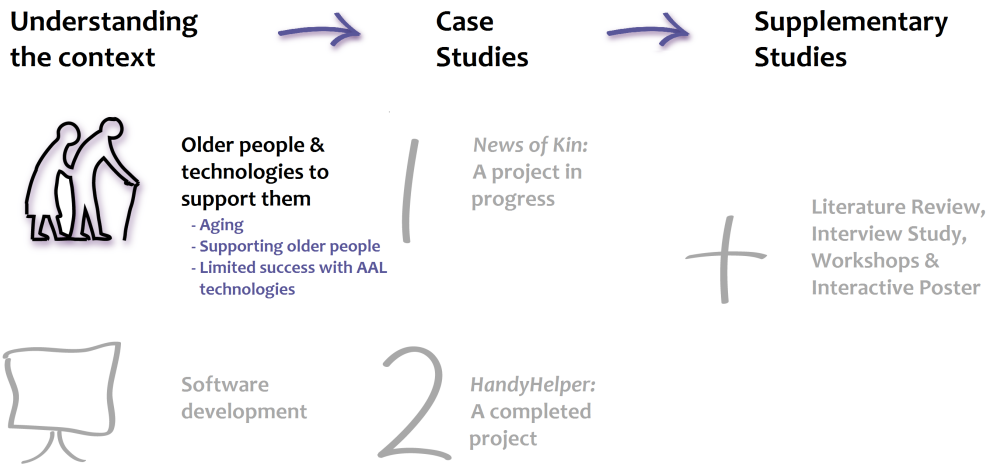
- Poster at AAL Forum, an international conference organized by the AAL Programme of the EU that funds projects in the area of AAL (Hallewell Haslwanter and Fitzpatrick, 2016a),

- Position paper in a workshop related to e-health at the NordiCHI conference (Hallewell Haslwanter and Fitzpatrick, 2016b),
- Workshop at the ICCHP, an international conference on computers helping people with special needs, which has a track on AAL (Hallewell Haslwanter and Werner, 2016).

Both case study publications have been cited by HCI researchers (Durick et al., 2013; Hornung et al., 2017). In addition, as a result of the research, the researcher was invited to take part in a working group of the Austrian innovation platform *AAL Austria* focusing on requirements gathering and user-centered design within AAL projects. The research also resulted in two conference papers related to the topic of the thesis: one about the prevalence of different User-Centered Design (UCD) methods in AAL projects in Austria (Garschall et al., 2016), and another about the use of critical incidents for the development of telehealth systems, including the type studied here (Grünloh et al., 2017).

CHAPTER 2

Background: Older People and Technologies to support them



The systems that were studied are sensor based monitoring systems for older people. This chapter provides an overview of aspects of older people's lives and the systems to support them, in order to better understand the needs related to these types of systems and problems that could arise when developing them.

Supporting older people is an important issue, since societies are getting older in Europe. This was brought to the attention of the wider public by an EU position paper in 2006 (European Commission, 2006). In 1960, the life expectancy of a man in Austria was below 70 years; by 2004, it had increased to over 75. By the end of the first phase of the AAL Programme in 2013, it had increased to over 80 in Europe (Busquin et al., 2013), and is projected to continue to increase. Furthermore, the absolute number of

"frail elderly", the term used for people 80 and above in the position paper (European Commission, 2006), is expected to increase by more than 10 million by 2030 (though elsewhere it is recommended to avoid the term "elderly", as it has a negative connotation associated with ill health (e.g. Hanson et al., 2015; Blythe et al., 2005)). Due to the post-war baby boom, the largest age group was 45-65 in 2006; by 2050, there may be half as many people over 65 as those between 15 and 65. People may be healthy many years past retirement at 65 (Age UK, 2014). Still, as people age they undergo changes that can provide challenges for developers (Blythe et al., 2005), especially as developers are generally not yet old themselves.

This chapter describes some aspects of older people's lives that set them apart from the general population, including both psychological and physiological aspects. Subsequently, it presents the types of systems that can help support older people, some benefits these types of support systems can offer older people, and some barriers to adoption. Thus, it provides important background information relevant both to RQ 1, which is related to *users*, and RQ 2, which is related to the *technology* behind these systems.

2.1 Aging

In Human-Computer Interaction, there is a risk with stereotypes - characteristics such as race or sex have a relatively large potential for error (Clemmensen, 2004). There are many stereotypes about aging. A search for images of "older people" in Google provides an overview of some of these stereotypes (see Figure 2.1 [1]): a grumpy-looking old man, someone who looks lonely, a contented-looking older women, someone in a hospital, an older couple holding hands - but also older people doing sports. The collection of images highlights an important attribute of older people - as people get older, they naturally become more diverse, both in terms of their experience, but also in terms of their cognitive, physical and sensory abilities (e.g. Gregor et al., 2002). System designers need to consider the diversity of abilities, and also that these change over time among older users (Gregor et al., 2002).

In the following, some of psychological and physiological changes that occur as people get older are described.

2.1.1 Defining "old"

There is no age at which people become "old". The age of retirement is often taken, 65 in many western countries, as it is a clear time when there is a transition. Certainly in research, various ranges are used (Hanson et al., 2015). People seem to think that others,

[1] Sources clockwise from upper left (accessed 13.5.2017): http://www.averilpower.ie/wp-content/uploads/2010/03/older-people1.jpg; ©Corbis Cusp/Alamy viewed at https://www.theguardian.com/society/joepublic/2011/oct/25/older-people-early-intervention-foundation; ©Monkey Business Images, ID 5929304, https://www.dreamstime.com; http://www.wellbeingandresilience.com/ageing/; ©Getty Images viewed at http://www.therecklessoptimist.com/?cat=34; http://www.huffingtonpost.co.uk/2014/04/17/apathy-lack-of-interest- emotion-older-people-brain-shrinkage_n_5165199.html

Figure 2.1: Images from a search for “older people” (source: see footnote)

and not they themselves, are old: in a study including retired people between 59 and 94 with an average age of 76, many people said they were not interested in technologies to support aging yet, but suggested they could be useful for other people - or for themselves, when they were older (Eisinger and Eisinger, 2011). There are certainly many examples of people who continued working into old age; for example, the inventor Benjamin Franklin, who reportedly invented bifocals when he was approaching 80 and the primate researcher Jane Goodall, who is still holding talks at over 80.

2.1.2 Some psychological aspects of aging

There are various psychological aspects related to aging that can be relevant when developing systems to support older people, but also when working with them.

Older people may be more set in their ways. This apparent conservatism, i.e., sticking to what they have always done, is thought to relate to people trying to maintain their sense of self-worth (Van Hiel and Brebels, 2011). The importance of maintaining a sense of self-worth is also demonstrated by the fact that many older men in particular identify themselves with the job they did before retiring (Tonolli et al., 2015). That older people may seem set in their ways or inflexible may also relate to older people being more conscientious (Roberts et al., 2006, p.15), which generally makes people do what they are supposed to do and do it correctly.

Research indicates people’s brains function differently as they age. Older people may have a more difficult time organizing activities (American Psychological Association, 2006). They may also have trouble ignoring distractions and multitasking (Gazzaley, 2016). This may make people less flexible, as it may be difficult for them to complete a task if they are interrupted; for example, to answer a question or to answer the telephone. Furthermore, due to memory problems, it can be harder for older people to remember recent events (American Psychological Association, 2006), and hence also where they put something. And since episodic or personal memory is more affected than semantic memory (American Psychological Association, 2006), which handles facts, older people may remember events that happened twenty years ago that they have told others about

again and again more easily than an exciting event that happened yesterday. But older people are not disinterested in the present, and express having an interest in both people and activities (Stenner et al., 2011).

Emotional reactions to events also change as people age. It has been shown that older people try to stay neutral and avoid emotion (Gross et al., 1997). Indeed, it is as if older people see the world through rose-colored glasses - enhancing their positive emotions and dampening the experience of those like sadness, anger and fear (Gross et al., 1997).

Difficulties related to aging

Older people may be marginalized in society. The term *ageism* refers to a bias against people based on age. For example, some communities do not welcome older people, fearing that they will be a burden, when in reality older people often make contributions through spending and working as volunteers in their community (Age UK, 2014, p. 69). The skills they have gained may no longer be relevant or valued; for example, being able to use a slide rule is not very valuable now that calculators are included on most smartphones. The *active ageing* movement encourages older people to engage in lifelong learning, take part in cultural activities, participate in physical activity, be socially involved, etc., in order to maintain their quality of life (WHO, 2002). This could be interpreted as saying older people have a duty to maintain health and function, and could even imply blame if they are not doing well. In fact, some argue it is a form of ageism (Tonolli et al., 2015). Even the wording "active ageing", implies that a certain passivity is present that needs to be fought against. However, the great majority of older people think they are fairly or even very active (Bowling, 2008). Even if they are not, this raises the question whether it is fair to require people to live up to certain standards based on future events that may never happen. At any rate, to avoid these types of negatives, it is important to reflect on the language used when writing about older people, for example, avoiding words like "the aged" (Hanson et al., 2015).

Although aging can be challenging, it does not necessarily mean that older people are less happy. There are physical losses and the loss of friends to deal with. However, a recent study showed that although older people who experienced hardships in their youth may be less happy than younger people who did not, generally individuals are happier as they get older (Sutin et al., 2013). Thus, older people may be less happy than younger people, but only because many younger people grew up in more prosperous times and experienced fewer hardships.

Older people are often portrayed as being lonely (Dykstra, 2009; Tornstam, 2005). In fact, in the United Kingdom (UK), one in ten older people report feeling lonely (Age UK, 2014, p. 44). However, it is actually only the very old (people over 80) who feel lonely, and even then the rate of loneliness is actually lower than for young adults (Dykstra, 2009). Despite societal changes and people moving more, these rates are actually decreasing slightly (Dykstra, 2009). Interestingly, the southern European countries, often perceived as family-oriented, generally show higher rates of loneliness among older people than those further north (Dykstra, 2009). There are various hypotheses to explain this, e.g. lower social inclusion of older people or more people living alone, which reduce social

contact (Dykstra, 2009). Loneliness is important, as it can have a profound effect on health. There is evidence that the incidence of strokes and heart disease increase by approximately 30% over the long term when people are socially isolated (Valtorta et al., 2016). As very old people are more likely to have lost friends and may not be able to walk or drive to visit friends, there is promise in technologies that support mobility and/or make it easier for older people to communicate with each other.

Other stereotypes, such as a propensity for napping, may not reflect reality. In fact, healthy older people actually need *less* sleep and fewer naps (Dijk et al., 2010).

Positive theories of aging

Some argue that aging is misunderstood (Tornstam, 2005). Aging need not be viewed in negative terms - people just have different values and ways of viewing the world as they age. For example, older people are generally less self-centered and have less interest in material things (Tornstam, 2005).

Just because older people spend more time alone, does not mean they are lonely or see it as a problem (Tornstam, 2005). That people spend more time alone may be linked to the fact that social vitality is reduced, a type of extroversion which relates to how gregarious people are, which also relates to the energy level people have (Roberts et al., 2006). Furthermore, many older people do not feel lonely and instead value solitude (Tornstam, 2005). Perhaps as a result, they get more selective about which activities they do and have less interest in superficial interaction. In fact, recent research shows that in other species, too, although older individuals are interested in social interaction, they engage in less social activity (Almeling et al., 2016), indicating that it could be a natural physiological phenomenon.

As described previously, subjectively people may actually be happier as they age. This could be related to changes due to being retired; for example, there is reduced stress which contributes to happiness (Baumeister et al., 2013). The *Socioemotional Selectivity Theory* posits that older people focus on positive aspects and emotionally gratifying aspects in order to support their well-being (Reed and Carstensen, 2012). According to Reed and Carstensen (2012), the theory is supported by many studies that show this positive skew is evident in a variety of ways, including what images people pay attention to, forming personal memories and even choosing which doctor to go to, and is due to emotional regulation and not cognitive decline. Some of this positive thinking is also visible from the outside. Contrary to the stereotype of the grumpy old man, like the one depicted in the image above, older people generally become more agreeable (Roberts et al., 2006).

Some suggest that instead of seeing old people as being powerless in the face of the many changes, the changing circumstances older people face may instead be viewed as challenges, to which they respond (Stenner et al., 2011). Older people may feel a sense of pride at their ability to do things they want to do, even if it is “just” going for a walk (Stenner et al., 2011).

2.1.3 Physiological changes

Older people are sometimes characterized in terms of decline and their physical, sensory and cognitive limitations (Blythe et al., 2005). This may be because many of these changes can be seen from the outside - as the skin grows thinner, people get more wrinkles, their muscle mass reduces and their joints get stiffer (Martin, 2016c,b). As people age, many do experience some sort of additional limitations (Gregor et al., 2002; Statistik Austria, 2011), such as vision problems, hearing loss, memory loss or arthritis. In addition to the pain, arthritis can make joints stiffer (NIH, 2016), which can make it more difficult to grasp things. In fact, statistics indicate people have increasing problems with walking, making rotational movements with their hands, and manual dexterity as they age (Statistik Austria, 2007, p. 24). Many of these physiological changes start quite young, when people are in their 40s, including presbyopia (age-related vision problems) (Martin, 2016a), which makes it hard to focus on things that are close, memory problems (American Psychological Association, 2006) and arthritis (NIH, 2016). In addition, the incidence of disabilities increases, such as age-related macular degeneration, which can cause blindness, diabetes, which can lead to amputations, and dementia, which leads to mental losses. Thus, there is increasing variability of physical, sensory and mental function between individuals (Gregor et al., 2002).

In terms of physical or motor disabilities, statistics show that even a large proportion of people between 55 and 64 in Austria have some sort of chronic health problems (Statistik Austria, 2011): 20% have problems with their arms or hands, 28% with their legs or feet, 42% with their backs, 29% have heart problems. These numbers increase with age, so that 68% of people over 60 have problems with mobility, even though only 6% require a wheelchair (Leitner and Baldaszti, 2008). Even more striking, 40% have multiple limitations. There is also an increase in chronic health conditions, including high blood pressure, diabetes and cancer, which can also make it difficult to climb steps, lift or even stand (Barrett et al., 2010, ch. 1). Reduced mobility may also mean that the differences between activities done one day and the next are fewer, making life more monotonous.

Compared with younger people, more older people with a disability report that they have been treated badly because of their disability (Leitner and Baldaszti, 2008). Thus, one must remember that people with disabilities are people first, and be aware of labels such as “the disabled,” as many people find such terms discriminating (Firlinger, 2003, p. 23). Research indicates that people with disabilities of all ages in general report being as happy as others, even if it difficult sometimes (Hoppe, 2013). This is not necessarily a paradox: the effect of a disability may be smaller than people realize from the outside, plus people adapt to new circumstances and put focus on other things (Hoppe, 2013).

The senses also decrease with age. Of people over 60 (Leitner and Baldaszti, 2008, p. 30): 23% have vision problems and 17% have hearing problems. Over 30% of these limitations are classified as serious. There may also be losses to other senses. In fact, 62% of people over 80 have a decrease in their sense of smell (Boyce and Shone, 2006). This may mean people are not longer able to detect smells like urine on their clothes that others find unpleasant, but the effects can be even be life critical; for example, if

a gas leak cannot detected (Martin, 2016a). More concerning is the loss of taste, often caused by illness (Boyce and Shone, 2006). This can cause people to put too much salt on their food or not to eat enough, which can in turn lead to other health problems. But it also means reduced enjoyment - food doesn't taste as good, and the flowers don't smell as good as they used to. A decreased sense of smell and taste may also be related to increased anxiety and depression (Boyce and Shone, 2006).

The mind and memory also change as people age and can bring new challenges. The brain starts to shrink and there is reduced blood flow. People have to work harder at organizing activities. And this can also affect eye-hand coordination. It can also make it more difficult for people to remember recent episodes, forming new memories and speaking fluently. (American Psychological Association, 2006)

Dementia is another health problem related to aging, though perhaps less prevalent than many think. In other European countries, studies show approximately 6.5% of people over 65 have dementia (Langa, 2015). Many of these people need to live in care homes - in fact, in the UK, two-thirds of the people in care homes have dementia (Age UK, 2014), perhaps distorting the impression of how prevalent dementia is. The rates of dementia are actually decreasing, even though people are living longer (Langa, 2015; Matthews et al., 2016). This is attributed to better medical care for heart problems that increase the risk of dementia, but also higher levels of education, which are thought to a give people a "cognitive reserve" (Langa, 2015).

These physiological issues are important and mean not just homes, but also public places and things people interact with there need to be accessible; for example, the check-out counters at shops and automated teller machines. The resulting social isolation if people cannot get out and about and do things is often overlooked, though it is important for older people (Peek et al., 2014). In addition, there are the aforementioned associated health problems that result from isolation. Even though Austria was one of the first to sign the *Convention on Rights of Persons with Disabilities* of the United Nations (UN) in 2008, many things are still not accessible, in part because companies are not required to adhere to these rules in product design. Even the rules for accessible buildings were only binding from 2016.

But more important, 59% of people over 60 reported that they sometimes or always have problems in their own homes due to disabilities (Leitner and Baldaszti, 2008, p. 43). Since the rate of decline also increases significantly (Gregor et al., 2002), someone who is fine one year could be in a significantly different situation the following year - and be ill-prepared for it.

The changes that people experience as they age and the limitations resulting from them make it important to look at ways to support older people in their everyday lives.

2.2 Supporting older people

To understand how to help support older people, it is important to understand more about their requirements and look beyond their physical and mental status (Blythe et al.,

2005). In the following, ways to enable older people to do the things they need and want, as well as the potential of new technologies to support this are described.

2.2.1 Assistance for older people

People living independently needing some sort of assistance may rely on people to help them. These may be informal carers, including people who live with them (i.e. partners, children, and others), children, other family members, neighbors, friends, or other volunteers (Jacobs et al., 2016). There are also professional carers or care services, which may be paid for publicly or privately (Jacobs et al., 2016), such as the Caritas or Volkshilfe in Austria that provide care services in private homes. Carers like these may perform a variety of tasks, including *personal care*, e.g. bathing, *domestic activities*, e.g. preparing meals or cleaning, *nursing care*, e.g. changing bandages, *administrative tasks*, e.g. support with financial issues, and *transportation* (Jacobs et al., 2016). Furthermore, there are services like meals on wheels (Jacobs et al., 2016) that save people having to shop and cook. However, family members may view people as needing more help than they view themselves needing (Wagner et al., 2012).

If this type of help is not available or does not suffice for people to continue living independently, there are residential geriatric care homes. These include *assisted living* units and nursing homes. Whereas in *assisted-living* units people have their own apartments and can even cook independently, but only have limited assistance available, for example, for bathing; *nursing homes* provide long-term round-the-clock support, including medical care (AARP and NAC, 2015; AECRO, 2017). In 2013 in Vienna (Stadt Wien, 2013), most people living in geriatric care facilities were between 75 and 89, though some were under 50. Over two-thirds of people living in these facilities were women and just over 15% were married, though not all of their spouses lived with them in the care facility. As mentioned previously, a large proportion of residents have dementia (Age UK, 2014). Life in a care home is not necessarily quiet - there may be numerous interruptions: for cleaning, meals, tea breaks, organized activities, being taken to the toilet (Wallace and Lindley, 2015).

Some people view sending older family members to a care home as a last resort, and many older people want to stay in their own homes as long as possible (Wagner et al., 2012). In fact, in the United States 73% of people over 45 report wanting to do so, with the number wishing to do so increasing with age (Keenan, 2010). People living in their own houses do report being more active (Bowling, 2008), but this could relate to the level of health required to live independently. However, when it is no longer possible to do so, a multi-generational living situation may not be realistic. Families may not live nearby, and moving people to a new environment may separate them from their social networks and effect their sense of isolation (Blythe et al., 2005). Furthermore, whereas in the past women often cared for older relatives, with more women working outside the home, they have less capacity to do so (WHO, 2015, p. 12). Though some believe the problem of caring for aging relatives is restricted to Europe and the United States, this is increasingly becoming a problem also in other regions that have strong traditions of

multi-generational living situations, including China, India and Africa (Eisenberg, 2015; WHO, 2015).

2.2.2 Assistive Technology for older people

Assistive Technologies (AT) refers to technology which assists people to overcome limitations on their own, whether these limitations are physical or cognitive. It can be used exclusively for rehabilitation or during regular life; for example, to detect critical situations, to support mobility, communication, and Activities of Daily Living (ADLs), such as eating, bathing and housework. AT is as diverse as the breadth of possible disabilities and human activities; for example, crutches, hearing aids, screen readers and home automation. AT assists people in doing what they want and need to do and as such promotes independence and can also help them participate in society. In the area of Information and Communications Technology (ICT), a distinction is sometimes made between augmentative technology and alternative technology. Whereas *augmentative* technology makes it easier to do things using the standard mechanisms, for example, "sticky keys" to enable a person to enter key combinations with a single finger or special mouse designs; *alternative* technologies use different abilities to complete the task, for example, voice input with speech recognition instead of a keyboard (e.g. Vanderheiden, 2002).

The features of age-related disabilities may differ from the forms experienced by younger people with disabilities that affect the same faculty, so that specialized tools may be required. For example, presbyopia, the age-related vision problems mentioned previously, affects the ability to focus on things that are close, but does not exclude also having problems seeing in the distance, thus requiring multi-focal lenses (Martin, 2016a) not usually needed by younger people with vision problems. Similarly, presbycusis (age-related hearing loss) affects not the full range of hearing, but primarily the high frequencies and filtering out background noise, which can affect understanding conversations (Martin, 2016a).

Furthermore, the extent and number of limitations are likely to worsen as people age (Gregor et al., 2002). This can be very challenging for people used to being able to do things independently or who have a solution that "works" for them. Depending on informal carers may not be realistic, as more women are working outside the home and also because due to increasing life spans, children of the oldest will be retired themselves and may not be able to help (European Commission, 2009, ch. 4). If every person over the age of 80 needed to be put in a geriatric care facility, the costs would be prohibitive, especially as the proportion of working people supporting the costs is shrinking (European Commission, 2009). Even if professional carers are needed, the cost of care in the homes of the "beneficiaries", as older people are termed in the report, is lower (European Commission, 2009, ch. 4).

In Europe the term AAL is used for assistive ICT-based technology specifically aimed at supporting older people in their own living environment. AAL initially stood for "*Ambient* Assisted Living", but this later changed to "*Active* and Assisted Living". This term is used both within the context of the AAL Programme of the EU that provides

funding, but also elsewhere; for example, by the German Association for Electrical, Electronic & Information Technologies (VDE). Other terms used include *aging in place*. The concept of AAL is to extend the time people can live in their own homes and reduce the resources required for care, by providing technology that supports older people and carers, or that enhances security (AAL Joint Programme, 2017). The initial focus on technology has shifted to more self-empowerment with the name change from *Ambient* Assisted Living to *Active* and Assisted Living (Aumayr, 2016). A recent review found the areas that have been targeted in practice are: being dependent on others for everyday life, risk of falling, chronic illness, dementia, social isolation, depression, personal welfare and problems with medication management (Khosravi and Ghapanchi, 2016).

Based on the demographic changes in Europe (European Commission, 2009) mentioned in Chapter 1, various funding programmes were introduced to encourage development of technologies to support this goal. This includes national programmes, such as the the Austrian bmvit programme *benefit*, the German BMBF focus on "Altersgerechte Assistenzsysteme" in the IKT2020, the British "Preventative Technology Grant" for telecare services and the AAL Programme of European Union (EU) mentioned previously. The AAL (Joint) Programme was started in 2008, and specifically encourages SME entering this field. In all, there has been significant investment through these grants. Despite the goal of getting systems to the market quickly (Busquin et al., 2013, p. 7), in 2013 the evaluation report of one funding programme concluded that the systems on the market were still restricted to a few niches (Busquin et al., 2013). Perhaps due to this, new funding schemes were initiated, both at the national and EU levels. For example, the AAL Programme was extended, this time specifically aiming to get more systems to market, and the national "The Long Term Care Revolution National Challenge" in the UK (part of innovate UK) was launched. This indicates that there is still a need for successful AAL systems.

2.2.3 AAL systems

This section describes the types of AAL systems available and gives some specific examples of systems that have been developed. Since sensor-based monitoring systems are the focus of this thesis, these are given the most attention.

Types of AAL system

There are various categorizations of AAL systems. For example, Eisinger and Eisinger (2011) used the following categories based on features: convenience (e.g., turning on lights), safety (e.g., fall detectors), telehealth (e.g., measuring blood pressure and blood sugar), communication (e.g., video-calls) and sensors (e.g., activity monitoring). Others have suggested slightly different categories; for example, differentiating between monitoring and therapy with telehealth (Chan et al., 2008), or integrating safety aspects either with sensors and telehealth/therapy (Chan et al., 2008) or telecare (Sanders et al., 2012). In comparison, Khosravi and Ghapanchi (2016) seem to define the categories more from the point of view of technological aspects, but with some overlaps between categories: ICT,

robotics, telemedicine, sensors, medication and video games. In Austria, an attempt has been made recently to develop a comprehensive taxonomy specifically for AAL systems (T*AAL*XONOMY) (Leitner et al., 2015). The top level categories here are: Health & Care, Living & Buildings, Safety & Security, Mobility & Transport, Work & Training, Vitality & Abilities, Leisure & Culture, and Information & Communication.

For this research, *telecare monitoring systems* of are particular interest, which in the T*AAL*XONOMY would fall under Safety & Security. This technology is relatively widespread and can automatically call for help in case of an emergency (Blythe et al., 2005, p. 673). Some systems in this category are quite simple, for example, a sensor with a threshold to detect when the gas on a stove has been left on to support people with mild dementia; others can involve complex algorithms to monitor ADL and react to exceptions to normal patterns, for example, if someone doesn't go to bed or shows no activity during the day, when they are usually at home. These systems may be used within private homes or assisted-living units in the formal care sector (Turner and McGee-Lennon, 2013). In addition to the person being monitored, there may be a person who checks the status or responds to alarms: a professional carer, a family member or a call center for emergency services (Turner and McGee-Lennon, 2013). Monitoring can also benefit long-term well-being: information about changes to patterns in daily life can in some cases be used by health care professionals to assess changes, to raise awareness in the individual or even to change behavior (Lee and Dey, 2015).

Some argue that these types of monitoring system may not really constitute care, as they do not support personal interaction (Mort et al., 2012), but they are important, as they may be attractive to people not otherwise open to care (Draper and Sorell, 2013). They can give older people confidence because they know the system will automatically call for help in case of an emergency (Blythe et al., 2005, p. 673), and also give them peace of mind (Turner and McGee-Lennon, 2013, p. 24). They can also benefit carers: by recognizing crises they may also give peace of mind to family carers (Mynatt et al., 2000, p. 69) and support formal carers with routine monitoring (Turner and McGee-Lennon, 2013, p. 25).

Some examples of systems

Numerous systems have been developed in the area of AAL, though not all were intended for the market or successful in getting to market. In the following, a few systems are described to show the breadth of what has been attempted and accomplished.

Based on the overview of telecare in Turner and McGee-Lennon (2013), in the following the systems are grouped as follows:

- *systems that support well-being and health*, e.g., assistance with ADL, reminding people to take medication, robots to fetch things;
- *telehealth systems*, e.g., monitoring blood pressure or providing contact with health care professionals; and
- *telecare monitoring systems* to increase security, e.g., fall detection.

- *other systems for older people*, including the more recent emphasis on *"independent living technologies and life-enhancing technologies – umbrella terms encompassing a blend of telecare, telehealth, and mainstream technologies that support wellbeing and health"* (Turner and McGee-Lennon, 2013, p. 22)

Telehealth is included here, as telecare and telehealth are closely linked (e.g. Blythe et al., 2005, p. 681). *Telehealth* looks more at medical monitoring or treatment, while *telecare* is related to alarms (Greenhalgh et al., 2013).

Systems that support well-being and health at home There is a broad variety of systems that support ADL (Leitner et al., 2015). Simple examples are home automation to support actions that normally require physical effort; for example, turning off lights or seeing who is at the door without having to get up. Other systems may support memory; for example, reminders about appointments.

Some of the more complex examples of systems supporting people in their homes involve robots. These can help people with physical limitations; for example, to fetch things, to pick things up from the floor, or even feed them. One of the early AAL Programme projects investigating the potential of robots, DOMEO, started in 2009 (AAL Programme, 2015). Toyota announced their Human Support Robot (HSR) in 2015, which can fetch objects (Kalogianni, 2015). Because these solutions promise to be very expensive, there have been initiatives to design cheaper alternatives, such as the care robot called the Hobbit (Fischinger et al., 2016).

Another area of interest is supporting mobility. In this category there is the iWalkActive: an "off-road" walker that is combined with a tablet to support people in finding and going on walks appropriate to their level of mobility (Morandell et al., 2013).

Communication systems can also support living independently, as these can reduce the sense of isolation and provide a way for people to get assistance (e.g. Blythe et al., 2005, p. 674). Older people generally prefer more focused communication and are willing to take the time for it, but do not want to be a bother or disturb others (Lindley et al., 2009). Thus, they may prefer to use a telephone to communicate in more detail and asynchronous mediums like e-mail to communicate with those in other time zones (Lindley et al., 2009).

Telehealth systems For people with health conditions, important physiological values may be monitored as part of using telehealth, such as measuring blood pressure for people with heart problems or blood sugar values for people with diabetes. These readings can be used to generate an alarm, or just be recorded. Furthermore, the results may be reserved for private use or may be sent directly to health care professionals. In fact, current European care delivery models center on these types of solutions for people with diabetes, Chronic Obstructive Pulmonary Disease (a type of lung disease) (COPD) and congestive heart failure (United4Health, 2016).

Solutions available on the general market can be used for telehealth for older people - even those without known health problems. For example, many modern scales include

Bluetooth wireless technology, which enables them to be connected to a Personal Computer (PC), tablet computer or even a smartphone. The data about weight is an important indicator for older people, as sudden weight loss may be a sign of emerging dementia (American Academy of Neurology, 2009), and not eating enough can lead to malnutrition, a compromised immune system and a deterioration of other medical conditions (Boyce and Shone, 2006).

Other telehealth solutions include video calls with doctors for a remote consultation or diagnosis (Turner and McGee-Lennon, 2013). Even though there are limitations, these systems can save time, effort and money required for travel, especially when a long journey would be necessary otherwise (Turner and McGee-Lennon, 2013).

There are also systems that are on the border between telehealth and supporting people living independently; for example, pill boxes. There are different types of pill boxes; for example, ones that remind people to take their medication at the appropriate time (Svagård and Boysen, 2016), or ones with embedded sensors that can detect whether people have taken their medication (Lee and Dey, 2011). In the system from Lee and Dey (2011), the data was visualized for the older people to reflect on, rather than passing it on to medical practitioners. This led some people to consider making changes to routines in an effort to do better when there was an unexpected discrepancy between how regularly they thought they took their medication and what was recorded by the system (Lee and Dey, 2011). Systems like this can support health, even though they are independent of carers and act only locally, rather than at a distance as implied by the term *tele*health.

Telecare monitoring systems Telecare monitoring systems are also quite broad. Turner and McGee-Lennon (2013) divided these into three generations. The simplest devices from the first generation include sensors with little logic; for example, emergency buttons and smoke alarms, or systems to detect whether someone has left the gas or water on, and automatically turn these off (Turner and McGee-Lennon, 2013). The second generation uses sensor data to generate alarms. For people with dementia, these may integrate position tracking, either using RFID (Radio Frequency IDentification) tags to detect when they leave the flat, or using location data; for example, using a mobile phone (Ly et al., 2016). More complex are fall monitors, which can be based on various technologies; for example, cameras to detect movement typical of falls (Zhang et al., 2012), sensors detecting vibrations of someone hitting the floor or worn devices with accelerometers (Turner and McGee-Lennon, 2013). The third generation of telecare monitoring systems is more focused on quality of life (Turner and McGee-Lennon, 2013); for example, by integrating services that allow older people to get advice or link to virtual communities. Because they are more complex and also newer, systems of the later generations are of particular interest, i.e., monitoring systems which use sensor data to generate alarms that can be combined with services that aim to improve quality of life.

Activity monitoring systems can be quite complex. These can be used to detect whether someone has not moved for a longer time and may need help, but can also be used to detect specific activities, such as whether a person has gone to bed or whether they have used the bathroom, something that can be relevant for people with dementia

(Chen et al., 2005). Errors in the detection algorithms can lead to missed alarms and/or false alarms (Wagner et al., 2012, p. 33), for instance, a false alarm could be generated if someone goes shopping or sits very still while watching a film, or real emergencies may *not* be detected, because the person is normally gone at that time of day or the dog is detected instead. Reliability must be considered, as people may come to rely on these systems (Greenhalgh et al., 2013, p. 93).

A variety of technologies can be used to determine whether there has been any activity; for example, motion detectors, temperature sensors, and sensors installed in beds or on kitchen appliances (Wagner et al., 2012). Built-in systems can use the existing power-line wiring, or computer networks (Turner and McGee-Lennon, 2013). If the sensors need to be built in, this can entail substantial effort to install. Thus, in homes they are typically wireless, using either radio waves or infrared (Turner and McGee-Lennon, 2013). Since the technology being integrated is so diverse, there has also been an attempt to develop open platforms for AAL, such as the universAAL platform that was built with a consortium including the TU Wien and AIT (Austrian Institute of Technology) (Hanke et al., 2011).

One example of a monitoring system is the one from the company Dutch Domotics in the Netherlands (AAL Programme, 2015), an outcome of the Rosetta project, which was funded by the AAL Programme (AAL Programme, 2015; Hattink et al., 2016, p. 20-21). Other systems provide a lower level of detail, but allow for reciprocal data exchange between older people and family carers; for example, a picture frame that uses images such as butterflies to symbolize activity (Mynatt et al., 2001), the Family Planter that uses optical fibers in a planter to display presence to distant family members in an unobtrusive way (Itoh et al., 2002), or a clock that combines activity data and active communication, e.g., "I'm up" (Riche and Mackay, 2007).

Other systems for older people Many systems combine monitoring with other features; for example, Tunstall Assisted Living and Independent Living solutions, which include both the remote control of devices and safety monitoring. Other solutions may include some sort of communication features; for example, video call functionality that can also be used by people with disabilities (Stefanov et al., 2004). These types of systems are sometimes referred to as domotics or smart home systems and may also be targeted at younger people. An early example of this type of system is PAUL from the German company CIBEK, which was piloted in 2007 (Spellerberg and Schelisch, 2009) (see Figure 2.2).

There is also a host of ICT aimed at older people that is not strictly assistive; for example, systems that support communication or civic involvement, and memory games. This includes terminals for nursing homes that provide a combination of information and entertainment services (Dale et al., 2016), or, for people still living at home, interactive games that can be played with people who are not close by that can help reduce social isolation (Doppler et al., 2016). In addition, there has been research into different interaction methods; for example, to see if mid-air gestures would easier for older people without computer experience to learn and use (Cabreira and Hwang, 2016).

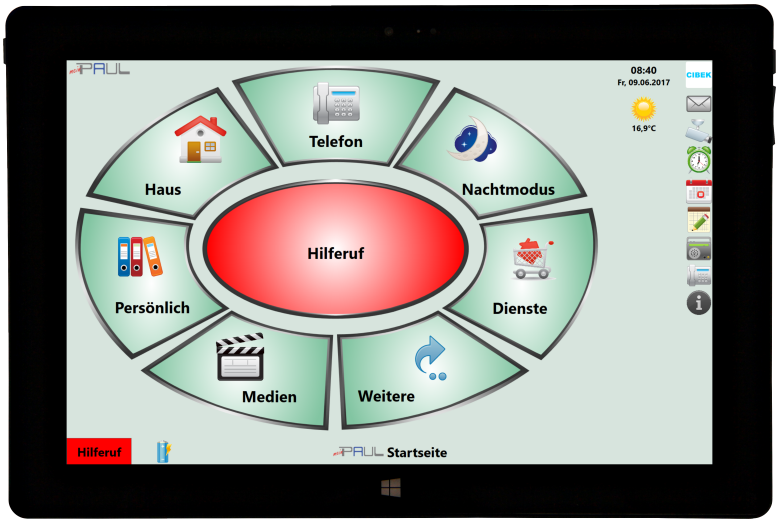


Figure 2.2: AAL system PAUL from CIBEK (used with permission)

Although these do not support people living independently, there is also AT that is designed to support carers who work with older people. One example is the RIBA II (Robot for Interactive Body Assistance), which is shaped like a bear and can lift people from a bed to a wheelchair. This can reduce the physical strain for carers, but perhaps also reduce the number of carers required. Although it performs functions much like a forklift, because it is for use with people it has a soft surface and sensors to prevent injuries, and also needs to maneuver differently and work autonomously (Mukai et al., 2010).

2.2.4 Benefits of AAL systems

There have been pilots of these more comprehensive solutions that include telecare monitoring features like those being studied in this thesis, both in Austria and elsewhere in Europe. In Austria there have been six test regions: *ModuLAAr* starting in 2012 (Programm benefit, 2014), and the more recent *RegionAAL, smart VitAALity, WAALter, West-AAL* and *ZentrAAL* which were still running in 2017 (AAL Austria, 2016). Each focuses on a different region, but may also differ in other ways; for example, although both *ModuLAAr* and *West-AAL* focus on smart home/monitoring features, *ModuLAAr* featured assisted-living units in Burgenland and *West-AAL* includes private residences in Tyrol (Programm benefit, 2014). The EU funded *REAAL* included pilots in five countries from 2013 to 2016 (Programm benefit, 2014). In the UK, there was the Whole System Demonstrator (WSD) (Department of Health (UK), 2011), the first large trial designed to evaluate telecare systems over a longer period of time. It was not a system in its own right, but included a variety of existing systems, including telehealth and telecare. The project was completed in 2011 and included over 6000 older people, half of these patients with chronic conditions such as COPD, heart failure and diabetes, over a period of three

years (Department of Health (UK), 2011).

Generally, the reports regarding the benefits of AAL systems are somewhat mixed. As recently as 2016, some researchers concluded that more research about their effectiveness was needed (Khosravi and Ghapanchi, 2016).

There are potential benefits for older people. Some potential benefits mentioned by the users of telehealth and telecare systems relate to broader goals, such as independence (Sanders et al., 2012) and the wish to continue living at home (Peek et al., 2014). Himmelsbach et al. (2017, p. 15) identified different ways in which AAL systems in the category security, which include sensor-based monitoring systems like those being studied in this thesis, can support the quality of life, for example, by increasing autonomy, life satisfaction and the feeling of security, while also potentially saving lives.

From the perspective of the social systems, there are also benefits. AAL systems that allow people to stay in their own homes have long been thought to have the potential to increase the quality of care (Mynatt et al., 2000). In addition, the aforementioned study by Himmelsbach et al. (2017), indicates that monitoring systems may also potentially reduce the amount of care needed, number of emergencies, hospital stays, etc.

There is some evidence of financial benefits for health care systems. Barlow et al. (2007) did a review of the literature on telecare systems evaluated the benefits of 98 publications covering systems for vital sign monitoring, safety systems (e.g., fall monitors) and systems to provide information and support (e.g., via telephone and internet). To ensure sufficient quality, the authors included only randomized controlled trials of any size and observational studies with 80 or more participants, thus excluding many studies. They concluded that the most effective interventions with respect to reducing health service use are automated vital sign monitoring and systems providing information/support. There was insufficient evidence regarding home safety systems, such as the monitoring systems that are the focus of this research. Since then, the Whole System Demonstrator Trial in the UK, the largest randomized trial for telecare and telehealth, provided a possibility for further studies. First results, based on the 3000 older patients with chronic conditions who were involved in the trial for at least twelve months, showed a striking reduction in the mortality rate using telehealth, as well as significant reductions in the number of visits to the emergency room, admissions to hospital, both elective and emergency cases, and days spent in the hospital (Department of Health (UK), 2011; Steventon et al., 2012). There is, however, some question whether the randomized-control model used to prove the effectiveness of medication is appropriate for comparing the situation with and without a clinical intervention (Pearce et al., 2015). The situation is even more complex when it comes to telehealth, as it is hard to find measures that include the breadth of benefits, but also to generate generalizable results, due to the great diversity of contexts and technology (Bergmo, 2014, pp. 9-10). Greenhalgh and Russell (2010) also argue qualitative reviews are more suitable for health systems.

Despite possible financial benefits, the situation with cost effectiveness is unclear (Barlow et al., 2007; Bergmo, 2014). One difficulty is that that there is no agreement on which measures should be used in evaluating costs related to telehealth applications, i.e. savings or effectiveness (Chan et al., 2008, p. 73). Some argue that the benefit to

health systems and society should be used (Chan et al., 2008, p. 73), while others say aspects beyond health that affect the individual might need to be considered, such as increased access to information, time saved and fewer trips for medical visits (Bergmo, 2014, p. 9). When looking at the outcomes for people with long-term health problems, such as heart problems and diabetes, no significant difference in cost effectiveness was found with the Whole System Demonstrator - in fact, the costs were higher if the costs of telehealth were considered (Henderson et al., 2013).

Furthermore, there have not been comprehensive studies on the effects of monitoring systems for people *without* health problems. Thus, it is not known whether people *can* actually stay at home longer due to detecting problems and enabling faster interventions (Wagner et al., 2012). Other aspects that may be relevant are whether people also feel more secure in the long term, which sensors are most effective in which situations, which features are used most, and whether the benefits outweigh the potential loss of privacy in practice.

There is also little evidence when it comes to individual benefits. More conclusive results are needed regarding the effects of modern communication technology on loneliness of older people in general, as there is some indication that the initial increase in feeling connected socially may decrease with time (Chen and Schulz, 2016). When looking at the quality of life and the psychological well-being of individuals with long-term health problems, no significant difference, either positive or negative, was found between having telehealth and normal care (Cartwright et al., 2013). People may in some cases be willing to accept a loss of privacy associated with sensor data if the need is sufficiently great and it enables them to stay in their homes (Wagner et al., 2012). However, *"community-dwelling older adults do not look exclusively at technology as a means to enable aging in place; they also consider alternatives such as help by others or the use of their current technology"* (Peek et al., 2014, p. 246). Although there are models for comparing different solutions (e.g. Chessa et al., 2010; Himmelsbach et al., 2017), these do not allow for the comparison of technical and non-technical alternatives that older people consider.

This shows that the benefits of AAL are a complex issue. Given the rate of change of technology, by the time the benefits have been proven reliably, new technologies will hopefully be available, which then also need to be proven.

2.3 Limited success with AAL technologies

Despite the investments and potential benefits, uptake of such technologies has been slow (Sanders et al., 2012). This is also supported by the fact that as described previously, new funding programmes were launched that continue to encourage investment in 2014. The goals of the new phase of the AAL Programme point to some of the problems: *"To intensify the market orientation across the Programme, giving more focused attention to aspects such as interoperability, standardization, harmonization, and transnational transfers so as to make results sustainable and achieve impact."* (Busquin et al., 2013, p. v). In 2014, a project was started in Austria to make AAL more visible and also to measure the effectiveness (Programm benefit, 2014).

In practice, uptake has been slow even with systems that make it to market. In the Whole System Demonstrator mentioned previously, it was hard to find people to participate, and even among those willing to discuss the possible installation, a high percentage did not participate (36%) (Sanders et al., 2012). Peek et al. (2016) lists some factors that could have an influence on this slow uptake: older users are not adopting the technology, there is lack of proof of the benefits, technical incompatibilities between vendors and lack of sustainable business cases. The large number of stakeholders, such as the older people, carers, managers of care organizations and policy makers, each with different goals complicates solving these problems (Peek et al., 2016). And those who do use these systems may perform some sort 'bricolage' or pragmatic customization to make them better fit their needs (Greenhalgh et al., 2013). Some aspects related to adoption are described in more detail below.

2.3.1 Experience with technology

One complication could be the amount of experience older people have with technology; even with monitoring systems, having control over them is important (Turner and McGee-Lennon, 2013, p. 27).

Although, older people may be perceived as being less technologically experienced, even very old people may have worked with computers in their work. Lindley et al. (2009, p. 1696) found that most older people who had used e-mail had been exposed to it through their work. A history of computers (Randell et al., 2003) can give us the facts to determine who *might* have used a computer in their work. Certainly, starting with the earliest computers, in the 1940s there were people who maintained and programmed computers. People with less technical professions may have also used them, as smaller computers like the PDP were wide-spread by 1965. Assuming someone started working with these computers just after matriculation at the age of 18, there are people who are now retired who spent their entire working lives with computers. Given that personal workstations were widespread in the 1980s, people who were working a desk job in an insurance company when they retired in 1985 might have used a computer for work. They would now be in their late 90s.

The United Nations provides data about how widespread the usage is (United Nations Economic Commission for Europe, 2015): the number of people using computers in Europe is rising quickly (see Figure 2.3). Now more than half of people between 55-74 have used a computer. In fact, more recent research supports that older people are capable of using digital technologies (Tonolli et al., 2015; Durick et al., 2013).

2.3.2 Problems with acceptance

Another difficulty is the *acceptance*, i.e., whether users accept and will use a technology. This is used as a measure of success for custom systems (Keil and Carmel, 1995), but can also be used to explain why a system is not being used or sold. Studies on the acceptance of AAL have been done qualitatively, quantitatively, and using mixed methods (Peek et al., 2014).

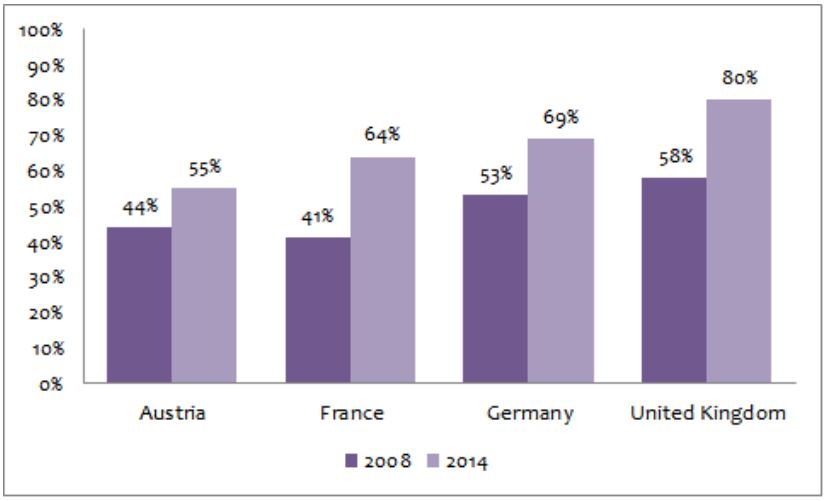


Figure 2.3: Computer usage by people aged 55-74 (source: UN)

Quantitative technology acceptance research is dominated by Davis's *Technology Acceptance Model* (TAM) from 1989 and the *Unified Theory of Acceptance and Use of Technology* (UTAUT) that was derived from TAM by Venkatesh, Davis and others (Peek et al., 2014). The main two factors of TAM are Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), which then decide whether people intend to use the system and in turn whether the system is actually used. This model has been tested in a variety of environments, including health care (Money et al., 2015). UTAUT, which extends the TAM model with additional factors such as gender, age, experience, whether it was used voluntarily and social influence, predicts future use up to approximately 70% (Peek et al., 2014). Satisfaction is only included in a later version of the model, which has not yet been tested with older people. A model specifically for older adults and health technology that has been shown to have a high level of validity includes the factors Doctor's Opinion, Computer Anxiety, and Perceived Security (Cimperman et al., 2016). One of the criticisms of these models is that they do not differentiate sufficiently between evaluations before a technology has been used and after the person has used it for a longer time (Peek et al., 2014).

When it comes to older users accepting technology for aging in place, these quantitative acceptance models do not seem to be sufficient. Peek et al. (2014) found that usefulness is particularly important, which is also one of the most important factors in the original TAM model, but says that "usefulness" alone does not adequately cover the benefits these technologies provide. A more recent study found the effort to learn the system, which is not part of these acceptance models, was actually more important for older people (Cimperman et al., 2016). Furthermore, the impact of aspects such as age and level of education, which are part of the newer UTAUT acceptance model, are not clear with older people (Peek et al., 2014). Peek et al also point out that more data is needed about technologies other than communication and assistive technology.

Results from *qualitative* studies of technology for aging in place give a more varied picture of aspects important to acceptance and barriers to adoption. There have been a number of studies, including a review article of technology for aging in place by Peek et al. (2014), a study of smart home systems for older people in Austria (Eisinger and Eisinger, 2011; Mies, 2011, p. 60), a study of people who either did not want to participate in a trial of the Whole System Demonstrator or who withdrew from it (Sanders et al., 2012), and a recent review of literature about AT for older people (Yusif et al., 2016). Most of these were based on impressions *prior* to having the system installed. All mention:

- Concerns about usability
- People being unsure of the need or benefits for themselves (at least at present)

Other aspects mentioned were:

- Concerns about privacy (Peek et al., 2014; Yusif et al., 2016)
- Threats to self-care: people were concerned they would become "dumb" (Eisinger and Eisinger, 2011; Mies, 2011, p. 60) or lazy (Sanders et al., 2012) from having so much support
- Fear of forgetting or losing the technology (Peek et al., 2014)
- Stigma of using these technologies (Peek et al., 2014; Yusif et al., 2016)
- Threat to independence, loss of autonomy (Sanders et al., 2012; Yusif et al., 2016)
- Disruption to existing services (Sanders et al., 2012)

Many older people report wanting to remain in their homes (Peek et al., 2014). There is some indication that they might be willing to use monitoring technology if it would allow them to remain in their own homes longer, though here again mention is made of other people (and not themselves) needing it (Wagner et al., 2012). People may resist having it installed, because they do not want their home to look like a hospital (Blythe et al., 2005). However, there seems to be pressure to use, e.g., from carers and family (Peek et al., 2014). People may agree to having it installed if they can diminish the concerns of their children (Luijkx et al., 2015).

Older people are concerned about the usability of these systems. At the same time, there is some indication that older people are reluctant to ask their children for help, even though they perceive their children as being better at using computers (Luijkx et al., 2015). If the device is designed for older adults, this can be particularly embarrassing. Interestingly, people are not reluctant to ask their grandchildren, and grandchildren can even influence acceptance through their enthusiasm (Luijkx et al., 2015). Perhaps due to these concerns, when asked, almost 69% of older users preferred the more familiar television (TV) with a remote control to the touchscreen (Eisinger and Eisinger, 2011).

Using a system or not using it is not as unambiguous as it sounds (Baumer et al., 2015). Some people may never have the opportunity to use something, others may choose

not to use it and yet others may use it and then stop. Looking at the reasons systems are not used can provide valuable information: usability or fears related to it may influence whether people use a system or continue to use a system, but there are also other factors at work (Baumer et al., 2015; Greenhalgh et al., 2013).

Cost has also been shown to be a concern for many users in some countries with nationalized health care (Eisinger and Eisinger, 2011; Sanders et al., 2012). In 2011, older people in Austria were on average willing to pay only €244 as a one-time fee – or €63 per month (Eisinger and Eisinger, 2011). People over 75 are more likely to suffer from financial hardship, so that smart homes may be only available to people who are relatively wealthy (Blythe et al., 2005).

The costs are particularly important, as the benefits of the systems do not seem to be clear to many - at least for themselves.

2.3.3 Functional issues

Since usefulness is a factor in acceptance models and the qualitative studies found that people are hesitant to adopt them because they are not convinced that they need them, it is also relevant to understand which functions are of interest to older people.

A study done in Austria asked 80 people between the ages 59 and 94 (average 76) which features available in some of most widespread home automation systems they would be most willing to use (Eisinger and Eisinger, 2011). Most of the participants reported not needing assistance in daily life and had not used this type of system in their own home. Each technology was first explained and then discussed/evaluated before continuing to the next technology. The three features rated most acceptable were *safety features*: checking whether the stove was off, fall detectors and fire alarms. Turning the lights on and off, a convenience feature, was also popular and rated fourth highest. Telehealth features generally had lower acceptance. In practice, gender and computer experience were not found to influence the acceptance of the individual components, as is generally predicted by the TAM acceptance model. The acceptance of vital signs monitoring was not correlated with age, though functions such as controlling the shades were - older people were *less* willing to use them. Furthermore, acceptance was generally lower when asked about the acceptability of having it in their own homes, versus general acceptance of the individual features (Eisinger and Eisinger, 2011, p. 27). Some caution is necessary, however, since some people said it was hard to judge the use.

It is also unclear if the functionality provided by current systems meets people's needs. In practice, systems may not meet the needs of older users without some adaptation (Greenhalgh et al., 2013). This is critical, as others have found that having technologies that meet a person's needs is particularly important for aging in place (Peek et al., 2014; Mies, 2011). Furthermore, it has been shown that the usage of this type of system changes over time (Spellerberg and Schelisch, 2009). Thus, since it is unclear whether the systems meet the needs, also in the long term, and, as described previously, the benefits are also unclear, it is understandable that some people are hesitant to invest.

2.3.4 Some issues relating specifically to monitoring systems

The monitoring systems being studied in this research are different from some other AAL technologies, in part because they include sensors - and a carer, who receives the alarms notifying them that the person may need assistance.

Since monitoring systems are related to health and security, it is essential that they be reliable. There is also the problem of false alarms (Blythe et al., 2005), and who is liable for the disturbed sleep of a relative or the costs of emergency service. The reliability of monitoring systems and number of false alarms can be a problem (Wagner et al., 2012) and requires detailed consideration both of the users and the technology during the design of these systems (Wilson et al., 2015, p. 472).

Especially in monitoring technology like that studied here, there is a tendency to add functions not originally planned that give more control to carers and may reduce the independence of people using these technologies (Draper and Sorell, 2013). This can be almost coercive, particularly if there is no possibility to adapt the system (Mort et al., 2013). This is compounded by the findings of Peek et al. (2014), that there is pressure to use the system in the first place, for instance, if older people feel it will reduce the level of concern of their children (Luijkx et al., 2015).

Monitoring can be intrusive. Others report that having any sort of monitoring is in conflict with maintaining autonomy and privacy, core values of older people, and that it elicits strong feelings in many (Sallinen et al., 2015). Older people also report being afraid of surveillance by strangers (Greenhalgh et al., 2013). Certainly, many people of any age would have a problem with having the sounds in their toilets monitored, a solution that has been proposed for monitoring dementia patients (Chen et al., 2005). However, there are ways that even video data can be masked for more privacy; for example, by replacing camera images with avatars, stick figures or a silhouette, or by blurring or pixelating the images. Some systems even allow the people being monitored to select the representations and choose different representations depending on who is in the picture, what room it was taken in, who is viewing the data, etc. (Padilla-López et al., 2015). Still, as has been shown with smart meter systems, even impersonal data, for example, when appliances are turned on, can generate much information, such as when people are eating, sleeping or gone from home (McLaughlin et al., 2011). Similarly, the data from monitoring systems not only reduces privacy, it could put older people at risk if their presence at home and routines can be determined. However, simply aggregating the data can reduce the number of events that can be recognized and provide more privacy (McLaughlin et al., 2011).

Monitoring systems can also be difficult for people with non-technical backgrounds to understand. *"Many (older people) had a hazy understanding of their assistive technologies"* (Greenhalgh et al., 2013, p. 91) or found the technology hard to judge (Eisinger and Eisinger, 2011). Researchers specifically mention the difficulties of working with intangible concepts with older user groups (Lindsay et al., 2012).

Since the people being monitored provide only "input" to the system through their activities, the people being watched are actually indirect stakeholders (Friedman et al., 2006).

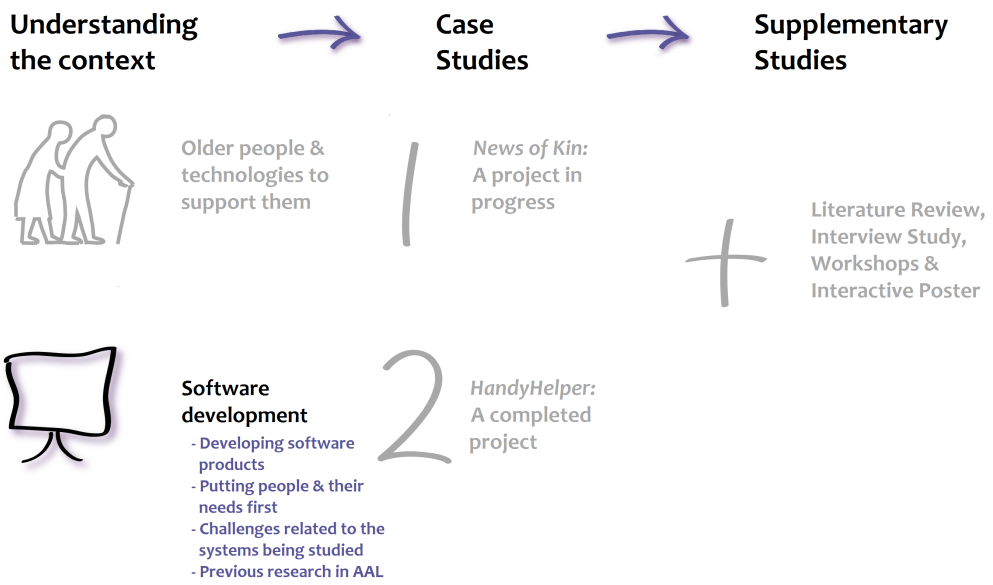
Furthermore, these systems can potentially reduce contact and increase isolation (Blythe et al., 2005), as carers may no longer need to visit as frequently. And yet where many fear the specter of becoming a burden, or being dependent on others, this isolation can be seen as the cost of being independent (Stenner et al., 2011). In addition, these types of systems may enable older people to fulfill their own goals of living independently and relatively autonomously in their own homes longer.

2.4 Summary

Based on the literature, there seems to be a need for monitoring systems that support older people living in their own homes; some governments believe that this is more economical, and many people express the wish to remain in their own homes as they age. With the projected growth in the number of older people, it may not be realistic to provide care homes for all people requiring some sort of monitoring. But despite the investment in the development of AAL systems and the potential market for these types of systems, they are not yet widespread, which may be related to the fact that the benefits have not been proven clearly, that the acceptance is still low, and that the costs may be still be too high. This may be due to decisions made during the development of the systems, decisions that affect aspects older people express concern about prior to buying them, and hence may influence their willingness to invest in them; for example, decisions about design that determine whether the systems are usable for older people, decisions about functionality that determine whether they are perceived to be useful, and decisions about how the systems protect the privacy of older people. However, despite these concerns, the development of these types of systems has not been studied previously. The next chapter will explore the technical view: the development processes behind the development of these systems.

CHAPTER 3

Background: Software Development



This research takes the perspective of Human-Computer Interaction (HCI) and therefore does not merely focus on the system or the users in isolation, but considers both aspects. Since the research investigated what happened during the development process and RQ 3 relates to software *development processes*, it is important to consider software development processes and the challenges developers face.

Software development follows predefined steps: first analyzing what is needed before designing, then developing and finally testing the result (Sommerville, 2007). It can be difficult to meet the high quality requirements for any product, and to be successful on

the market. Many software projects take longer than planned to be completed and the resulting systems are not of sufficient quality, which leads to increased maintenance costs (Dynamic Markets Limited, 2007).

The challenges for the developers also depend on the type of software being developed, thus in addition to examining at the general processes, it is important to consider how monitoring systems for older people differ. As mentioned previously two important characteristics are the complex sensor technologies involved and the highly diverse group of older people who will use them, some of whom have little experience with these types of technologies. Consequently, during the development process of such systems, it is essential to have a good understanding about their needs and the possibilities before committing to a solution.

The following chapter first describes the more traditional software processes, before considering aspects from HCI, where the people who use the system and their needs are given priority. Subsequently, it describes the differences when developing monitoring systems for older people. Finally, some details of other studies in the area of AAL are presented to give a better understanding of what motivated the research and show where it fits in.

3.1 Developing software products

3.1.1 The development processes

The fundamental activities of software development involve *analyzing* the requirements, then *designing* the system to decide how best to solve the problem, th*en implementing* it and *testing* that it fulfills the requirements (Sommerville, 2007). There are many different models of how to combine these steps. Depending on the model, the steps can either be carried out sequentially, as in the *waterfall* model of development, repeated to develop a series of prototypes prior to the final version, as in the *spiral* model, or repeated with multiple planned deliveries, as is the case with the *iterative* and *agile* models (Sommerville, 2007, ch. 4). The analysis is done by analysts, who may be developers or have knowledge about the application domain. It is advisable to start with a smaller number of more qualified people to do the ground work, before adding more people for the next phases (Mayr, 2002, p. 41). The tests usually proceed step-wise: first the individual units are tested by the developers, then more tests are done after parts have been integrated, and finally the complete system is tested (Sommerville, 2007). The final tests of the system may be executed by a person not directly involved in the development. In the *iterative* model, further requirements are planned for inclusion in future versions, but also results from tests and use flow into future versions; the *agile* model has shorter iteration cycles and the requirements are reconsidered more fundamentally with customer input before each new iteration. Even after a system has been completed or delivered, some sort of maintenance is required. This includes fixing errors that have been found, adding new functionality and adapting for changes, such as new versions of operating systems (Sommerville, 2007, p. 493).

There are different types of users and stakeholders for a system - people who have an interest in the system and are affected by it. These stakeholders need to be considered during the requirements analysis (Sommerville, 2007, ch. 4). There are also different groups of users who use the system in different ways. For example, a word processor may be used by someone who works as an office worker at a company or a student. While the office worker may use the system almost daily and needs a standard letterhead, the student may only use it rarely and needs functions like footnotes, that the experienced office worker does not need. If the system is used in a company, there are also other stakeholders, such as the people who select and purchase it and technical staff who manage the updates, etc. These people are also affected by the design decisions.

During the design phase, both the way the system is organized and the appearance are considered (Sommerville, 2007). For this purpose, important details may be recorded; for example, using Unified Modeling Language (UML), a non-proprietary notation (Object Management Group, 2005). UML includes many models, most of which are graphical. These may be split into *structural* models that describe the parts of the system and how they are related statically, models that record the *dynamic* interaction between these parts, and diagrams that record information about the requirements and workflows being supported, such as *use cases* (Douglass, 1998; Object Management Group, 2005).

Traditionally, software is tested against the requirements using both validation and verification processes (Sommerville, 2007)*: validation* checks whether the system includes all the planned functions; *verification* goes deeper and assesses whether it has implemented these correctly and has considered all cases (Sommerville, 2007). Both are necessary: simply because the system runs, does not mean it includes all of the functions it should; moreover merely because the functions are present and work in one case, does not mean the system works in a realistic range of different situations. Validation can be performed by anyone by using the normal interfaces. However, due to the large number of tests that would be required to test every possible condition, it is not possible to test exhaustively (Myers et al., 2012). Thus, *verification* is often done by programmers who know the structure of the code, in order to concentrate on aspects that are most likely to contain errors (Spiller and Linz, 2012). Especially with agile methods, the verification of the individual units may be executed using automated tests, in some cases these may even be written by the programmers before the code (Martin, 2009). Depending on the area of focus, there may also be other standards to be checked. For example, medical systems must also be tested to ensure the safety of patients, e.g., by checking they comply with the international standard *IEC 60601-1 Medical electrical equipment - Part 1: General requirements for basic safety and essential performance,* or the Austrian *Medizinproduktgesetz (MPG).*

In practice, the choice of the model of development is important for people managing the process. Execution risks, including the choice of model, have a significant impact on project outcomes (Wallace and Keil, 2004, p. 71). For this reason these models are still a matter studied by researchers (Munassar et al., 2010). The *waterfall* model is associated with a number of weaknesses in practice (e.g. Munassar et al., 2010), one of the main weaknesses being that problems only become apparent very late in the process (Kleuker,

2013, p. 29) and hence it should only be used when the requirements are well-understood in advance and unlikely to change (Sommerville, 2007, p. 68). A survey of practitioners revealed that projects managed with traditional waterfall methods are perceived to be less successful than those managed with iterative or agile models (Ambler, 2010). With some products, the requirements may not be entirely clear at the start, for example, due to lack of experience with technology or lack of understanding of the application area. Having at least one iteration for developing a prototype is valuable when working with new technologies, because the feasibility can be checked (Kleuker, 2013, p. 94). Having multiple iterations enables teams to react to problems at an early stage and allows for changes in requirements (Kleuker, 2013), and is recommended for small and medium size systems and also for user-interfaces (Sommerville, 2007, p. 69). There is, however, a risk that additional functions that were not originally planned and may not really be needed are added with each iteration, adding complexity and complicating usability, the "creeping featurism" of Norman (1988, pp. 172–174). Good project management can help combat this practice of adding potentially unnecessary functions (Wallace and Keil, 2004, p. 71). Another option is using the *agile* method Scrum, where the customer decides what to include next (Schwaber, 2009). Rather than always applying the same model, the decision regarding the choice of a software process model should be based on project attributes, such as project size, complexity or whether the requirements are sufficiently understood (Tiwana and Keil, 2004, p. 74).

3.1.2 Quality in software

In software, the quality of a system is often defined by what may also be called *non-functional* requirements: functional suitability, reliability, performance efficiency, security, compatibility, maintainability, usability and portability, as described in the standard of the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) *25010 Systems and Software Engineering*, which now incorporates software quality aspects from ISO/IEC 9126 (ISO, 2011, 2001) (see Figure 3.1). Each one of these requirements can be broken down further, as shown in the figure; for example, performance efficiency includes time behavior, i.e. how fast the program is, resource utilization, e.g. the memory and processor usage, and capacity, e.g. amount of data or concurrent users supported. Developers tend to put more focus on *speed* of performance, though *reliability* is generally more important for users (Procaccino and Verner, 2009). For these non-functional aspects, unlike with functions, it cannot simply be said that the system has them or not (i.e. yes or no), because more (or in some cases less) is better. Thus, it is more an issue of whether the results are sufficient. An additional difficulty is the expectation that every system should be reliable, fast, usable, etc. However, the choice must be carefully considered, as no system can fulfill all these requirements, because some are in conflict with one another (Whitworth et al., 2006). For example, it may be hard to provide both reliability and flexibility, or usability and functionality. In practice, it may be necessary to choose between having more functionality and reaching the desired quality, or between quality and delivering on time (McBreen, 2002, p. 63).

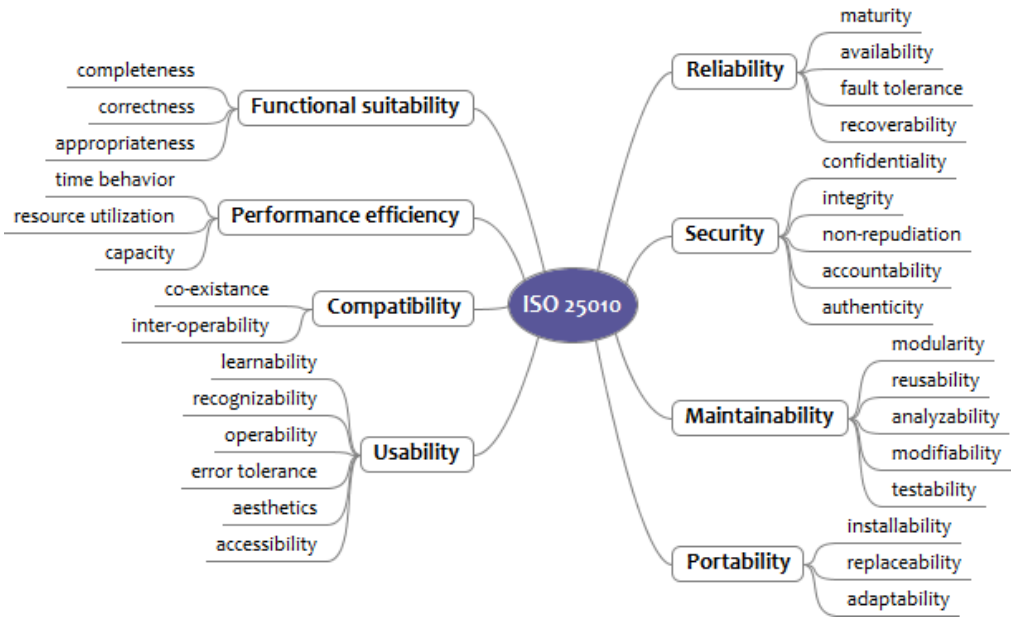


Figure 3.1: Software quality requirements as defined by ISO/IEC 25010

The tests evaluating the non-functional aspects, like reliability, speed or load, are called *performance* tests (Sommerville, 2007, p. 546). They differ from normal tests in that rather than seeing whether something works, measurable limits are needed to see if the values measured are sufficient for the users. With respect to time behavior this might be specified as: the system must perform a certain operation in less than one second. In part because the conditions can vary substantially, for example, according to which programs are running in the background, these tests often attempt to find the limits, and thus increase the load or stress within realistic boundaries until the performance becomes unacceptable or the system fails (Sommerville, 2007). If the limits are set during the requirements analysis, many of these aspects can be tested without the users.

3.1.3 The long way to success

Not all projects that are started end successfully. The perceptions of what "success" means vary, but in many areas they relate to having a working system and a satisfied customer, and not just being on time and within budget (Berntsson-Svensson and Aurum, 2006). Many issues can arise before the development is completed and the system has been adopted to achieve this "success". Some potential problems are described in the following section.

Risk factors during the development

In many software projects, the effort required is much greater than anticipated. In 2007, a study of 600 projects found that 62% of projects were delivered late, 49% were over budget, and 47% had higher maintenance costs than estimated (Dynamic Markets Limited, 2007). More recently, there have been indications that smaller projects are more successful (Ambler, 2010). Furthermore, smaller companies are more likely to research user needs (Gray, 2016), which could promote customer satisfaction.

Adhering to established processes supports having successful projects (CMMI Product Team, 2010). As Sommerville (2007, p. 567) put it: *"In short, good processes lead to good systems"*, and particularly dependable systems need good processes. Getting the ISO 9000 quality certification requires that processes are documented and applied (Sommerville, 2007, p. 567). The Capability Maturity Model Integration (CMMI) programme, which was developed at the Software Engineering Institute at Carnegie Mellon University, allows companies to be evaluated based on their processes (Mayr, 2002, pp. 98-100). CMMI® bases on whether the processes used are recorded, measured and thus repeatable, but also retained when projects become stressful (Mayr, 2002; CMMI Product Team, 2010, pp. 26-30). This does not necessarily mean that the same processes need to be used for every project - there may be several standard processes to choose from, or they may need to be tailored to the requirements of a specific project (CMMI Product Team, 2010, p. 25, 160). The results enable companies to improve their processes, but they are also published and provide support for people choosing partners. Although, a partner at the top level is not always necessary, a certain maturity in processes aids reaching objectives related to costs, being on schedule and quality.

Some of the other top risks in software projects include project management practices, lack of customer involvement, working with new technologies, complexity and changing requirements (Tiwana and Keil, 2004). Important aspects relating to project management include applying formal methods, such as tracking progress, but also choosing the appropriate process models, e.g., like the iterative or agile models described previously.

The features of projects vary considerably, which can also affect the risk. For example, the size of teams can vary from 1 to more than 24 (Ambler, 2010). In addition, the duration varies greatly - in 2008, projects were split approximately evenly between being more or less than one year in duration (Bannerman, 2008). The risk can also be influenced by factors like third party involvement, dependency on these third parties and the strategic importance of the project (Bannerman, 2008).

Risk management can help support success. Risks can be evaluated by the *probability* that these will occur and the *impact* on the project should they happen, which are multiplied to calculate the severity (Mayr, 2002). Thus, the most severe risks are both likely to occur and have a bigger impact. Researchers looking at which risks commonly occur in software projects instead focus on other dimensions: the *importance* to success, and the whether these are in the *control* of project leaders (Tiwana and Keil, 2004). The importance corresponds to the impact. The control is important, for there is little point investing effort in risks, if there is no realistic chance of doing against them (Mayr, 2002).

The long path to adoption

In the end, it is often a question of costs. It can take a long time before a new product is accepted by the customers. Developers have to be paid, even if a profit is not being made.

With completely new products, the Technology Adoption Life Cycle (TALC) describes the acceptance based on the characteristics of customers. It states there are only a few *innovators* that basically buy any new technology that comes out, followed, by the *early adopters* who see the potential of the product (Moore, 2006). Both of these groups only make up a small percentage of the overall users - the majority of people are more practical or conservative, and so wait to see how the product and market is developing, which takes a certain amount of time, but then the innovators are also willing to pay more money to be on the cutting edge. Although this model was developed in the 1950s, it has also been used more recently to look at the introduction of technology in other areas to understand how to increase adoption (Sahin, 2006).

With products developed for the mass market, the measures of success include the number of sales, market share, good reviews, long life cycle and enhancements or services (Keil and Carmel, 1995). Thus, it entails having a working system (e.g. for the number of sales) that makes a good first impression on people (i.e. for the reviews).

3.2 Putting people and their needs first

To help ensure that systems are successful, developers need to understand the users. Various methods and approaches for achieving this aim.

3.2.1 User-Centered Design

The UCD or *human*-centered process (see Figure 3.2) supports creating usable systems and is included in the standard *ISO 9241 Ergonomics of human-system interaction* (ISO, 2010). UCD has been been widely applied (e.g. Mao et al., 2005; Vredenburg et al., 2002).

The first step is to explore the *context of use*. The context of use is broadly defined, and includes not only the hardware and software utilized, but also the physical and social situation in which the system is used (ISO, 1998). Analyzing the use context helps to gain a better understanding of the intended users and their goals. Only after developers have more information about the people who will use it, the tasks they will do and the environment in which the system will be used, can they understand the requirements the system really needs to fulfill. This is a key difference, as in conventional software development the technical possibilities may be the starting point for project requirements or be relatively set at the start of the project. By doing a thorough analysis first, it is possible to practice *informed design*, i.e., the ideas about the system emerge from what is learned about the users and their needs.

Another difference is that rather than considering the design and development phases separately, as is common for software developers (Sommerville, 2007), in UCD these phases are combined in a single step that designs and produces some sort of prototype

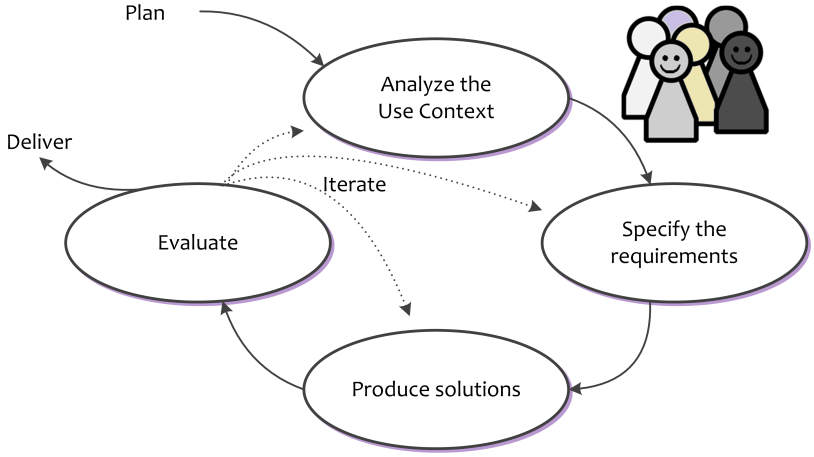


Figure 3.2: User-Centered Design process as defined by ISO 9241-210

or system version that can be evaluated. Like the iterative model, multiple evaluations and versions are planned in UCD. Evaluation methods common in UCD, like cognitive walkthrough or user tests, explicitly consider aspects about the users, tasks and use context. Unlike the iterative model, where the development always returns to the requirements analysis, in the UCD model partial iterations are also possible; for example, for changing the design without reconsidering the requirements. This makes sense, as there may be multiple designs that satisfy the requirements. Furthermore, if the use context was studied thoroughly early on, it may not be necessary to return to that step later.

In order to ensure a system is usable, UCD aims to have multiple evaluations to establish whether the system meets the goals before it is completely finished, while changes can still be made to the requirements and design, as is shown with the arrows in Figure 3.2. Thus, two types of evaluations are distinguished: formative and summative. *Formative* evaluations aim to get input at a point when something can still be done, and so they are performed after intermediate iterations; the final *summative* evaluation sums up the situation before delivery (see Figure 3.3). Traditional software development focuses on the tests before a delivery, which are summative in nature. With UCD, even before a system is complete, information is gathered (Rubin and Chisnell, 2008; Tullis and Albert, 2008): to check whether it contains the needed functionality, whether people can find functions, whether people find the proposed design appealing, to compare two design suggestions, diagnose problems or even to explore needs. In contrast, the *summative* evaluation, sometimes called benchmarking (Rubin and Chisnell, 2008), can be used as the basis for a certification, such as those needed for medical products.

The people who perform the tests can also have an influence; for example, developers who choose the functions may find different problems from usability experts or employees of a care agency that help people who actually use this type of system. Users, either actual future users or people who are like them, may also be included in tests (Rubin

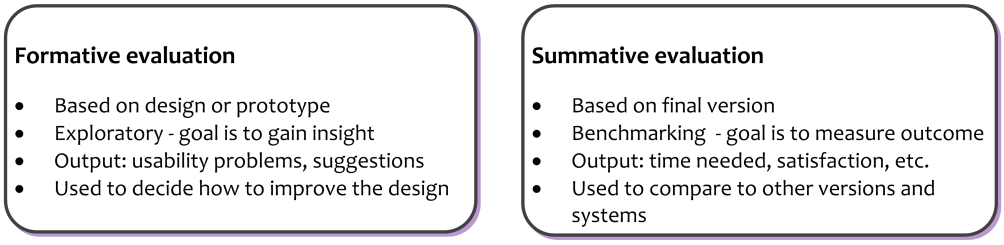


Figure 3.3: Types of evaluations

and Chisnell, 2008), but the tests need to be designed carefully to ensure validity, as who does the tests, what they test and in what environment can have an influence on the results (Lindgaard, 2014). Evaluating whether users truly *accept* a system is only possible after the system is complete.

3.2.2 Usability and User Experience

Due to this additional analysis and evaluation, UCD helps to ensure that the needs of the users and their situation are met, and hence supports the development of more usable systems. *Usability* may seem subjective, as not all people may have the same opinion regarding how easy to use a system is. However, a formal definition exists: *"The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use."* (ISO, 1998) Nevertheless, it is also about giving people a satisfying overall User-eXperience (UX): before, during and after the use.

The measures of usability are given by the definition: effectiveness, efficiency and satisfaction, whereby *effectiveness* is a measure of how well the system fulfills the functional goals (ISO, 1998). The *efficiency* is often measured quantitatively, e.g., according to how many clicks or how long it takes to do a certain task. These measures are not entirely different from the viewpoint of traditional development: there is a certain link between effectiveness and validation (i.e. if a system does what it should), and also between efficiency and verification (i.e. how well it does it). Usability goes further, as it not only looks at the system, but also at how it works for the intended users, tasks and context of use, and at how *satisfied* the users are with it, which is subjective.

With regard to usability, there may be trade-offs between effectiveness and efficiency, and between usefulness and ease of use. Adding many functions would help reach the goals of the user more comprehensively, but having an increased number of functions can make the product more complicated, as there are more functions to choose from and more steps become necessary to select a function (Norman, 1988). This is a phenomenon that can be illustrated by everyday tools: for instance, to borrow an example of Michelis (2003), a knife: the Swiss army knife offers a wide variety of tools, but these can be hard to find and require an extra step to open, and they not particularly ergonomic (Michelis, 2003). Thus, when it comes to chopping vegetables, a normal knife specialized

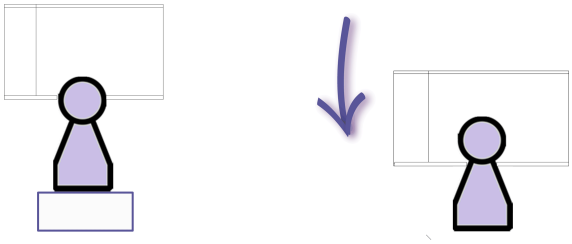


Figure 3.4: Universal design: do we adapt the user (left) or the system (right)?

for chopping may be easier to use. Developing products specialized for a specific target group and not the mass market has proved to be a successful strategy for products (McBreen, 2002, pp. 50-51).

The newer UX tradition has a different focus, even though the term is now defined in the same standard as UCD (ISO, 2010). In addition to ease of use, it includes the emotional state of the user, his/her engagement with the system and the memorability of the interaction (Hellweger and Wang, 2015). Thus, feelings of joy, fun and pride play a more important role, rather than just "satisfaction". Practitioners think there is a considerable difference between the UX and usability and that usability provides a good but insufficient basis (Cruz et al., 2015).

When taking a more human-centered view, systems like websites need to be usable or accessible for a wider group of people (Shneiderman, 2003). This also encompasses people with different abilities and limitations. There are different ways this can be approached with regard to people with disabilities. Traditionally, there was a focus on what people were "lacking" and on trying to compensate those "barriers", like the assistive technology described in Chapter 2. More recently there has been a trend toward *universal design*, finding solutions that are more accessible and usable for everyone by reducing the requirements for interaction (Marcus, 2003) (see Figure 3.4). As an example, in order to assist people in opening a door, a button or an automatic door could be installed. This does not necessarily imply that the design has to be "one size fits all", some personalization may be needed due to the diversity of the users (Dale et al., 2016). Furthermore, there are a few systems which exist outside this viewpoint, since they may be designed for a need experienced only by some. For example, a fall detection system, which can enable a person at risk to live at home independently only has to be suited to the people who actually need it, and not to the wider population.

3.2.3 Available methods and guidelines

There is a broad variety of methods to support UCD, UX and usable systems (e.g. Sharp et al., 2007; Shneiderman and Plaisant, 2009; Rubin and Chisnell, 2008); for example, *contextual inquiry* to collect information directly in the use context, *task analysis* to understand the precise needs of the tasks being carried out, *card sorting* to improve the structure of choices in a system, *expert reviews* to get feedback on a design from

usability specialists, or formal *usability evaluation* to acquire detailed information about user performance with a finished system. To achieve UX, aspects like interaction design, prototyping and visual design are particularly important (Psomas, 2007). There is an online interactive toolbox that supports choosing usability methods suited to the specific needs of a project (Bevan et al., 2010). The goal is to reduce the time required and the risk by considering factors such as time and skills available, complexity, context, consequences of errors, how well needs are understood and access to users (Bevan, 2009).

A study of UCD showed that many of these methods were used in companies, even before the projects being studied in this research started (Mao et al., 2005). Furthermore, UCD methods have been successfully applied in projects using agile methods (Jia et al., 2012) and in the area of AAL (Leonardi et al., 2009). Recent research indicates that user tests are widely applied for evaluation (Lindgaard, 2014). However, even applying a UCD method correctly early in the development may not be sufficient to ensure systems meet end-user needs (Friess, 2012). In practice, developers may to not adhere to the methods rigorously and instead adapt them (Gray, 2016; Leonardi et al., 2009). In addition, it has emerged that in some cases the results of analysis are not sufficiently integrated into the overall development process (Bednarik and Krohns, 2015).

The Web Content Accessibility Guidelines of the W3C (WCAG) provides guidelines for making web pages accessible for people with various sensory, physical, motor, language and/or cognitive impairments (W3C, 2010). Although it is aimed at web sites, many points are also valid for other types of user interfaces. It is based on the criteria that something must be perceivable, operable, understandable and robust, also for those with impairments. Even though the guidelines are a number of years old and the technologies available have changed, human abilities (and disabilities) have stayed much the same.

3.2.4 Beyond UCD

Sanders and Stappers (2014) argue that UCD is no longer really state of the art, and that it is necessary to design *with* users, also to gain insight about what people might need in the future. UCD can be defined as "the active involvement of users for a clear understanding of user and task requirements, iterative design and evaluation, and a multidisciplinary approach" (Mao et al., 2005, p. 106). In the 1980s, when PCs were relatively new, it was not unusual for the future users to be *considered* by the team, and actually *included* only for isolated aspects, like reviewing design sketches (Sanders and Stappers, 2014). As an example, the method personas (e.g. Adlin and Pruitt, 2010), which describe fictitious users, aims to keep the focus on the users and enables them to be considered early on, but *"actual users do not play a big role during the design phase"* (Blomquist and Arvola, 2002, p. 200). In the 2002 technical report *ISO/TR 16982 Ergonomics of human-system interaction – Usability methods supporting human-centred design*, methods were split into direct and indirect user involvement. Here *direct* involvement also included usability tests with users, whereby users have less impact on the features and design. This may be too late, as research indicates that understanding the customer's problem and involving users contributes to success in software projects

(Berntsson-Svensson and Aurum, 2006), and *lacking* user involvement is one of the top risks (Tiwana and Keil, 2004).

Reflecting on new technologies, like smartphones, that make it easier for people to interact with systems, it is becoming more commonplace for users to be involved in design teams in a way they have a larger say. By 2014 the way of working had changed so that today *co-design* has become more common way of working with users, which can range from Participatory Design (PD), in which users actively participate, to co-creation, where users play an even more central role in shaping the system (Sanders and Stappers, 2014). Through these developments there has also been a growing awareness that projects cannot be judged on financial return alone, but that also UX and social values, such as privacy need to be considered.

Due to the fact that users have different knowledge and skills than developers, different methods are necessary if users are to be included in the development process. Rather than using software models like UML, methods are needed that ensure the users can contribute. A variety of participatory design methods is available, some for individual phases of the development and others that span multiple phases. Many of these are not new (see Muller et al., 1997). A focus on methods may be considered too constraining (Muller et al., 1997) - more "traditional" *techniques*, such as scenarios, prototypes and simulations can also be used (Kensing and Blomberg, 1998). The statement that methods may be too constraining can be explained by the fact that methods can limit teams, because they may stick to the "rules" of the method, rather than reacting to the specific needs of the situation (Kensing and Blomberg, 1998). This would speak in favor of methods for a single step or those less precisely defined rather than methods that cover the entire process. Another pitfall of methods is that teams may may choose them because they know them, instead of searching for methods more suited to the problem at hand. As with development models (Tiwana and Keil, 2004), knowing different methods provides developers with an arsenal of possibilities so that they can choose appropriate steps.

It is also important to note that some people view using PD as a political or power issue, i.e. that those affected by the system should have a voice, where others use it for more pragmatic reasons, e.g. to gain user commitment or expertise, or even in a more theoretical or philosophical manner, e.g. for trying to understand how others experience the world (Greenbaum and Halskov, 1993). If people help to design the system, they may be more willing to accept it (Muller et al., 1997), but due to these different perspectives, people who see it is as political issue may not view applying it for practical reasons as giving people enough of a voice to truly influence the outcome.

Not everyone agrees that PD is the right approach. Jackson and Greenhalgh (2015) say older traditions like PD are based on industrial needs and do not go far enough for complex interventions and that for the development of health applications co-creation is essential, as it involves users earlier in the process and more intensely. Nonetheless, in companies user participation may be difficult due to economic pressures (Lievesley and Yee, 2007; Bednarik and Krohns, 2015). However, there are also other, non-participatory, methods of development, like Value Sensitive Design, that assign the values that are

important to the users, such as privacy or autonomy, a greater weight than aesthetics (Friedman et al., 2006).

3.3 Challenges related to the systems being studied

There are a number of challenges to be addressed associated more specifically with monitoring systems for older people. In the EU, they must conform to the *Medical Device Directive* (93/42/EEC), which requires that they have the CE certification mark (Sethi et al., 2011). However, even though some users have medical conditions, at least in Germany, the more extensive standards for medical products are not relevant for AAL systems in the home (Deutsches Institut für Normung e. V., 2010). Still the development may be complicated by the complex and innovative technology involved, the high reliability required and the fact they are aimed at an older user group.

3.3.1 Complex and innovative technology

Both new technologies and complexity are inherent in the monitoring projects being studied, for example, due to the pattern recognition required. Both of these factors are considered to be some of the main risks in software development (Tiwana and Keil, 2004).

Furthermore, these systems are based on sensor technologies. In projects developing systems based on sensors and electronics, the teams are generally less diverse and developers tend to be predominately male (Cuartielles et al., 2015). There may be issues inducing these developers to recognize the values, beliefs and interests of other groups, such as women (Cuartielles et al., 2015).

AAL technologies are in principle innovative systems, therefore it may take more time before products become established on the market. In innovative areas, financial grants might be available that could help companies bridge the gap until a profit can be made or simply to encourage them to risk developing something that is not guaranteed to work. For grants, specific criteria may need to be fulfilled for a successful proposal, e.g., innovation or project partners that meet certain requirements. As an example, the AAL Programme of the EU requires a lengthy application including partners from at least three countries (AAL Programme, 2017). Even if the application is successful, the full costs are not covered. Moreover, there are reporting requirements that demand additional effort. As mentioned earlier, including more partners, whether these are developers, consultants or vendors, is considered to be a major risk factor for software development projects (Bannerman, 2008).

For new innovations, the Technology Adoption Life Cycle described previously may be different. Moore (2006) says that rather than passing smoothly from “early adopters” to “innovators” and on to the larger “majority” of the users, for innovative systems there is a gap between the time “innovators” buy and the “early adopters” start buying, and there is an even wider gap (or chasm) between the “early adopters” and the “early majority” (see Figure 3.5). This means that not only does it take longer for systems to be adopted, but many products never get past this chasm. There are many examples

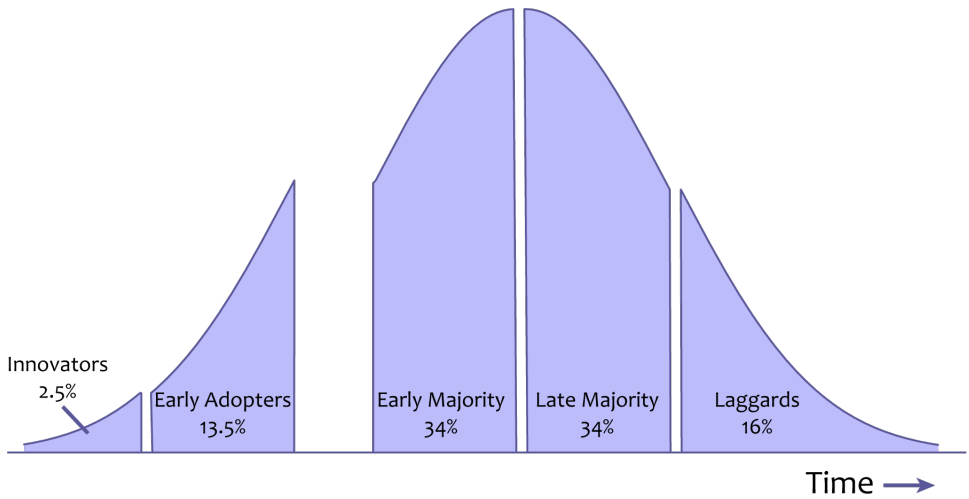


Figure 3.5: The revised Technology Adoption Life Cycle (Moore, 2006)

of products that failed before they crossed this chasm. Moore (2006) posits the reason for this is that "early adopters" are aware that the technology is new and are prepared for the fact that there may be some initial problems, but the "early majority" and "late majority" merely want it to work with as little disruption as possible. Therefore, since the majority of customers are waiting for reliable reviews, the reviews of "early adopters" are poor references for them because the "early adopters" were looking for something new and different. Although initially published in the 1990s, Moore's theory has been republished and is still a topic of discussion (Schawbel, 2013).

3.3.2 High reliability required

For technologies like sensor-based monitoring, complex algorithms may be required to get accurate results. For example, with monitoring systems there is a large variety of conditions that may occur, e.g., different lighting. In addition, the behavior being monitored may vary from one day to the next: even people living alone who rarely go out may sometimes receive guests, or people may sit quietly for hours while reading, turn off all the lights to watch a movie or go out briefly without there being any need for concern. Complex Bayesian statistics may be used to interpret the data from sensors and recognize patterns (Bishop, 2006, p. 22). Bayesian statistics can help to determine how likely an event is by looking at the likelihood of various components. For example, in order to evaluate the necessity of triggering an alarm when someone has left their home, it is necessary to know in which percentage of cases they have left for harmless reasons previously at this time of day.

For these types of systems, the software quality requirements that the technical solution should try to fulfill include usability, privacy, reliability, maintainability, flexibility (Himmelsbach et al., 2017). *Reliability* is an import issue, as a missed alarm might mean

$$MTTF = \frac{1}{FailureRate}$$

$$FailureRate(system) = \sum_{i=1}^{n} FailureRate(i)$$

Figure 3.6: Calculating Mean Time To Failure

an older person does not receive help in time in an emergency and repeated false alarms can be an annoyance, as mentioned in the previous chapter. There are some inherent difficulties as there are conflicts between these goals: the *flexibility* or adaptability to work in different situations is inherently in conflict with *reliability*, which is also needed; and *privacy* is in conflict with *connectivity*, which is needed to contact others in case of problems (see Whitworth et al., 2006).

As highlighted before, reliability is a key issue in the types of systems under scrutiny in this thesis, and projects may be delayed due to problems achieving the required quality that necessitate late code changes (Mayr, 2002, p. 69). Various measures are used to calculate reliability (Sommerville, 2007). For systems that are in operation for a longer period of time, like monitoring systems which are always running, an important measure of reliability is the *mean time to failure* (MTTF), or how long it takes until the system fails on average (ETS, 2008; Sommerville, 2007, p. 209). Thus, if a system fails once per day on average, the MTTF would be 24 hours. If the components are arranged in sequence, the failure rate of the entire system can be calculated by taking the sum of the failure rates of the individual components (ReliaSoft, 2010) (see Figure 3.6). This means that systems with multiple parts arranged in sequence are more prone to problems as one unreliable part can reduce the overall reliability. For example, if a system has two parts in sequence, each of which fails once per day, the complete system fails twice per day, i.e. it has an MTTF of 12 hours. This may be the case in monitoring systems, as they have sensors to detect the problems, then a component that decides whether to trigger an alarm based on that data, followed by a device that receives the alarm - a failure in any one part would mean the alarm is not received.

3.3.3 Understanding the requirements of older users

Understanding users is particularly important where the users are so different from the developers. There are even companies that produce equipment that "simulate" being old to help people understand what it is like. But the *diversity* of older people also creates unique challenges for designers (Blythe et al., 2005; Lindsay et al., 2012). Furthermore, developers seem particularly unwilling to engage with older users (Lindsay et al., 2012, p. 1207).

Satisfaction is important as it could affect recommendations and thus also ultimately the success of a product. With regard to the types of technology being studied in this thesis, improving usability might be able to reduce the barriers identified (Sanders et al., 2012), for example, by reducing the technical competence required or by choosing

functions that do not threaten independence or current health care services. When designing for older people, even small aspects about the environment that at first do not seem to be relevant can be important (Wallace and Lindley, 2015, p. 84).

With respect to older users and those with limitations, it is recommended to involve real users as soon as possible (Thimbleby, 2008). Being focused on the people who will use the system in each phase is particularly important: during the analysis to ensure the true needs are understood, in order that the right functions can be included; during the design so as to remember to apply guidelines regarding older users and consider aspects from other systems they know; but most importantly, since most developers are not older people and not "typical" due to being developers, at some point the system should be tested with older people to check their needs were understood and that the design is suitable. Evaluation reports of AAL projects indicate that most projects involve users in some form (Busquin et al., 2013; Geyer and Good, 2016). However, it can be difficult doing PD with older people when intangible concepts, like sensors, are involved (Lindsay et al., 2012).

There are special considerations when gathering information about the needs of older people and those with disabilities. UCD can be applied, but it is not a guarantee of success (Thimbleby, 2008). One difficulty is that UCD does not really account for the fact that the users themselves may change, which is the case with older people (Gregor et al., 2002). It can also be challenging to work in care homes: Wallace and Lindley (2015) describe the difficulties of working amidst busy everyday activities of staff and organizing around the many appointments when trying to work with the people living there. Furthermore, it is not always possible to include users, for example, older people who are ill or weak (Grönvall and Kyng, 2013), in which case it is recommended to use some indirect methods to limit the amount of participation required from them (Thimbleby, 2008). Using narratives from real users can also support empathy in designers (Grünloh et al., 2015).

As mentioned previously, when designing for older users, many have some sort of disabilities or limitations, which might need to be considered in the design itself. The WCAG that was mentioned earlier also has advice specifically about designing for older people (W3C, 2010). These guidelines can be implemented without user involvement, but the result still needs to be evaluated. It is also recommended to provide either adaptable systems or multiple versions to suit specific needs (Thimbleby, 2008).

The evaluation can also be challenging due to some aspects related to older people and the systems to support them that were described in Chapter 2: lack of experience with technology, diversity of older users and various stakeholder groups with different interests, but also due to the need for long-term tests in a realistic context to ensure reliability (Müller et al., 2015).

3.4 Previous research in AAL

Different aspects can be investigated to gain understanding why more AAL systems are not on the market. Some people have looked at aspects related to the acceptance, for example, about what is important to users (Greenhalgh et al., 2013) and barriers to

the adoption of the systems (Blythe et al., 2005); others have looked at the technical aspects of the development (e.g. Eichelberg et al., 2014) and deployment (e.g. Sallinen et al., 2015). Of particular relevance to this research are aspects related to HCI that others have investigated, including gathering better information about the needs, ways of facilitating working with older users and being sensitive to a wider range of issues. These aspects are discussed in more detail below.

3.4.1 Better information about the needs

Researchers have looked at the needs of older people and telehealth/telecare systems. Research indicates that for monitoring systems in the home, although medical security is the most important concern, higher needs such as isolation and privacy also need to be considered (Blythe et al., 2005). The guidelines of the European Telecommunications Standards Institute for telecare products (ETS, 2008; Sethi et al., 2011) include a few suggestions regarding privacy.

Ethnography has been used to gather detailed information about users needs when designing these types of systems. Some have even suggested specific elements that need to be included in order to understand the complex patterns of use (Blythe et al., 2002). This includes information about current technology, personal history and what people hope to gain from the system. To get this information, the users need to be considered or included in some way.

Wallace and Lindley (2015) used cultural probes (Gaver et al., 1999) to gain an impression of what it is like to live in a care home and generate new ideas. Cultural probes ask people people to record information based on unusual objects placed in their own environment. In practice, however, Wallace and Lindley (2015) found that the method had to be adapted when working with the older people in care homes, and instead worked with multiple users together directly, rather than having them record their impressions themselves.

There are resources that have been developed to support people developing systems for older people. This includes a toolbox of suited methods developed by the AAL Programme of the EU (YOUSE, 2015), sample personas of older people (CURE), and also some design guidelines (in German) (mobi.Senior.A, 2016).

Besides, there are *living labs*, which can support the development of innovative systems by providing access to an environment to test and/or a group of users willing to participate (Ståhlbröst and Holst, 2012). A number of living labs exist that specifically target AAL technologies and are open to any organization. These include the AAL Living Lab Schwechat in Austria, Smart House Living Lab in Madrid, Spain, Bremen Ambient Assisted Living Lab in Germany, AIPA Ageing in Place Aalst in Belgium, iHomeLab Living Lab in Luzern, Switzerland and INNOVAALab in Apulia, Italy, just to name but a few (see also ENoLL, 2017).

3.4.2 Ways to facilitate working with older users

As already stated, PD is a way in which users are included in the design process of systems. Several studies have been carried out which indicate that PD can be a successful strategy when developing technology for older people. Some of these are described in the following section.

A couple of simple techniques that are not commonly used have been successful with older people, such as critiquing current systems (Vines et al., 2012) or even games (Uzor et al., 2012). Further, specific methods have also been developed aimed at working with older people. Two examples include the HODI (Habitus of Design Inspirations) technique, which aims to allow older people to comment better on a design by providing the information about it step-wise: first a user scenario or design concept is presented, followed by additional background data related to the concept, then the rationale behind the design, and finally allowing space for users to comment on the design (Subasi and Fitzpatrick, 2012); and also a use-case based diagram notation to support explaining prototypes to other stakeholders in AAL projects (Krainer et al., 2017).

Based on their experiences, Lindsay et al. (2012) identified four key issues that need to be addressed when doing PD with older people: maintaining focus, representing issues in a way to allow users to influence the design directly, envisioning intangible concepts, and adapting PD methods to be more appropriate for processes not related to a work environment.

3.4.3 More sensitivity during the development

Some researchers in HCI emphasize that sensitivity is required as health IT moves into the homes of the patients (Fitzpatrick, 2012). To a certain degree, this means re-imagining the way systems are designed. Rather than designing systems to monitor older people, where people are observed and passive, systems should include older people as active agents (Fitzpatrick et al., 2015). Others have pointed out that older people have the ability to learn modern technologies, but may choose to do so only if the systems fill a need (Durick et al., 2013), making it important that teams are sensitive to the needs of older people. Another relevant related concept is reciprocity - people often prefer an exchange or give and take. There are many possibilities here; for example, reciprocal learning (Harley and Fitzpatrick, 2009), the exchange of services (Luckner et al., 2015) or the reciprocal exchange of data (Mynatt et al., 2001). Finally, some have found that the appearance of systems does matter (Fitzpatrick, 2012) - and that monitoring devices should be unobtrusive (Wagner et al., 2012). With devices that may be associated with frailness this is particularly important, as the stigma matters for acceptance when it comes to technologies for aging in place (Peek et al., 2014; Joshi, 2016). Recent research underlines that the freedom of choice and lack of stigma should be considered in the development and introduction of AAL systems of all types (Himmelsbach et al., 2017, p. 15).

The different perspectives that need to be considered during the project have been examined by others. When evaluating publications about the development, promotion and

evaluation of telehealth and telecare technologies, Greenhalgh et al. (2012) identified four different discourses: the modernist, humanist, political economy and change management. The *modernist* discourse is technology-centered, and is related to efficiency and cost-effectiveness. In this discourse terms like "smart", "intelligent", "ubiquitous", "agents" are used to describe the systems. The *humanist* discourse is user-centered and looks at people and the technology in use. As a result, the technologies considered may be more related to maintaining autonomy, communicating with others and leisure activities. The *political economy* discourse is more critical and is focused on the emancipation of certain user groups. The *change management* discourse is more pragmatic and based on supporting the existing routines of the various stakeholders in an effort to get the systems adopted. The authors stress that no one discourse should not win out, but that all are necessary. After all to make a difference, the technology needs to work *and* needs to be adopted.

3.4.4 Promising approaches from other areas

In other application areas, development processes of projects have been studied qualitatively to gain understanding of what is happening. For example, some researchers have studied decision-making during development to understand when certain personas were mentioned (Friess, 2012). Others have studied design meetings during the development of interactive systems to gain insight, for example to understand the point in time and way in which artifacts and user data were introduced (Nielsen and Bodker, 2010). Ethnography has been used to see how certain development methods are used in practice to understand the problems, through attending meetings, doing interviews and studying documents (Blomquist and Arvola, 2002). There have also been investigations into the way UCD is combined with the agile development model, based on interviews, supplemented with observation and documents (Hussain et al., 2009). Others have gained insight into user-centered practice through interviews alone (Bednarik and Krohns, 2015). Prior to this research little had been done to investigate the development of AAL specifically.

3.5 Summary

Although there have been a large number of development projects in the area of AAL entailing large investments of time and money, there are few systems on the market, as is evidenced by the fact that funding schemes continue to encourage development in this area with more focus on getting to market. Monitoring technology is particularly interesting, since it may be acceptable for people otherwise not open to care (Draper and Sorell, 2013). Nevertheless, there is no evidence yet of the benefits of this type of system (Barlow et al., 2007), even with systems related to specific health issues (Henderson et al., 2013).

Previous studies have focused on acceptance (e.g. Peek et al., 2014) or the technological aspects (e.g. Chessa et al., 2010), but there are also aspects related to the development that warrant study. The domain is not an easy one, both due to the diversity of the

needs of older users and the complex technology required. Many telecare and telehealth systems do not meet the needs (Greenhalgh et al., 2013). Due to the special needs, it can be hard to understand what older people need (Blythe et al., 2005). Working with older users does indeed pose challenges, especially when dealing with intangible concepts (Lindsay et al., 2012), such as those related to the sensors in the monitoring systems being studied. Thus, developers may need to work differently. Moreover, there is a tendency to add functions that may make the systems coercive (Mort et al., 2013), further limiting the acceptability. These problems have their source in the development process.

Despite the challenges and lack of successful systems, few studies have investigated the development of projects in the area of AAL to understand the problems that arise. Examining the development process of individual systems could provide detailed information to help understand the issues faced by developers. Since methods, like user involvement, that work more generally are seemingly insufficient to reach the desired goals in AAL, it is worthwhile to study the development of systems in this area to understand what happens in detail during the development for systems that aim to go to market, but fail. This could contribute to understanding to support developing more successful systems in the future.

The next chapter will look at the goals of the research and the research methodology used.

CHAPTER 4

Methodology

This chapter starts by presenting the aims of the thesis and the theoretical viewpoint taken. After that it describes the studies that were conducted, the methods chosen, and gives more details about how the methods were applied in practice, including the choice of participants. Additional details about the methods specific to one study, for example, the materials used, are included in the individual chapters relating to the studies. At the end of the chapter, some information is provided about the role of the researcher.

4.1 Guiding research questions

The goal of this research was to explore the development of AAL technology, with a focus on companies and systems including sensor-based telecare monitoring components, with an aim to identify issues teams face that could affect the success of these systems and to gain understanding about how these issues fit together.

Based on the literature review, the guiding research questions (RQ) were:
Related to the *users*:

- RQ 1: How are stakeholders, including older people, considered and included in the process?

Related to the *technology* being used:

- RQ 2: How does using sensor technology affect the development?

Related to the *development processes* being applied:

- RQ 3: How is the development done in practice?
  - RQ 3.1: Which user-centered methods and techniques are used?

  - RQ 3.2: How are decisions made during the development about which features to include?

To support the goal of *exploring* and being open:

- RQ 4: What other issues arise that could potentially affect the success?

The data collected was analyzed to identify the difficulties development teams face. For example, were these difficulties related to having older users, using sensors, or the way UCD methods were used. The work took the viewpoint of HCI, so aspects relating to the users were of particular interest. It looked at aspects, such as how teams included, considered and discussed the users in the development process, and how the stakeholder needs were negotiated to decide what features should be included. The results can be of use to practitioners in order to avoid these problems or to researchers in finding more systematic solutions to them.

4.2 Theoretical underpinnings

There is a broad variety of viewpoints that can be taken with qualitative research (Flick et al., 2000). The theoretical viewpoint or tradition can affect both the research questions and the data analyzed. Some methods for data collection are associated with a specific tradition, while others, such as case studies, do not come from one specific tradition (Cohen and Crabtree, 2006). Furthermore, one of the pitfalls of the analysis method chosen is taking the wrong approach for the research questions (Braun and Clarke, 2006, p. 26).

The importance can be illustrated by reflecting on the research on the benefits of AAL systems presented in Chapter 2. Some applied *positivist* methods (e.g. Cartwright et al., 2013; Henderson et al., 2013; Steventon et al., 2012), using inferential statistical analysis of quantitative data to study the benefits of these types of systems. The same intervention was also studied using a *realist* view, for example, the study by Sanders et al. (2012) exploring the barriers to adoption. The latter approach is more open and aims at descriptions that can provide explanations rather than setting a hypothesis at the outset. It also has the advantage that it can provide results even if the desired result is not reached (Pawson et al., 2005), in this case by interviewing people who chose not to participate or who withdrew from the study.

For this research, a *constructivist* point of view was chosen. To better understand the impact on the research and why it was chosen, it is relevant to briefly reflect on the difference to other viewpoints.

4.2.1 The way in which the constructivist view is different

Various viewpoints have been used in HCI to understand the work of people:

- *Phenomenology* has been used to understand cooperative work as a basis for design (e.g. Robertson, 1997);

- *Ethnomethodology* has been used to describe how users work in order to better provide support, for example in the area of Computer-Supported Cooperative Work (CSCW) (Button and Dourish, 1996; Randall et al., 2007, p. 35);

- *Constructivism* has been used in interaction design, but also to understand the work of developers in a richer way (e.g. Muise and Wakkary, 2010; Floyd, 1992; Floyd et al., 1992).

These three viewpoints are described briefly below based on Flick et al. (2000).

Phenomenology assumes there is an underlying purpose or intention at the root of the actions of others. At the same time, people are only semi-conscious of this. Thus, there is a difference of how the people see their own actions and how these actions appear to the researchers who view it from the outside.

Ethnomethodology (not to be confused with ethno*graphy*) focuses on the steps used to do everyday actions in order to understand certain objective social rules or norms (Dourish and Button, 1998). It assumes that the world is intelligible to someone who observes actions in specific circumstances. For example, studying everyday interactions between developers and older people to see what decides which requests are implemented, e.g. through conversational analysis.

Constructivism on the other hand, considers also the social context in which something occurs. It is closely related to the ethnomethodology, but adds a layer of interpretation. Constructivists attempt to understand how the people involved see the world to understand *why* they act in a particular way, and as such are interpretists - seeking to construct an interpretation rather than discover "the reality", as in ethnomethodology. This type of research puts an emphasis on understanding (Charmaz, 2006, p. 126), and unlike quantitative statistics, may infer why something happened and consequences of actions. In contrast to the positivist tradition, it posits that nothing is truly objective: the context in which something took place and also the person studying it affect the interpretation (*relativist*). Thus, the same sentence said by a developer to an older user may have a different meaning if it is said in a meeting or in the hallway in passing. Furthermore, one researcher hearing that sentence may make a different inference than another who has studied different work environments.

As a researcher, I felt that in this case there were no underlying roots or intentions, thus ruling phenomenology out. Furthermore, I felt that what was being studied was not entirely knowable, as posited by the ethnomethodological viewpoint, and that not just the steps, but also the purpose or reason behind doing things a certain way were relevant. For this reason, the constructivist point of view was selected.

4.2.2 Effects of taking a constructivist view

This research aims at *understanding* what is happening during the development. Thus, the constructivist point of view can be considered appropriate (Charmaz, 2006, p. 126). As indicated by the research questions, this research is not just looking at the methods applied, but trying to understand why development processes are not successful: are users

not being asked the right questions when gathering requirements, can they not contribute in a meaningful way, are their answers not being heard, are other requirements being giving higher priority, are there problems implementing their requests, etc. Constructivism supports this, as it aims to uncover the complexities of specific data (Charmaz, 2006).

Taking a constructivist view also has an effect on the way the research is done. While some methods to analyze data are relatively independent of the theoretical or epistemological framework chosen, the way others are applied may differ according to the chosen framework (Braun and Clarke, 2006, pp. 6-10). With a constructivist view, the way the data are collected and ideas behind the research are also relevant (Charmaz, 2006). Whereas an objectivist approach to analysis, like that in the grounded theory of Glaser and Strauss and also Corbin and Strauss, posits there is a knowable world that has to be exposed by unbiased researchers, the constructivist view, to which Charmaz belongs, believes that no data and no analysis are really objective - it depends on the context in which the data was collected, but also the experiences of the people analyzing it (Charmaz, 2006). Thus, this context must be considered and recorded.

With a constructivist approach, it is not necessary that the researcher has the same experience as the people being studied. Since interpretation is necessary, it is important to be sensitive to possible bias. For this reason, the background of the researcher is relevant. I am older than most doctoral candidates, am an expat, and have over thirteen years of experience in companies in four different countries doing software development, user interface design and project management. I have previously researched about participatory design methods (e.g. Muller et al., 1997). For the past twelve years, I have worked as a lecturer for software development and HCI for students studying engineering, and also provided support to companies in these areas. As alluded to in the introduction, my interest for the topic is primarily professional and emerged from these experiences. Working with engineering students who were developing sensor-based systems for automation, it seemed they often forgot the people and tasks behind the systems. Furthermore, I had experienced that some students were dismissive of people over 40 - until they realized that the person they were telling, and who was teaching them, would be included in that. I wondered how the development of the types of systems being studied was different from that of other types of systems, how people developing systems sensing older people stayed user-centered, and what difficulties they faced. Due to prior experience, there could be a bias towards established UCD methods. As a sole researcher, including another person in the analysis was important to try to overcome my own assumptions and blind spots. This was done by discussing the data and results with the thesis adviser.

4.3 Research studies

In order to answer the research questions, a series of qualitative studies was conducted. The research included two in-depth case studies of projects developing monitoring systems for AAL in order explore and gain information about what happens during the development. This was followed by supplementary studies to extend the results

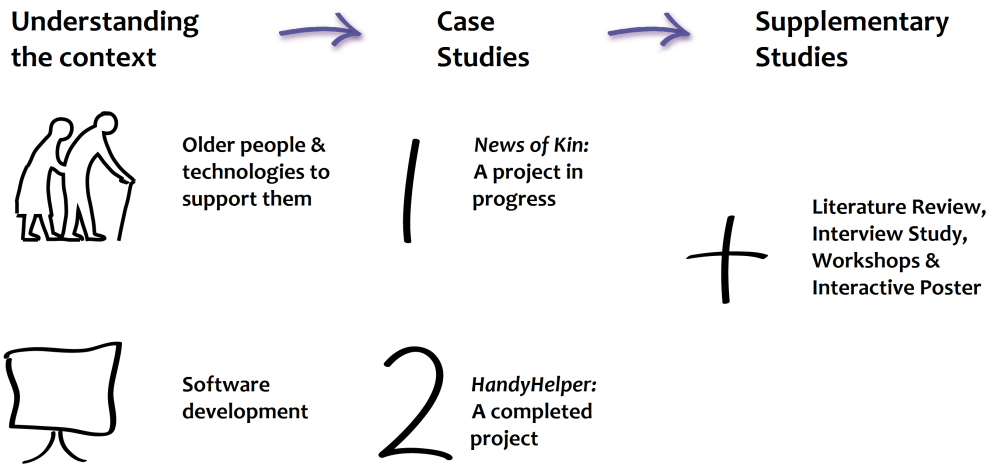


Figure 4.1: Overview of studies conducted for this research

by identifying further issues, but also to check whether issues identified had also been experienced by others. A schematic overview is provided in Figure 4.1. The studies were done independently of one another. However, the studies shown further to the right built on knowledge gained in those studies further to the left. Thus, the case studies (in the middle column) built on what was learned through the literature review on topics relating to the context (in the left column), just as the supplementary studies (at the right) built on the exploratory case studies of projects. The studies are described below, in the order in which they were started:

- *Initial literature review to understand the context*: This was be done before the start of the empirical work. This is important to understand where the research fits into existing research (Adolph et al., 2011). Based on the aspects investigated by the research questions, the initial literature review covered aspects related to older *users*, *technologies* to support them and software *development processes*. The literature was revisited during the final analysis and writing up of the individual studies.

- *Case Study 1 "News of Kin"*: To get about information what happens during the development, ethnographic methods were applied to study one project in detail as a participant observer. The plan was to take part in project meetings. To get a more complete picture this was supplemented by studying project documents and interviewing team members. In an effort to gain insight, I looked at aspects, such as what was said during the development, what was recorded, on what basis design choices were made, what methods were used - aspects that cannot be collected from documents alone, nor can they be reconstructed accurately retrospectively. Due to the amount of detail available, this case study provided valuable insight particularly with respect to RQ 1, 2 and 3.2, which relate to the users, sensor technology being

used, and the way decisions were made. Since understanding of users is particularly important during the requirements analysis, and since also important decisions about the design and architecture are made early in the project, the focus was put on the first iterations, i.e. until a working version was available, though not until the system was stable enough to be marketed. At the outset the success of the project could not be known, though in the end it was not successful in getting to market.

- *Case Study 2 "HandyHelper":* To get information about the entire development process, which in AAL may span a number of years until a system is ready for market, a retrospective analysis was conducted. In order to identify factors that may contribute to less than successful outcomes, it was essential to choose a project that did *not* succeed. By covering the whole process, this case study was particularly valuable for RQ 4, which concerns wider issues that could affect success. This case study analyzed available documents about the development of the project, and supplemented this by interviewing people who were involved in the development. Since the company in the first case study was a start-up with experience in AAL, to support having heterogeneous cases, a larger company with no prior experience in the area was selected for this case study.

- *Supplementary studies*: These studies gained evidence of the relevance of the issues identified by checking if others had experienced them, identified additional issues, gathered information about how the issues were interconnected, and got suggestions about how to solve some of these. First the literature was consulted again, to compare the findings of the case studies to reports of software development and also other projects developing AAL technology around the same time. Then, a series of empirical studies was conducted, which involved people who had been involved in the development of AAL technologies. This included an *interview study*, *workshops* and an *interactive poster*, again with a focus on companies. These studies were important, as case studies are by their nature idiosyncratic - this supported gaining information about a larger number of projects from a broader group of people with expertise in these types of technologies. Since the case studies were both in Austria, for these an effort was made to include people from other countries, as well. These studies also supported the quality of the results by checking the relationship of the case studies to "the real world".

In addition to this, but not part of the results, further empirical studies were done with students to explore some of the issues identified in Case Study 1. Although the use of empirical studies with students is considered valid in the area of software engineering to gain preliminary evidence (Carver et al., 2010), these are not included in the thesis results since the focus here was on companies, but only in the appendices (see Appendix F). However, they are mentioned here since a constructivist view was taken, as they may have had an influence on the results.

Table 4.1 shows which studies addressed which research questions. A ✓ indicates that this study provided data related to the corresponding RQ. Although both case studies

Table 4.1: Research questions addressed by each study

Study	RQ 1 users	RQ 2 sensor technology	RQ 3.1 methods	RQ 3.2 design decisions	RQ 4 wider issues
Case Study 1	✓	✓	✓	✓	✓
Case study 2	✓	✓	✓	✓	✓
Literature review					
Review of *AAL* *Programme* projects	✓		✓		
Interview study	✓	✓	✓		✓
Workshops					✓
Interactive poster					✓

Table 4.2: Contributions of each study

Study	Taking a new perspective	Rich case study description	New issues	How issues connected	Suggestions to address
Case Study 1	✓	✓	✓	✓	✓
Case study 2	✓	✓	✓	✓	✓
Literature review	✓				
Review of *AAL* *Programme* projects	✓				
Interview study	✓		✓	✓	✓
Workshops	✓		✓	✓	✓
Interactive poster	✓		✓		

addressed all research questions, they had a different focus: Case Study 1 was particularly important with respect to RQ 1 and RQ 2, as it was possible to follow the discussions during the development meetings and also RQ 3.2 as it was possible to see how decisions were made in practice; Case Study 2 was particularly important with respect to RQ 4, as it was possible to see how things developed during the entire development process. Both case studies and the interview study provided valuable data with regard to RQ 3.1 regarding methods applied.

Table 4.2 shows the relationship between the studies and the types of contributions made. All studies took the new perspective of looking at the development processes and all empirical studies generated issues. With regard to seeing how the issues were connected, the studies supported this in different ways that complemented one another: the case studies and interview study provided important contextual information about projects that supported understanding; the workshops provided a series of categories that helped to make sense of how the individual issues fit together. The contributions of the thesis will be discussed in more detail in Chapter 8, after the results have been presented.

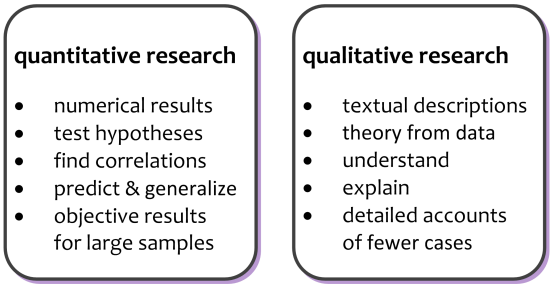


Figure 4.2: Some strengths of the different research approaches

According to Creswell (2003, ch. 7), the chosen methods were suited to the goals: case studies supported exploring an area to get information about the issues; ethnography, based on observations over a prolonged period, was appropriate to the goal of understanding; and thematic analysis supported identifying themes that were not immediately apparent.

The choice of participants in the empirical studies was also important to the quality of the results. The choice of case studies and participants for the supplementary studies is described below, after the choice of methods is explained.

4.4 Choice of methods

In the following, the methods chosen and their relevance to the research is described. More details about the way the methods were applied in practice are provided afterwards.

4.4.1 The suitability of qualitative methods

Due to the questions asked, for this research a qualitative approach was chosen. The focus was on exploring and understanding, rather than creating something, at looking at complex data to see what issues there are. Qualitative methods are suited to this (Braun and Clarke, 2013, p. 4). Using qualitative methods supported getting more background, for instance, as to why people did things.

Other methods would have been possible, also with case studies. For example, using quantitative methods would have been possible by first setting a hypothesis or counting how often certain words were used. Mixed methods would also have been possible, for example, by doing a survey as part of the supplementary studies (Pluye and Hong, 2013). However, some of the strengths of qualitative research (see Figure 4.2) closely related to the research questions: explaining and understanding.

Qualitative methods can be used in a variety of ways. They can be used to describe a situation, and can provide a story that can touch us (Pluye and Hong, 2013). It may also be possible for the researcher to attribute cause or provide explanations using them. Generally, the theory is developed based on the data collected, rather than using the data to prove a hypothesis. But here the stance taken has a deciding influence (Braun and

Clarke, 2013; Charmaz, 2006). In this research, the case studies describe what happened, and were used to provide explanations.

Qualitative methods are not new in computer science research, methods such as narrative analysis, ethnography and grounded theory have been applied (Holz et al., 2006). *"Qualitative case study has been rapidly gaining acceptance as a valid and valuable research method in a large number of diverse scientific domains."* (Baskarada, 2014, p.20). This is true also in computer science: prior to 2004, qualitative methods were not widely used in computer science, with case studies being most common (Glass et al., 2004, p. 91); more recent research indicates that qualitative analysis of textual data is now relatively common (Clear, 2014, p. 23). With relation to the topic of this thesis, qualitative research is an accepted method in software engineering (Dybå et al., 2011; Seaman, 1999), and is not new to HCI (e.g. Floyd et al., 1992). Furthermore, qualitative methods are most common in information system research, which includes studying the development or implementation (Glass et al., 2004, p. 90).

4.4.2 Methods to collect data

The methods chosen for this thesis include *case studies* based on observations, interviews and artifacts, including one ethnographic case study done as a participant observer, and one retrospective case study. To get information about other projects, *interviews* with individual people, *workshops* and an *interactive poster* were used. Of these, the methods case studies, ethnography and interviews have been used in HCI previously (Wobbrock and Kientz, 2016). Since the research is looking at how development is done, software engineering is also relevant. In qualitative studies in that area, the methods participant observation and interviewing are principal methods (Seaman, 1999). The methods applied are described below.

Case studies

Using case studies allowed getting richer data to support gathering details about what is happening over a longer time during a project. Combining more objective, but also narrower, sources, like documents or observations, with interviews supported getting a complete picture and also understanding *why* things were done (see Smith, 2001).

Case studies are suited to studying things that are not yet well understood, for getting information about how and why, especially when the context is relevant, but can also be used to confirm results of previous research (Baskarada, 2014), and thus were suited to the topic of this research. They have the disadvantage that the researcher has little control over events. Each case is unique. The quality of the results was supported by looking at multiple cases that were carefully chosen (see Baskarada, 2014).

In qualitative research different types of case studies are distinguished: *intrinsic, instrumental* or *collective* (Cohen and Crabtree, 2006). An *intrinsic* case study could for instance describe how one older person manages in everyday life as part of research about older people to exemplify people in that situation. Used *instrumentally*, it could describe the person's experiences to explain the problems with a system. This differs in that it

describes the person, but is the primary goal of the case study is to explore something else, i.e. the system. *Collective* case studies include multiple case studies with something in common that are considered as a whole to help explore a topic. An example of this would be a study of older people who live alone without relatives nearby, based on ten people in this situation. Of these, *intrinsic* best describes the type of case studies used in this research.

Case Study 2 was a *retrospective study*, i.e. it looked at something in the past. This is a special type of case study, because it aims to recreate something (Flick et al., 2000, p. 255). Retrospective case studies have the advantage that the outcome is known at the outset. For this type of case study, consideration needs to be given to which documents and materials are included. Interviews can provide other viewpoints to supplement materials from the past. Consideration also needs to be given in terms of how things have changed and how this may affect our views, something that is especially relevant with the constructivist viewpoint being taken.

Case studies have been used in areas related to this thesis: case studies have been done both about AAL projects (e.g. Müller et al., 2015), and also to study software development (e.g. Friess, 2012; Blomquist and Arvola, 2002)

Observations

For Case Study 1, observations were used, as they can provide very detailed information (Sharp et al., 2007). Whereas in an interview, someone may report something inaccurately or answer based on what they think is important, through observations it is possible to see exactly how people do things, what the context is like, etc. From an observation, it is possible to glean details the person may not be aware of or may filter out, but it is not possible to know *why* things were done that way. It is also not possible to know if something is always done in that way by observing only one instance.

Case Study 1 was an ethnographic study done as a participant observer. Observing in situ is a key method for *ethnography* (Randall et al., 2007). Ethnography involves studying a specific group over a period of time to describe and understand their actions (Charmaz, 2006, p. 21), and so gives a more complete view. Since observations provide only a partial view, they need to be supplemented and cross-checked using other methods (Smith, 2001); for example, through interviews, documents and artifacts. Due to the large amount of data involved, they can provide data not available by other means, but entail a great deal of time to collect and analyze the data. To support non-participants understanding and evaluating the data, a *thick description* may be produced, that describes the actions in detail and put them in context (Cohen and Crabtree, 2006).

Participant observation is somewhat different, because rather than passively observing, the person takes part in the activity (Flick et al., 2000, pp. 385-389). This method was used for this research, as the method is particularly useful when exploring a topic (Flick et al., 2000), and can provide a very complete source of information about events (Becker and Geer, 1970, p. 133). Being actively involved complicates issues such as taking notes. Another problem is the amount of data. Furthermore, the research may lose focus of the research goals in the day-to-day activities. Gold (1958) differentiates

the role of the researcher based on the balance between being an observer and being a participant. This ranges from *the complete participant* who observes covertly, to *the participant as observer*, *the observer as participant*, and, lastly, on the other end of the scale, *the complete observer*. In Case Study 1, the planned role was that of *observer as participant*, something that was also agreed with the project leader at the outset. Participant observation has been used in HCI, both to gather information about the way technology is used (e.g. Rode, 2011) and also to research development practices (e.g. Blomquist and Arvola, 2002).

One limitation of observations is that it may not be possible to observe an entire process. Thus, the choice of what to observe is essential. For Case Study 1, the early phases of the development were chosen. It was thought that these could provide the most valuable insight. Developers often stick to design features of the user interface decided early on (Hassard et al., 2009). In addition, the software architecture is determined early in the development, a choice which can support or limit the ability of the system to meet the requirements (Falessi et al., 2011).

Another consideration with observations is that the people being observed may perform better, something called the Hawthorne effect (Obrenović, 2014). However, this was not an issue for this research, as this effect holds primarily for experiments and not for extended field observations like those used to understand complex situations with a social element, such as work environments (Obrenović, 2014).

Although the method comes from anthropology, ethnographic accounts based on observations have been used in HCI going back many years, including the seminal analysis of work practices at London Underground by Heath and Luff (1991). It has also long been used to study the work of developers (e.g. Robertson, 1996; Blomquist and Arvola, 2002; Friess, 2012). When studying development processes, ethnography based on observations supports uncovering important details related to the research questions of this thesis, for example, which users or personas considered at the outset were really used as the basis for design decisions (Friess, 2012).

Interviews

For this research, interviews were used both to gather more information about further projects in the interview study, but also as part of the case studies. Interviews are suited to exploring topics (Sharp et al., 2007), for example, investigating what people do, exactly how they do it, and even why. Used separately, as for the interview studies, they provide more context than surveys and give researchers the chance to ask back (Sharp et al., 2007) and thus support understanding. Used in combination with other sources, as was the case with the case studies, they support getting a more complete view (Smith, 2001; Adolph et al., 2011) and different viewpoints (Charmaz, 2006; Flick et al., 2000; Smith, 2001). It is possible to get first impressions during the interview itself, but most of the information comes from the analysis afterwards.

Interviews can be categorized as structured, unstructured or semi-structured (Flick et al., 2000; Braun and Clarke, 2013, p. 78). *Structured* means that all of the questions are set in advance. This format supports comparing the answers of participants. Still the

questions can be asked in a different order to support a more natural flow of the interview. However, even if the questions are set, it is not necessarily easy getting the information desired (e.g. Northrop, 2011; Flick et al., 2000, p. 359). *Unstructured interviews* are the other extreme, where no questions are prepared. This format is suited to exploring something new. In order to gather rich and more accurate data, it is preferable to ask open questions, e.g., starting with "how". When asking about someone's work, it is best to ask them in the real context, much like the method contextual inquiry does (Holtzblatt and Jones, 1993). The *semi-structured* format combines the two formats, allowing the interviewer not only to check back if something is not clear, but also to explore topics that were not initially considered, while still ensuring that the desired topics are covered. For this research, a semi-structured format was chosen, as it supported answering both the more specific questions, like RQ 1 through 3.2, and also gathering information about other issues, as required for RQ 4.

Consideration also needs to be given to the way in which the results are recorded. In ethnography, there is some disagreement about this. While some recommended that people take only notes, others recommend making recordings so that these can be listened to multiple times to make more sense of the data (Randall et al., 2007, p. 184), even if the notes are used for the analysis (Randall et al., 2007, pp. 17-21). If notes are used as basis for the analysis, there may be a filtering (Randall et al., 2007) and it is important to mark anything in them that is a subjective interpretation. Whereas when taking an ethnomethodological viewpoint, detailed descriptions, non-verbal actions and the exact sequences need to be recorded; in a constructivist study, the original sources are more important, as notes and even a thick description can be considered a construction. With audio- and video-recordings, there is the possibility to transcribe in more detail and with more precision. However, even if a full transcription is made, it is useful to take field notes (Braun and Clarke, 2013, pp. 92-93).

There are several different options with transcription (Flick et al., 2000); for example, transcriptions can include *utterances*, e.g. "um" or where the stress was put when speaking, *actions*, like a person scratching their head, or also *positions*. There are specific transcription methods to record these different details reliably, though it is recommended only to include those details that are relevant to what is being studied (Flick et al., 2000), and so methods used may vary between fields, for example, between psychology and linguistics. Here utterances and actions were only relevant insofar as they gave information about meaning, and did not need to be recorded systematically, making an audio recording sufficient.

Others have used interviews in HCI to study development methods, both separately (e.g. Bednarik and Krohns, 2015) and to supplement other sources (e.g. Blomquist and Arvola, 2002).

Collecting data from a wider group

To supplement the case studies, the research also planned to collect data from people with experience in the development of AAL technologies in order to get information about a larger number of projects. Rather than conducting interviews with a single person,

including multiple people in sessions allows for synergies between the participants (Sharp et al., 2007). For this, group interviews (Flick et al., 2000), focus groups (Sharp et al., 2007) and workshops were considered. Workshops were chosen, as unlike interviews and focus groups, they go beyond discussing problems and allow something to be *produced*. Furthermore, the format used allowed people to record their ideas and experiences, and use these for subsequent steps.

Since one aim was to consider solutions, the *future workshop* method (Apel, 2004) was considered for application, as in this people with a common problem are given the chance to work together to solve it. The method is used less for technical problems like the subject of this thesis, than for social issues. There are three main phases (Apel, 2004). The first phase is the "critique" phase. Participants sit in a open circle and first discuss the problem. Issues are written on small cards that are then clustered by topics. Those issues that are then selected and prioritized. The next phase is the "fantasy" phase. Various techniques are used to help people open up and come up with possible solutions. All ideas are recorded, even if they are not realistic. In the final, "implementation phase", the solutions are transformed to a set of realistic steps. Since the goal is to *solve* the problem, at the end, an action plan is developed and the tasks assigned within the group. For this research, elements of the future workshop were used to support considering not only issues, but also possible solutions. Since the actions being considered in the workshops in this research were not directly relevant and could not be acted on by the participants, only the *critique phase*, including the discussion, clustering and prioritization or rating of issues, and an abbreviated *fantasy phase* were incorporated.

Finally, an interactive poster format was used to reach a more international audience. Although not widely described as a method to collect data, it has been used previously in HCI to study development practice, for example, to collect data (Hallewell Haslwanter et al., 1994; Muller et al., 1995) for a study on participatory design methods (Muller et al., 1997). This method of collecting input was thought to be valuable, and hence was used again for later research (e.g. Muller, 2001). Using a poster format for the research in this thesis allowed participants to build and comment on earlier contributions from other participants. This was important both for the rating, but also with regard to seeing if other people had experienced similar issues. Rather than rating on an absolute scale, participants could consider the rating of other issues in rating the new ones they added (see also Figure D.2 in the appendices showing the poster). With respect to similar issues, it allowed participants to decide themselves whether they thought the issues described were the same, rather than having the researcher decide. However, in comparison to a survey, less data could be collected.

4.4.3 Methods to analyze data

A variety of methods for analyzing qualitative data exist (Braun and Clarke, 2013). Some important ones are content analysis, grounded theory and thematic analysis.

Content analysis comes from the ethnographic tradition and attempts to identify meanings which emerge from the text being analyzed, i.e. the meta level. For identifying

issues, qualitative content analysis (Priest et al., 2002; Cohen and Crabtree, 2006) was judged to be less suited than thematic analysis and grounded theory due to the focus on the meta-level. *Grounded theory* is a well established and very systematic analysis method for qualitative data, that was developed in an attempt to counter positivism by providing a framework for "legitimate" qualitative research (Cohen and Crabtree, 2006). However, since the topic of this research was exploratory, a theory was not needed. Since thematic analysis is lighter than grounded theory, and according to Braun and Clarke (2006, p. 8) is suited if researchers do not want to develop a theory, this method was chosen.

Thematic analysis

Thematic analysis is a widely used method that aims at identifying themes that match the whole of a data set. Since it is not a well-defined method, Braun and Clarke (2006, tab. 1) attempted to formalize the method for psychology by defining a series of steps:

1. Familiarizing yourself with the data
2. Initial coding
3. Finding themes from the codes
4. Reviewing themes, mapping them and checking back with the source material
5. Developing the story and naming themes
6. Writing it up

Like other qualitative methods, thematic analysis should be applied systematically and thoroughly (Braun and Clarke, 2013, p. 201). The 4th step is an important one, as it can help to ensure that the themes really match the data set (Braun and Clarke, 2006, pp. 21-22).

There are great similarities between this method and grounded theory, for example, collecting data, coding, identifying themes or categories, mapping or diagramming the themes or categories, and finally developing an account (see Charmaz, 2006, p. 11). Still, Braun and Clarke (2006) say thematic analysis can be considered a separate method. One big difference is that grounded theory aims to build a theory, although not all researchers include theory building (Charmaz, 2006, p. 133). Still, in trying to build a theory, grounded theory looks at the data to decide when saturation has been reached or whether more data need to be collected (Charmaz, 2006, pp. 113-115), rather than analyzing only the data available as is usual in thematic analysis. Although Braun and Clarke (2006) do not include this type of iteration, they also stress the importance of the completeness with respect to the quality of the results. Thus for this research, an extra step of identifying gaps in the data, and iterating if necessary, was added before writing up.

A type of thematic analysis has been applied in areas related to the topic being studied in this thesis: it has been widely applied to textual data in computer science (Clear, 2014, p. 23); it has been used to identify some challenges related to smart home systems, including AAL systems incorporating monitoring features (e.g. Wilson et al., 2015; Sanders et al., 2012); and it has been applied in HCI, e.g., to identify the issues older people have with existing technologies (Money et al., 2008, 2009), to study development processes (e.g. Blomquist and Arvola, 2002; Grünloh et al., 2015), and to study the way design decisions are made (e.g. Hassard et al., 2009). Thus, it has been used in areas related to the research questions in this thesis, e.g. understanding challenges related to a certain technology and studying design decisions during the development.

4.5 Way in which the research methods were applied in practice

In the following the methods used for collecting, recording, analyzing and validating the data are described in more detail. This is important as the credibility of the results relates to the quality of the data (Charmaz, 2006, p. 18), and as there are potential pitfalls of thematic analysis. According to Braun and Clarke (2006), these include:

- Not doing analysis,
- Using the initial questions, e.g. from the interviews, as themes,
- Weak analysis, e.g. themes overlap or are inconsistent,
- Themes that are not supported by the data or are not conclusive, and
- The type of thematic analysis does not fit the research goals.

4.5.1 Data collected

The goal was to collect rich data appropriate to qualitative analysis from a number of different sources.
For Case Study 1, studying the running project, data was collected as follows:

- Observation of / participation in the meetings during which most interaction and discussion took place. These allowed information to be collected relating to all research questions.
- Semi-structured interviews with different team members at different points during the development to gain their perspective, clarify points that were unclear and also to gain information about parts of the projects that were not observed directly.
- Analysis of documents generated during the development process. This provided additional information about the project, but also indicated what information from the meetings the team thought it was important to record.

For Case Study 2, looking at the completed project, the sources used were:

- Documents available about the project from throughout the development, including both documents from the project and documents by others about it. From these, information could be gained about which stakeholders were included, how users were included, and which features were included.
- Semi-structured interviews with people involved in the development, in order to include the views of different stakeholders and to get additional information that was not available from the documents. These supported getting information about issues the development team faced during the development, why certain design decisions were made, and clarifying points that were unclear from the documents alone. In some cases, follow-up e-mails were used to clarify individual points after the interview.

The data for the *supplementary studies* included the following sources:

- *Interview study* This included four people involved in projects developing monitoring technology for AAL. Participants were asked about methods applied, users involved, issues encountered and recommendations for other people developing these types of systems (the list of questions is provided in Appendix C). Since it is recommended not to rely on interviews alone when studying development using qualitative methods (Adolph et al., 2011), for all interviews, additional documentation about the project was used for understanding what was said, though not included in the actual analysis. In some cases, follow-up e-mails were used to clarify individual points.
- *Workshops* These supported gathering data from additional people with experience in the development of AAL technologies. The process involved discussing and brainstorming issues, checking if issues from the case studies had also been experienced, clustering the issues, rating them, and finally developing solutions for some of them. To support the goal of understanding, information about the participants was collected and audio recordings were made at the workshops.
- *Interactive Poster* Through presenting the poster at a conference, an international group of people with experience in the development of AAL technologies could be included. People could support issues from the case studies, workshops and previous participants, or add new issues with a rating. This data had the least contextual information.

All data collection was performed by a single person (the doctoral candidate). This made it easier to get an overview. Discussions with the thesis adviser in some cases supported recognizing where more data was needed.

4.5.2 Data analysis method

The analysis was based on thematic analysis (Braun and Clarke, 2006), with some elements of grounded theory.

The following iterative process was used:

1. Studying the data.
2. Analyzing the material to find "codes" in the data, e.g. line-by-line open coding.
3. Identifying the themes, e.g. the most important and/or frequent codes.
4. Reviewing the themes, e.g. identifying where these themes occur.
5. Making sense of the data, for example, creating lists and chronological accounts to look at the overall story, writing memos about the relationships between the themes/codes, mind mapping. etc.
6. Identifying gaps in the data that need to be filled.
7. Writing up a (partial) narrative or story, including compelling quotes.

The first five steps and the final one are the steps for thematic analysis as described by Braun and Clarke (2006). As mentioned with the description of thematic analysis earlier, the penultimate step, adding a layer of iteration, was adopted from grounded theory (Charmaz, 2006) to increase the completeness of the data by gathering additional data when something was unclear.

With regard to the exact steps used, one important aspect for the case studies was checking for subtle differences between the initial codes in the data and the themes, something that can be time consuming (Brown and Stockman, 2013). The analysis for the case studies was more extensive than for the supplemental studies, especially the step *making sense of the data*. For the workshops, some of the making sense was done by participants, who categorized the issues.

The two methods on which the analysis was based are compatible with constructivism (Braun and Clarke, 2006; Charmaz, 2006), even though thematic analysis is often associated with the realist point of view (Braun and Clarke, 2006, pp. 6-9). The codes used in the first step should be based on the material, rather than proving a hypothesis. However, Braun and Clarke (2006, p. 7) stress that the codes or themes used do not just 'emerge' even with an inductive or open analysis, i.e. using themes that come from the data - the researcher takes an active role in choosing those of interest to the research. From a constructivist point of view, the analyst looks less for motivations, than socio-cultural explanations that fit the accounts (Braun and Clarke, 2006, p. 14). Furthermore, latent or underlying themes that go beyond what is said directly, are more common when this point of view is taken (Braun and Clarke, 2006, p. 14).

4.5.3 Tools used to record and analyze data

Since the validity and quality can also be affected by smaller details, the tools used to collect and analyze the data were given careful consideration.

Data collection

The data collection attempted to be fairly comprehensive, so as not to filter out important aspects before the analysis, but also to allow things to be checked later. The method of handling the data collection was set after the first sessions, i.e. interviews and observations, and applied consistently for the rest the research.

For the meetings in Case Study 1, where little if any interaction was required, relatively thorough notes were taken. Audio recordings were made. Due to the large amount of data and the lower density of information in the meetings, they were not transcribed in full and notes were used for the analysis. The recordings supported filling gaps.

During interviews, in some cases a few notes were taken in order to better focus on what was said and what to ask. Again, audio recordings were made. The recordings were used for transcription and supplementing notes. Recordings were made using the Android app Tape-A-Talk, that allows audio recordings to be made with a smartphone.

All transcriptions were done by the researcher. F4 was primarily used, a tool that allows an audio file to be listened to while the text is typed in a window, and has functions to support reviewing parts that were not understood. Figure C.1 in the appendices illustrates the transcription with this tool. For the interviews from the Case Study 1 that were in English, Dragon Naturally Speaking™ was used, which does transcription based on input from the microphone. Since the software adapts to the speaker, to get accurate transcriptions the audio recordings were listened to on a headset and re-spoken for the transcription software, and then checked and corrected. The first method was slower, but had the advantage that the transcription and the audio record were linked, so that it was easy to go back to a certain passage. In places were there were laughs or long pauses that might be significant to the meaning, these were also included in the transcript.

With regard to project documents, copies of the complete documents were used for the analysis. These were stored chronologically and included the date in the file name, so it was possible to see how the themes changed over time.

Data analysis

The techniques for the data analysis were chosen after investigating tools for qualitative data analysis (e.g. Lewins and Silver, 2004). In order to be consistent, the same tools and methods were used throughout.

The coding was done manually. However, even with manual coding, it can still be helpful to use a tool to manage data (Adolph et al., 2011; Lewins and Silver, 2004). For the case studies, the tool ATLAS.ti™ was used. This tool allows themes to be marked manually and memos to be made. It can be used with open or closed coding. This made it easier to later join initial codes to themes, to see which recurred, to see how the themes developed over the course of the project, to navigate to other places they were used to see the context, etc. Figure B.1 in the appendices shows an example of how codes could be navigated.

To get a better understanding, thick descriptions of the case studies and interviews were written during the analysis. In addition, tables, mind maps, and free hand drawings

were made in order to get an overview and make sense of the data. Excel™ was used for the tables and the tool FreeMind was used for mind maps.

The materials studied were in English, German and French, languages in which the researcher has worked. Thus, the original source materials were used for the analysis.

4.5.4 Choice and handling of participants

Choice of case studies

Case studies inherently only provide information only about a limited number of cases. Since it was necessary to gain access for interviews, documents about the projects and observations, it was difficult to find candidates.

Both case studies originated from contacts the researcher had prior to starting her studies. Case Study 1 came about through someone with whom I had previously discussed collaboration. He contacted me when he received funding for a relevant project, and agreed that I could be a participant observer. With respect to Case Study 2, I became aware of the project and the problems it faced through colleagues and other researchers; the contact to people involved in the project was then established through a work colleague. As part of the literature reviews for the supplementary studies, the projects were checked to make sure that they were in line with the state of the art, e.g. in terms of methods they applied and team size.

The two case studies, Case Study 1, the smaller *News of Kin* project, and Case Study 2, the more comprehensive *HandyHelper*, complement each other in a number of ways:

- *Length of period and detail* Case Study 1 provided more detail than would have been possible from a project that had been completed; Case Study 2 showed a project over the entire development. Case Study 1 provided lots of detail about the first phase of development, about which there was the least information for Case Study 2.

- *Size of company and project team* Case Study 1 was a smaller project done by a start-up; Case Study 2 covered a bigger project developed by a large, established company. Through the two projects, a range of team sizes could be considered. Case Study 1 included a core team of 2 people; depending on the phase, Case Study 2 included up to 20 developers, not including non-developing partners. Case Study 2 also included a number of partners in one phase. Since that the EU wide funding AAL Programme encourages the entry of SME into this field (AAL Joint Programme, 2017), it is appropriate that one company was an SME.

- *Experience in AAL* Case Study 1 was about a company that had previously developed interactive systems for older users, but had less experience with sensors; Case Study 2 was about a company that had not previously developed a system for older users, but had experience with home automation components. Both projects included technical experts outside of the company to get expertise about sensors.

- *Internationality* Case Study 1 included experts from two other countries. In contrast, Case Study 2 included participants exclusively from one country.

- *Period in time* Case Study 1 provided information about more recent projects, whereas Case Study 2 gave insight into the situation just after the report on aging from the European Union (European Commission, 2006) and the first wave of AAL in Europe. One of the people interviewed from the older Case Study 2 thought wireless technology could be an important development - technology that was evaluated in Case Study 1. In part due to the fact that Case Study 2 was one of the early AAL projects, it was closely watched by the press and frequently reported on, in part due to the large show home that was one of the first showcasing this type of technology.

- *Comprehensiveness of the system* Case Study 1 aimed at a minimal solution, whereas Case Study 2 aimed at a more comprehensive solution. Both included a monitoring component of what Turner and McGee-Lennon (2013) call the second generation of telecare that used sensor data to generate alarms, and planned to integrate quality of life features, like systems of the latest generation.

- *Private homes vs. care homes* Case Study 1 was aimed at people living in their own homes and their family members caring for them, though it could also be used in assisted-living units; Case Study 2 was initially aimed at people living in their own homes, though the later phases of the development aimed specifically at people living in assisted-living facilities with professional carers.

- *Making it to market* It was known in advance that Case Study 2 was not entirely successful; Case Study 1 was studied from the start, so although it also experienced problems and did reach its goal of making it to market, this was not known at the outset. Case Study 2 did make it to market, but was withdrawn as it as did not pay off, and so was not successful in reaching its goal of having a commercially viable product.

- *Funding* Both received external funding, but used different sources of funding that had different requirements in terms of innovation, reporting and partners.

The terminology used with regard to the selection of case studies varies (Baskarada, 2014), so that multiple classifications are possible. Both case studies can be considered *intrinsic* (see Cohen and Crabtree, 2006; Baskarada, 2014, p. 5), as they exemplify the development of systems aimed at older people integrating sensor-based components and were aimed at gaining a better understanding of the development that was studied, and not of something else. Case Study 2 took place in the past, and hence was also *retrospective*. Since it was chosen due the problems it experienced, it belongs to the selection basis termed by Baskarada (2014) as *"worst cases"*, that are suited to seeing why things are not working. Together the case studies cover important variations, and so are *representative* (Baskarada, 2014, p. 7) or *heterogeneous* (Braun and Clarke, 2013).

Choice of participants in supplementary studies

For the interview study, it was important to cover a number of projects developing AAL monitoring systems, ideally from the same time frame as the case studies (2008 to 2014). The goal was to find participants from companies or, where that was not possible, research organizations that planned to take the system to market. An attempt was made to include at least one smaller company (like Case Study 1) and one larger company (like Case Study 2). To include the experiences of different cultures, furthermore, it aimed to include someone from a country from the southern part of Europe and another from the northern part of Europe. Finally, to cover the diversity of European countries, an effort was also made to include one participant from a more populous country that has access to a larger market and one from a country of a similar size to Austria. These goals were reached.

For the workshop and interactive poster, a broad group of people involved in the development of AAL technologies were included. Participants of the first workshop were invited to ensure the desired diversity was covered. Based on the case studies this included different type of organizations (research organizations, universities and companies of different sizes), different amounts of experience in AAL (people who had been involved in multiple projects developing AAL technologies and some that were relatively new to the area), and different disciplines (e.g. technical, business, health care, HCI). The second workshop and interactive poster were held at international conferences, which enabled participants from a number of countries to be included.

For the supplementary studies, it was not possible to limit the input to monitoring technologies: one workshop and the interactive poster were open to all participants; furthermore, some participants had been involved in multiple AAL projects, some of which were not telecare monitoring systems.

4.5.5 Measures to support validity and quality of the research

How can one be sure that the results are valid? For experiments, repeatability needs to be considered, something that is not relevant for non-experimental or qualitative work.

Validity relates to making good choices. For example, there are many ways of choosing case studies (Baskarada, 2014). One can choose extreme cases, e.g. a *bad* one, to demonstrate what is going wrong, or a *good example* to see what might contribute to success; or a *typical* or paradigmatic case; or a case of *special interest*, matching specific, less common, criteria. If multiple case studies are used, one can choose the *extremes* or maximum variation with to see what the differences are, or *representative* cases, that include important variations. The best choice depends on the goals of the research.

Validity can also be affected by things outside of the control of the researchers. For example, *access* to projects or information about them may be denied. Even if a group only denies access to information relating to their own image, it can slant the results. (Flick et al., 2000, pp. 288-290)

Especially when it comes to constructivism, validity means being aware of the biases that come up in the research and documenting these. In the following, first the aspects

considered to support the validity and quality are presented, then the way these aspects were considered in this research.

Aspects considered

For qualitative work, there has been much discussion about the criteria that ensure validity or quality (Flick, 2007). Certainly having multiple cases or sources generally supports validity (Charmaz, 2006). Baskarada (2014) describes five aspects to consider in qualitative case studies, like those that form the basis of this research, all of which are also mentioned by other sources (note the naming here differs from the original source):

- *Checking back* It is important that the results relate to what is being measured and that the data match the claims made. For case studies, some strategies to support this include having multiple sources of evidence (called *triangulation*), having people involved review the case study (called *member checking*) and maintaining a chain of evidence for conclusions. Braun and Clarke (2013, p. 282–286) also mention triangulation and member checking as quality criteria for qualitative research.

- *Credibility* The source of the data is relevant to the quality. For case studies, this includes both the choice of case studies and volume of material included. It can be improved by comparing multiple cases. Although this criterion is less relevant for exploratory case studies (Baskarada, 2014, p. 8), also Charmaz (2006), who comes from the constructivist tradition, supports the importance of credibility for qualitative research.

- *Transferability* Another point to consider is whether the results can be applied or transferred to other cases. This is the counterpoint of the generalizability in positivist, quantitative experiments. In qualitative case studies, this is more of an analytic question and about which there is reportedly little consensus. Braun and Clarke (2013, p. 280) say transferability is relevant, and that it bases on describing the context and circumstances specific to the case being studied, so that it is possible for the reader to evaluate whether the results might hold also in other contexts. Recording the context is generally an important aspect when a constructivist viewpoint is taken (Charmaz, 2006).

- *Transparency* It is important to make the procedures transparent, so it is possible to check what was an interpretation (Flick, 2007, p. 16). With regard to case studies, this relates to the way data was transcribed, analyzed, and whether there is a database with the sources of data (Baskarada, 2014), things that contribute both to having a reliable record of what happened and making it possible to trace any conclusions made. This is the counterpoint to reliability in positivist studies, something that is not an appropriate criterion for qualitative work (Braun and Clarke, 2013, p. 279) or at least needs to be interpreted differently (Flick, 2007).

- *Data quality* Among other things, the data should be accurate, believable, and easy to interpret. Problems with data quality can relate to the way it is collected, stored,

accessed, or analyzed. Also Charmaz (2006, p. 18) highlights the importance of data quality.

Braun and Clarke (2013, p. 280) add the criteria *ecological validity*, which they feel is also desirable, though not essential, for qualitative research. This refers to the relationship between the "real world" and what was studied; for example, whether the context in which the data was collected matches the normal context. This also affects whether the results are applicable to real settings. From this point of view, observations have a higher ecological validity than interviews.

Checking back: triangulation and member checking

In addition to aspects related to the choice of case studies and participants described previously, other measures taken to support checking the claims made:

- Multiple sources of data were used for both case studies (the *triangulation* from Braun and Clarke (2013); Flick (2007)). For Case Study 1, observations, documents and interviews were used; for Case Study 2, documents from different sources and interviews were used.
- Some of the results were checked with participants (the *member checking* from Braun and Clarke (2013)). For Case Study 1, this was done through the final interview with the project leader; for Case Study 2, people involved in the project were invited to the workshops, so they could check whether they also thought they had experienced some of the issues identified by the researcher.

Credibility

Some steps were also taken to support the credibility of the sources:

- Both case studies covered a *longer period of time* from the project: for Case Study 1 this included the entire first development cycle; for Case Study 2, the entire development that extended over four years was considered. Flick (2007, p. 19) underlines the value of "prolonged engagement" with respect to credibility.
- It was also supported by adding an *additional step to the analysis process* described by Braun and Clarke (2006), in order to identify gaps and ensure there was a sufficient volume of data for the case studies. The importance of having sufficient data is also mentioned by Flick (2007) and Charmaz (2006).
- *Covering a wider variety,* by having two diverse case studies and including additional people through the supplementary studies, also supported this (Baskarada, 2014; Braun and Clarke, 2013).
- Having two cases and *comparing results* between them also supports validity (Baskarada, 2014). Furthermore, the results were checked against the literature, to see if some of the individual issues identified have been reported by others working

on projects related to sensors and older people, and hence likely to be related to these aspects and not other things, such as using poor methods in the projects. When doing this, the time period of Case Study 2 was also considered, something that is important with retrospective case studies (Flick et al., 2000).

- Since there was only one researcher, *the results were reviewed with the thesis adviser*, to check the explanations, for example, that any causality inferred was justified by the data. According to Flick (2007, p. 19), this also supports the quality of qualitative research.

Transferability

The following aspects support describing the context to support readers being able to evaluate if the results can be transferred:

- *The context and circumstances were described* for each case study. According to Braun and Clarke (2013, p. 282), if this information is available the burden of transferability can be put on the reader.

- *Having more than one* case study, each with different attributes, and including more people through the supplementary studies, supported making it more likely that the results can be transferred by covering a wider variety. This supports having a more heterogeneous view mentioned by different researchers (e.g. Baskarada, 2014; Braun and Clarke, 2013, p. 56).

- Through the supplementary studies, it was possible to *check if other projects had experienced similar problems* and applied similar methods, which also supports readers in judging the transferability of the results.

Transparency and data quality

Both transparency and data quality of qualitative case studies relate to the way the data were collected, transcribed, stored, etc. (Baskarada, 2014). Measures taken to support these included:

- To support the traceability of the analysis, *the data used was kept, and way it was transcribed and analyzed was recorded*, so that the analysis could be checked by someone else, what Flick (2007) calls transparency.

- To increase the data quality, i.e. that it a reliable record, *audio recordings* were made of meetings and interviews, to give an accurate and objective record that could be returned to.

- *Using a tool for the themes* helped to increase the accuracy or objectivity, for example, in determining if the themes changed over the course of the project. Flick (2007, p. 15) supports the importance of having a consistent meaning.

Ecological validity

Some of the steps described with external validity also supported checking the ecological validity described by Braun and Clarke (2013), i.e. that it represents the "real world":

- *Checking that the attributes of the projects and methods applied* by them were similar to projects in the "real world", e.g. checking the team size, project size, development practices to the literature.

- *Checking with a larger number of people* through the workshops and the interactive poster to see whether they had experienced some of the issues identified in the case studies.

The ecological validity was better for Case Study 1, which based on observations, than Case Study 2, especially since some of the documents studied for Case Study 2 were intended for public view, and the interviews were conducted many years later and half were not held in the place the work was originally done.

4.5.6 Ethical aspects

The ethical aspects are important to consider in the research design, also when software development processes are being studied (Singer and Vinson, 2002). Since the university has no formal ethics approval process, general principles used in software development were applied. According to Singer and Vinson (2002), aspects that need to be considered when human subjects are involved include being informed, consent, coercion, the ability to withdraw and anonymity.

Signed consent forms were obtained from all participants who were observed or interviewed (see Appendix A) in the case studies, interview study or workshops. This ensured people were informed, and that they consented, could restrict the type of data collected, and knew they could withdraw.

All people for the case studies and interviews were under little pressure to participate. Although some people who the researcher knew were asked to participate in the workshops, none of these people were under obligation to the researcher or would have had a disadvantage if they had not participated. To reduce the pressure on them, the adviser was not copied on e-mails and only people who indicated interest were contacted again for the second workshop.

Regarding anonymity, the data files used for the analysis did not include the real names in either the file or file name. The data was stored on devices stored in locked cupboards or ones accessible only with a password known solely to the researcher. Details of the company, project, location and job title were not fully described in the results to maintain the anonymity of participants. Furthermore, pseudonyms were used in the publications. Many of the documents from Case Study 2 were publicly available, and hence considered exceptions (Singer and Vinson, 2002). However, an effort was still made to maintain the anonymity of the company in order to protect their image.

People who contributed to the interactive poster could chose to participant or not, but did not explicitly give their consent. Through the text on the poster, they were informed about the purpose of the research. Their contributions were anonymous, as no link was made between the contributions to the poster and the participants.

The main ethical dilemma was in Case Study 1. As a participant observer, it was sometimes difficult, as making comments or suggestions could influence the process that was being observed. On the other hand, the researcher felt beholden to the company for allowing her access.

4.6 Role of the researcher in this research

Finally, in order to judge the research and the contribution of the researcher, some information about the role of researcher in relation to this research is presented.

The idea for the research emerged from preliminary discussions with the adviser and a project discussed previously with a company. The researcher worked alone, and as mentioned previously, had contacts that supported getting participants. All data collection was performed by her. Assistance was received from the thesis adviser, particularly in relation to learning to apply qualitative methods and writing these together. Furthermore, some analysis sessions were done together with the thesis adviser to ensure a high quality of the results. For the workshop, the final design was developed in a meeting with the adviser. Another researcher supported running the second workshop.

Since the thesis was done on a part-time basis, the first studies were started several years ago (2012).

4.7 Summary

In order to gain understanding, a constructivist qualitative approach was selected. Several studies were planned: two case studies to gain detailed information from two different projects about the issues that developers face, and then supplementary studies to extend these results and check whether other teams who had developed AAL technologies had experienced similar issues. Using an analysis method based on thematic analysis supported identifying also issues that were not immediately apparent. The ethnographic methods applied in case studies, the categories and ratings from the workshops, and the recommendations from the participants supported understanding how the issues fit together.

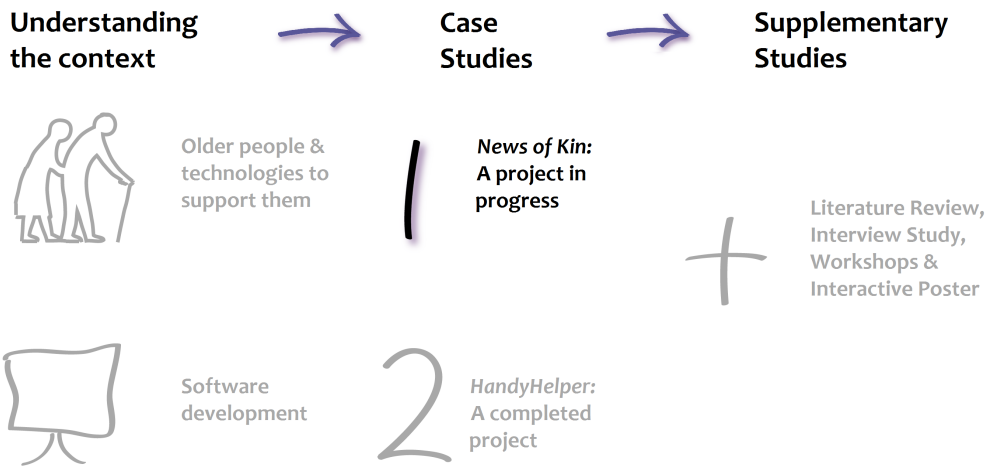
Next the results will be presented, starting with the Case Study 1, which studied a small AAL project during the development.

Part II

Empirical Results

CHAPTER 5

Case Study 1 *News Of Kin*: A project in progress



As described previously, little is known to date about the what happens in detail during the development of sensor-based monitoring systems for older people. To explore this, a project based on sensor technology being developed in a small company in the EU was studied as a participant observer in development meetings. The project is referred to here as *News of Kin*. The company was concerned about older people and engaged in a UCD development process. Using ethnography and taking part in meetings allowed information about details during the development process to be gathered, that would not be available from documents alone, such as how users were considered and discussed by the team, what methods were used and how decisions about functionality were made, and contributed to understanding more about the issues the team faced. Thus, although it

supported gathering data relevant for all research questions, since it observed the process, it was particularly valuable for RQ 1 relating to how users were involved, RQ 2 about how using sensor based technology affected the development and RQ 3.2 relating to how decisions were made.

At the time of the study, it could not be known if the project would fail or succeed. The goal was just to observe the project during the development. The project was approached openly, albeit after a preliminary literature survey: to observe what happened and look at where the problems could be. The case study and key findings in this chapter have been published in a peer-reviewed HCI conference proceedings (Hallewell Haslwanter and Fitzpatrick, 2013) - the flow of the argument is kept close to that in the publication. Furthermore, most of the direct quotations from the project have also been published there. Additional material has been added, including material that did not fit in the scope of that publication (in section 5.4) and an account of events that happened afterwards (section 5.6).

5.1 The project

The premise behind the project, as described by the project leader, was as follows: In the old days when families lived nearby, a family member could see whether their relative had raised the blinds or whether someone was moving around in their house. And so without directly asking the person, others could know if the person was okay. Here "okay" means, moving about normally; not okay means needing some sort of help, for example after a fall or stroke. Now that many families live far apart, this is not always possible.

Thus, the idea of the project was to use sensors to check the status of a parent and automatically send messages to a younger family member to notify them if there appears to be a problem. The project leader had previously worked on an AAL Programme funded project to develop a solution including both monitoring features and services, and so knew that others had attempted comprehensive solutions. His vision was instead to solve the problem with technology available to everyone - using normal Android tablets and simple sensors readily available. The hope was that it could give a good indication, if not 100% reliability. The new app was conceived as an add-on to an existing interactive communication system to facilitate communication between older relatives and their family members who do not live with them that had been developed by his company. The existing system is not described in detail to protect the company's anonymity and their commercial interests.

The company is according to the definition of the European Commission (2003) an SME, more specifically a "micro-sized enterprise" as it had fewer than ten employees and an annual turnover of less then €2 million at this time, and still what could be termed a "start-up" (Robehmed, 2013). The company was conceived in 2006 and founded in 2008 to develop an interactive communication system mentioned above. The communication solution was commercially available at the time of the project. From this system they had experience integrating ambient devices, which were used for simplified user interaction. Through previous projects, the company had experience working with older people, and

Table 5.1: Case Study 1: People involved in the development

Role	Background	Relative	Country
Project leader	Business	✓	
Developer	Computer science, app development	✓	
Adviser	Sensing	✓✓	Country 2
Adviser	Electrical engineering, Living Lab	✓	Country 3
Adviser	Pattern recognition		
Adviser	Intelligent control systems		Country 3
Researcher	Computer science, usability		

also access to end-user organizations with contact to older people that could be valuable in the project studied.

The project was funded by a national grant for innovative projects in general and not specifically for AAL. The funding was sufficient to cover two months salary for one programmer/developer, plus the associated costs for leading the project. This was considered sufficient to produce a first prototype, or proof of concept. Although this was short, the goal was to check if this type of simple monitoring system was feasible, not to have a marketable system. In software development, like the Pareto principle or 80:20 rule, a large proportion of the results come from a small amount of effort, especially if the functionality and/or reliability can be reduced (Waters, 2007). If it proved successful, the plan was that additional funding could be obtained to do further iterations in order to complete the system, as was actually done. It is important to reiterate that this was being done by a small company, which simplified communication and that the project leader was also the CEO and so had a vested interest that the project be successful.

The development team consisted only of the project leader and the developer. The developer had previously worked on projects for people with disabilities, but had not worked on systems for older people or using sensors. The project leader had a business background, had been involved in developing the communication app likewise for use by older people, and the AAL Programme project mentioned previously. Furthermore, the company had experience working on mobile devices (tablets, smartphones) and developing apps for them. Although, they had less experience using sensors, the sensor technologies planned for use had been proven in other projects (Cucchiara et al., 2004).

To ensure there was more expertise regarding both AAL and sensors in the team, in addition to the development team, there were three advisers from other organizations with whom the project leader had worked previously, who were planned to be involved in the project meetings. In addition, there was the researcher, plus a further adviser who joined the team later. See the overview of people involved in Table 5.1. These advisers were not paid - their motivation was in part personal and in part professional interest. Furthermore, a user organization that had access to a large number of older people was planned for inclusion, but canceled just before the project started.

It was planned from the start, that there would be frequent project meetings. Since the team was split geographically over three countries, the meetings were planned as

audio-conferences to be held over Skype™. From the outset, it was expected that meetings would take place weekly. Rather than regular meetings, meetings were to be initiated by the project leader and developer as needed. Since the project leader and developer were in the same office, they usually sat at a single computer that was located in the meeting room during the meetings.

The project did not have rigid planning. According to the project leader, it was conceived as a highly iterative process, repeating cycles of analysis, design, development and test. It was expected that prototypes would be produced and form the basis of the next steps - in part because it was not clear at the outset which sensors were useful and what problems might be encountered. The basic functionality was set in advance - to determine if a person was with a high likelihood okay and otherwise notify a relative. To understand the user needs in order to decide how this could be done, persona-like descriptions of exemplar users and usage scenarios were planned. The initial prototypes were not intended for testing with users, but were meant more as a proof of concept to be evaluated by the team. Extended user testing with family members and perhaps also in a living lab was planned with later prototypes. Both the analysis and evaluation methods planned are recognized as UCD practices (Vredenburg et al., 2002).

Since the user organization canceled, the development team could not gain access to a large group of older users as planned. The external advisers who had worked in this domain could not find another organization to provide support on short notice. In order to still work in a user-centered manner, the project leader chose to consider the relatives of the team members in the design process, since all team members had either parents or grandparents who lived alone and living further from where they lived. Table 5.1 indicates which team members had relatives that were described and considered - each check mark stands for one relative.

5.2 Research methods

Qualitative, ethnographic methods were applied, with the researcher in the role of a participant observer.

The data about the project was collected by visiting the offices, participating in project meetings and subscribing to chat sessions. Furthermore, the researcher had access to documents and artifacts from the project and studied these. These documents included minutes of all meetings for which minutes were taken, instructions on using the prototypes, a presentation about the technical solution and all five prototypes that were developed. A list of all materials used is included in Appendix B - Case Study Materials.

Since the bulk of the interaction with the extended team was at the project meetings, the focus was put on these. This included nine of the eleven project meetings (a check mark in the final column of Table 5.2 shows the meetings where the researcher was in attendance), with a total duration of 10 hours and 20 minutes; for the other two meetings, the meeting minutes and chat comments were available. If possible, the researcher went to the office where the project leader and developer were located. Signed consent forms were obtained from all members of the team (see Appendix A).

As a participant observer, the researcher was part of the team and outside of it. Her role as a researcher was known to all at the outset. As mentioned in Chapter 4, the researcher was initially *the observer as participant* (Gold, 1958), as she was not fully involved, but in practice moved closer to *the participant as observer* during the course of the project, in part due to her role as tester. The researcher made an attempt not to interfere in ways that would change what was being studied, but did contribute when asked. Since she had experience in development, the issue of language, of understanding, that is sometimes an issue with this type of observation (Becker and Geer, 1970), was not an issue. This experience also helped to build rapport. In an attempt not to disturb the flow of the meetings, questions only relevant to understanding what was happening were not placed during the meetings, but written down and asked later after the meeting.

To gather more information about background and the reasons behind why things unfolded as they did, five semi-structured interviews were held with team members at various stages during the project. The project leader was interviewed shortly before and after the project, to gain information about his goals and his views of how it went. An interview was held with the developer during the project, just after the first prototype had been completed and again after the project was over to understand issues he faced. In addition, an interview was held with one of the advisers after the end of the project. The interviews had a combined duration of 4 hours and 15 minutes.

Audio recordings were made of all meetings in which the researcher participated and all of the interviews. In addition, notes were taken. For interviews, additional notes were made immediately after the interviews and full audio transcriptions were made later. Transcription was more important for the interviews, as the density of relevant information was greater than in the meetings. For the meetings, since it was possible to take more detailed notes, only the notes were transcribed and then supplemented by the audio recordings as needed.

The data was analyzed based on thematic analysis (Braun and Clarke, 2006), as described in Chapter 4. Related to RQ 3.1, a focus was put on the way and point in time the users were considered in the project. The analysis was started before the end of the project. This included a line-by-line open coding of all notes, transcripts and documents available (see also Figure B.1 in the appendices showing an excerpt from the coding). During the analysis, the recordings were in some cases used to get additional details or to check something. After the last project meeting, but before the final interviews with the developer and adviser, the common themes and sub-themes were identified. After this, a selective coding was done using the themes that were identified. This helped to gain more understanding, for example at which point in the project themes were first identified and how prominent they were. All analysis and coding was done manually, although a software tool, ATLAS.ti™, was used to facilitate navigating the text.

In the following, pseudonyms have been used to protect the identify of the people involved. The interviews with the developer and the adviser were held in German. The original source materials were used for the analysis - any quotations presented with the results were translated by the researcher. Words in *italics* are taken straight from the data; an ellipsis (...) is used to indicate places where words have been left away to make

Table 5.2: Case Study 1: Meetings and topics discussed

Meeting		Topic or *milestone*	Researcher in attendance
1	day 2	Project goals, constraints, describe users and needs	✓
2	day 4	Requirements analysis - brainstorm use cases, available sensors	✓
3	day 11	Discuss possible solutions	✓
	day 16	*First prototype running - sensing*	
4	day 17	Discuss prototype - first experiences Consider further grant application (AAL Programme)	✓
	day 17	*Second prototype ready*	
	day 19	*Third prototype*	
5	day 20	Discuss prototype - architecture, possible rules	✓
	day 26	*First version of configuration files*	
6	day 27	Discuss prototype - configuring rules	✓
7	day 34	Discuss prototype - further patterns	
8	day 35	Discuss prototype - organizing tests	
	day 39	*Fourth prototype ready*	
9	day 39	Discuss prototype - status, plan	✓
10	day 41	Discuss long-term tests - results from team members	✓
	day 44	*Fifth / last prototype ready*	
11	day 45	Discuss long-term tests	✓
	day 51	Chat regarding problems, need for real data	

it easier to read.

5.3 Chronological description

Since the study followed the development, the description starts with an overview of the meetings. In total, eleven meetings were held (see Table 5.2).

5.3.1 Requirements analysis

The first two meetings focused on requirements analysis.

The first meeting started with a description of the goals and constraints. This led to some early discussion about the technical feasibility. With regard to understanding the needs of the users, the team had expected that a group of carers would be included in the project to gain information about a wide group of older people. However, it was announced that they would not be participating after all. In lieu of this, the project leader suggested that everyone in the team describe specific family members for whom the system might be relevant. The older relatives considered were relatively diverse (see summary in Table 5.3). These included both men and women between 70 and 84.

Table 5.3: Case Study 1: Older people considered during the design

Name	Age	Relationship to team	Computer skills	Scenario
Timothy	84	Father of the project leader	tried once	going to bed
Delores	86	Grandmother of the developer	none	drinking coffee
Helene	70	Mother of an adviser	extensive	door gong
Herbert	78	Father of an adviser, separated from Helene	regular use	
Catherine	73	Mother of another adviser	none	listening to the radio

Though most still lived at home, one person living in an assisted-living facility was also included. Of the people described, two regularly used computers or smartphones and the other three did not. The team members described their older relatives in their own words. In some cases the project leader asked for additional details that could be relevant to the system, such as activities they do away from home, the layout of the home, technical abilities, relevant health problems and the goals of the system in relation to this person. The information about the exemplar users was then summarized in the form of persona-like descriptions in the meeting minutes. According to the interviews, two of the people based their input on things their relative had actually told them in conversation.

The second meeting was held a few days later. Here the team moved from discussing the people, to the situations or patterns that could be potentially used by the system to determine whether the older people were okay (these situations or patterns were called "use cases" in the project). At this point, the goals for the system were based on the perceived needs and preferences of the older users: *"need real value for users: showing pictures, news feed"* and *"should not tell too detailed about activities, wellbeing (sic)"*.

At the end of the second meeting, the team discussed what sensors could be used to detect these patterns. The conclusions or messages needed were summarized as: okay, not okay, warning requiring immediate action, status unknown and system offline. The project leader cautioned that the system may not be meaningful, it may be wrong, or the use cases might be too different from an indicator of a good or bad day. It was not explicitly stated how the situations would be chosen - from the discussions it seemed those that were common or most feasible to implement.

The minutes from the first meeting were extended after almost every meeting to include new information and were then put on a cloud server, so that everyone in the team always had access to the latest version. Printouts were not seen by the developer's desk, but the team did refer to these exemplar people and their activities in future meetings. Furthermore, small changes to earlier sections were sometimes made at later meetings.

5.3.2 Development and test

The meetings (meetings 3 through 9) focused on developing a solution to meet these needs.

In the 3rd meeting, the focus was on what could be recognized in practice with certain sensors, for example a microphone to recognize if someone was talking. The sensors available in a standard Android tablet at this time are shown in Figure 5.1. Bluetooth sensors were also considered. The sensors led to a discussion about problems. For example, how close does someone had to be to be sensed, how can one distinguish if it is the radio or person in the room speaking, the differences between sensors on different devices, and the batteries running out with Bluetooth sensors, just to name a few. Several people in the team reported that they had talked to their older relatives about the project, and mentioned receiving positive responses, but also the concerns of their older relatives about being able to operate the app. One person remarked that this was our challenge. It is interesting to note that one older relative thought it would be nice, if it worked in both directions getting *"information about the other person, without getting on their nerves"*.

The first working prototype was completed a few days after the 3rd meeting - just two weeks into the project. The first prototype visualized the input from the different sensors, e.g. if a sound was detected and how loud this was. In all there were five prototypes. Later prototypes included thresholds, had configurable thresholds, sensed/recognized certain patterns, and sent notifications. A user interface was not provided for the older users, although having one was discussed in the meetings - instead the tablet in the person's home could display photos while it was sensing. The configuration files defining the patterns and thresholds were formatted with XML. The notifications were sent by e-mail or text message on a phone - Short Messaging Service (SMS). After a new prototype was available, the extended team members (i.e. advisers) were supposed to test the prototype in their own context, which they also did. The researcher was also asked to do this.

Once the prototypes were available, the meetings involved discussing the experiences with the prototypes and deciding how to continue. Many of these discussions focused on technical issues, such as thresholds and modeling the patterns. The team realized that considering thresholds alone would not suffice, as some signals, like Helene's door gong that went off when she opened the door, might be important at night, but meaningless in the morning, and other events may require input from different sensors to recognize. Two further advisers with technical expertise supported the team during the development phase. There was some discussion about how extensive the activity modeling should be (i.e. were Bayesian statistics needed or simple rules sufficed), whether the team should proceed in a more requirements driven way, or whether more consideration should be invested in the user interface. Halfway through the project, the project was still on track. In fact, the team members were so convinced that the app would work that they were already working on a follow-up grant application.

The exemplar people were also sometimes referred to during the development phase. In fact, in one meeting, another family member was introduced, because they matched a

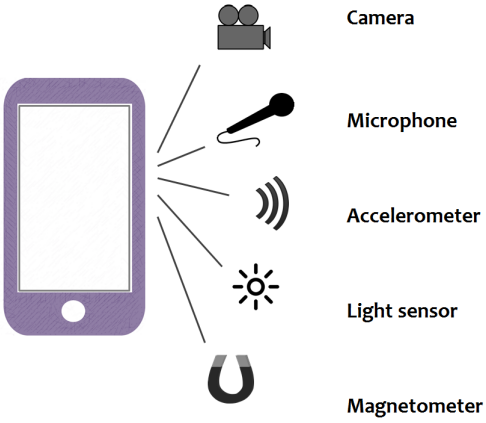


Figure 5.1: Sensors available in a tablet computer

profile discussed in the project and were also thought to be a good person to test the system later. Furthermore, new patterns were introduced, e.g. *closing the blinds* as a clear sign that someone was there in the evening. The difficulty of finding older users to test AAL systems was also discussed.

It was not always clear to the team how to judge the results. One pattern was to recognize people walking by. However, one person testing mentioned that the facial recognition did not recognize their partner. The project leader said: *"It recognized us. Even if you are walking slowly. It also works from the side, as long as it sees two eyes. I'm quite impressed."* The developer first agreed, but then remembered, that it didn't work if someone was directly in front of a window. The team wondered how often would it be placed in front of a window, or where a face could be detected. It was also discussed that even for people with our technical knowledge, there were limits to how complex the configuration could be.

The final meetings (10 & 11), focused on more realistic tests. Extended tests with some of the older family members were planned at the end of the project. The project leader had found a company to donate tablets, so that all team members / their relatives could test. The first step was for members of the team to leave the prototype running at work or home during a period of several days. The discussion in meetings turned to what could be detected or recognized in practice. By this time, both a daily summary message and emergency messages, i.e., when deviations from 'normal' patterns were detected that were deemed to be important, had been implemented. Judging by the logs, the sensing and recognition of individual events seemed to be working, however the message generation (based on multiple events) was not working properly. In the interview at the end of the project, the project leader stressed how crucial this was: *"the, you know, the absolute bare minimum test - I expected to get the e-mail, you know. No one got an e-mail."* Because this was not working, the the system was not tested with the older relatives of the team members, as was initially planned. Certainly, it would have taken a great deal of information from the older people to see if the logs were accurate.

By this time, the three months of funding had ended and the developer had another position lined up. Thus, the project was put aside. It wasn't clear *when* it ended, at some point no more meetings were arranged and the chat quit being used.

Afterwards, the project leader was unsure whether to continue with this project, because it wasn't really clear if the app would function reliably or how much work would be required: *"We would all accept it doesn't work. Fine it doesn't work, we'll forget the whole thing. But since it was something valuable ... you can't accept to just stop without a clear, negative sign, now."*

In the following, some people considered during the design are described, followed by the main themes identified by the analysis.

5.4 Some older people considered during the design

To illustrate how users were considered at the start of the project and some of the details that were considered, some older relatives from the project are described here. Generally, the team felt that age was not of central importance, and mentioned that people of the same age had different needs - to illustrate this, in the following, two women are presented who are close to the same age, but whose lives and abilities are very different. Health issues were also given a lot of consideration in the meeting minutes - for this reason, an older male relative who had health issues is described, who was also one of the older and most discussed relatives. These three people were also the first three relatives presented. The topics are mentioned in the order in which they were presented by the team member.

5.4.1 Catherine

Catherine was at the time of the project a 73 year old widow who lived alone in the three room apartment she has lived in for many years. She is a person who dresses neatly.

Early in the discussion, it was mentioned that she is not used to using complex technology. She can phone, also using a mobile phone. She usually has her phone with her and turned on, as she wants people to be able to reach her. She does not send SMSs - apparently she doesn't really see the point. As far as her son knows, she has not used a touchscreen, but she is able to use a television - and even record television programs, even though the remote control for her new television is very complicated and in English (a foreign language for her). The team briefly considered what sort of user interfaces would come into question for her, and concluded it would probably need to be fairly simple - ideally similar to what she already knows.

Catherine does not seem to be socially isolated. She has a neighbor who comes by and watches out for her. She has friends from various clubs she meets up with. Her son does not live nearby, but they phone regularly. Furthermore, she still phones with her sister and other relatives almost every week. If she misses the phone call, it is almost a sure sign that she isn't doing very well.

Physically she is frail and has to take medication, but is still able to get around. She won't talk about how she is doing unless she is asked specifically. She uses a rollator, because she is unstable on her legs, and has fallen in the past and even broken a leg. But luckily she has an lift / elevator in the building. Approximately one year ago, she gave up her driver's license voluntarily, because she was afraid, and she no longer dares to go out in icy weather. Still she usually goes out of the apartment every day, at least to get the post, and likes to go swimming every Monday.

At home, she spends much of her time in the living room, where she also has an LCD TV and a home trainer, she gets up and moves around the apartment a lot, that is, unless her favorite show is on. She eats breakfast every day, starting with coffee from her coffee machine, and cooks once a day. She also likes to listen to the radio.

Her son, an adviser in the project, would like a message, maybe once a day, so he doesn't have to worry. He also thinks that she would be relieved if she could see his face in case of an emergency.

Later in the project, her son realized that she talks to *someone* on the phone several times every day. But since it wasn't always the same person, still no one might notice if she did not phone anyone for a few days.

Based on her patterns, the team thought the tablet could be placed in the living room, where she would pass it regularly and it was in sensing range of the television, radio, home trainer and possibly also the kitchen.

5.4.2 Helene

Helene was then 70 years old. She is separated and lives alone in a three room apartment in the 4th floor.

Physically she is very fit. She uses the stairs and regularly goes to exercise classes for seniors. She is also mentally fit.

Helene used to be a software developer. She has her own computer, which she uses daily for surfing, e-mail, etc. If she sees a purpose in using a technology, she can also use complicated systems. But she is not interested in technology for technology's sake - for example, she doesn't use Skype^{TM}, after all she has a telephone.

Her son is concerned about her. She recently reported that she woke up (presumably not in her bed) and didn't know what had happened. As a result, he has installed a gong that goes off when she opens the door to the apartment. She also has arthritis. She takes a number of different medications, has a lot of pain and goes to the doctor frequently. Even though she can be very talkative, she does not say much about how she is really doing - either to him or his sister. She doesn't want to be a bother, and has even considered moving into an assisted-living facility. She doesn't really seem to have someone she can talk to about things like that, except her husband. They live separately (a couple of streets away) and have for many years - even when she was still working. Now they just do special things together.

She is very active and leaves the house almost every day, and is sometimes gone most of the day. She goes to book club, sports classes, medical appointments and more - she is gone so much, her son has to make an appointment (by e-mail) before he comes by.

But this isn't that often, as he is often out of the country with his work. It can be hard even to reach her, as her mobile phone often isn't charged. And she sleeps very deeply.

Her son's goal is to provide a "*channel of trust*", to let him know if she is not well, without her feeling like she is whining. It is unclear where the tablet could be located in her apartment - the only place she is regularly every day is the kitchen, and there is not much space there.

5.4.3 Timothy

Timothy was described in detail by his son, the project leader.

"Timothy is 84, male, has mild, well actually now moderate, dementia, that can be classified as Alzheimer's. We all know it will get worse - it's just a question of when and how fast. He forgets an amazing amount....Besides that, on a good day, he's fine – you can speak to him and he knows where he is. He has interests, he does better, he does worse, he has plans and thank goodness he is out and about with this fun senior, who has basically adopted him....She drags him along, cooks for him once a day, goes out for meals with him daily, takes him to choir, sports..."

Timothy has vision impairment from a stroke, which was shown to be a problem with respect to using a communication app on a touchscreen tablet in a previous project:

"That makes it very difficult for him to use touch screens, because he has no spatial vision – with just one eye he can't judge distances and touching is difficult. Often it happens that he wants to touch the tablet and then he's touched the screen....He'd love to use the system, to interact and navigate, but when I watch him it is basically impossible – he can't remember the steps."

Later in the same meeting, it be came clear that this *"fun senior"* was not a just neighbor, but actually his partner. Because of this close relationship, it was even mentioned that she might be able to interact with the system on Timothy's behalf: *"Another input would be that another person basically confirms that everything is okay."*

5.5 Results

This section presents the two main themes of the project that were identified by the analysis. Both relate to which 'users' were being considered. The first, *the disappearing older user*, is about how the 'user' was first central and gradually disappeared. Closely related is the second theme, *the privileged developer*, whereby the needs of the developers gradually gained precedence over those needs of the older family members considered.

5.5.1 The disappearing older user

During the course of the project, the users seemed to 'disappear': at the beginning rich descriptions of the user were provided, these were then recorded in abbreviated form, during the development the same people were reduced to passive signal generators by the team. In the end, they ceased to be the real people they initially were, and their

own children generalized them. At the same time, the technical aspects gradually gained importance over these human aspects.

Timothy: summarizing his rich story

Although the people were described in detail in the first meeting, these descriptions had to be summarized in the meeting minutes. The summary took a similar shape for each person, describing where they live, any health issues, their ability to operate mobile phones and computers, and their social contacts. In the following the case of Timothy is used to illustrate this. Timothy was mentioned in all of the nine meetings the researcher attended and half of the minutes from these meetings.

As shown in the initial description of Timothy above, he was described as a person who goes out regularly, has a partner and does all sorts of activities with her. With relation to the system, he was described as wanting to use the tablet, and being frustrated when he tried, in part due to having difficulties seeing and remembering how to use it.

The rich stories told by the team members, were then summarized and recorded in the minutes in a persona-like form. The information that was recorded about Timothy based on the information presented by his son was as follows (technical details about the apartment have been left away here):

- *"lives alone in a cared (sic) home, city*
- *84 years, male*
- *dementia (Alzheimer's), forgets a lot"*
- *"... has a senior mobile phone but struggles using it*
- *cannot handle a computer*
- *sees badly, less than 10%*
- *because of that anything to touch is tricky. Cannot really use touch displays*
- *has a hard time remember relations, names, places, times*
- *stays mostly in the living room*
- *has female neighbour (86) who takes him out regularly:*
  - *neighbour is very agile*
  - *could possibly be included as contact person"*
- *"has an emergency contact system, but does not use it"*

In the 2nd meeting, the goal was to look at typical activity patterns of each person. Here the focus was on those that could potentially be recognized by the system and used to decide if the person was okay. For example, for Timothy getting up late was thought to be a bad sign, because it often meant he had a fever or felt dizzy. Another pattern mentioned was not coming home at night, as it could mean Timothy was in hospital – something that happened once or twice a year. The project leader seemed truly concerned about his father, and mentioned even little things like going to bed late could be *"a mild indicator, where I would just like to know it and do something or it means he isn't feeling well."*

The meeting minutes again included a summary of these these detailed discussions. The patterns discussed were categorized into bad, good, regular behavior patterns and information related to the tablet. For Timothy, the bad signs included the ones mentioned above, but did not include the weaker indicator of going to bed:

- *"gets up late - doesn't feel good;*
- *had no breakfast*
- *doesn't leave home*
- *does not come home at night ..."*

The section patterns included a few points relating to the "neighbour" mentioned in the 1st meeting:

- *"almost daily, his partner comes by*
- *almost daily, someone from the home looks in"*

Here specific details, some of which could be relevant were not discussed; for example, which rooms his partner visits, how long she stays and whether he visits her instead.

Similarly the amount of time spent considering the users also decreased, despite the an extensive focus on the individuals in the first two meetings. Even though Timothy was referred to again many times, he was not mentioned by name again, and hence starts to disappear.

From people to signals: how people are referred to

During the following meetings the people become largely reduced to their 'patterns' and the signals these can generate for the sensors. This seems a big contrast from the detailed descriptions, where the people were referred to by name. But this started already in the 2nd meeting, where the sensors that could be used were also discussed at the end. For example with respect to the last person described, the minutes contain: *"a camera would see the person often, notice the person pass by"*. Where Delores lives alone, this person would almost certainly be Delores. But even with some of the others, there was a focus on the patterns that could be sensed.

The increasing distance from the people was also illustrated by the way people were referred to. For example, Timothy was introduced by name and still referred to by name in the 2nd meeting. Later these same people were referred to by their relationship to the team member. For example in the 5th meeting, referring to Timothy: *"With my father, I want to know right away when he got up."* This was also done with others, e.g. Delores becomes *"my grandmother"*.

Though this may seem like an oversight, everyone was referred to by name in the first meetings, but after the first design no older person was mentioned by name again. The last person mentioned was Catherine. This was in relation to leaving the radio running, which could be mistaken for someone being present. Instead the activities from their stories were used as placeholders for the person. Some examples were where the sense-able act of going to bed became a proxy for Timothy or the door gong for Helene. The team still seemed to remember that these referred to a specific person: in the 9th meeting, when discussing the door gong pattern, Helene's son was asked to provide more details. That the older people became sensor generators rather than active agents, may help to explain why no user interface was developed for them, even though during the meetings it was indicated that at some interaction was planned. In fact, in the 3rd meeting, it was explicitly mentioned as one of the challenges that made the project interesting.

As the project progressed, the same people were referred to by more general terms, for example *"seniors", "your seniors"* and *"person"*. For example in the 5th meeting: *"Even just entering the values isn't possible for my senior."* The focused analysis showed that this became more common in the final three meetings that were concerned with testing. For example: *"test intensively, so that we can get to seniors quickly"*. There was not much differentiation, and it wasn't discussed if one of the relatives considered would be better for tests than another.

Generalizations and stereotypes take over

Just as people were referred to using more generalized terms, the project also came to use more generalizations and stereotypes of old age. Where at first the five specific people were still being considered, later it became about older people generally, many of which did not match the details about the relatives discussed at the beginning of the project.

The generalization of frail or failing older people started in the first meeting, where the minutes describes Helene's condition as *"rheumatism, typical elderly weaknesses"* and become more common. This was in contrast to the initial description of her, which does not fit the stereotype of older people or frailness in many ways: reading e-mail daily, busy and active every day, even going to exercise classes.

The stereotype of lack of computer experience was also mentioned in many meetings. The first time was in the 3rd meeting when discussing the design: *"They always say this: I can't do it, it's beyond my grasp"*. At the same time, this holds for at most three of the five older people discussed. The stereotype overrode facts: Helene worked in software development, but was summarized only with *"has a* PC*, can browse, use e-mail; but very limited interest, needs a strong motivation and clear benefit"*. Based on this stereotype, the developer suggested early on that menus could be confusing. Instead he suggested

that only a few buttons should be included in the user interface for the older users. In the end, two user modes were planned: a "restricted" mode with little interaction and a passive mode without any interaction. It was assumed that there would be a "delegate" who would manage the account for the older person. The prototypes included only the passive mode.

Another generalization was loneliness. Although both Catherine and Helene do not sound isolated, later it was said: *"[older people] are typically alone, they don't meet their old mate on the street just like this, they aren't so mobile... and increasingly kind of get forgotten."* But it is as if the older relatives had been forgotten or disappeared from the project memory.

As wrong as it may seem to generalize or fall back on stereotypes like these, it may in fact be partially necessary to develop a system like this. For, as the project leader noted at the beginning of the project: *"If every old person is actually different, then we never have a chance of picking up anything that means the same."* This tension between the individual people and the need for generalizations was evident at different times. During the 10th meeting a technical adviser asked if it can be assumed only one person would be "using" it: *"That's not a big problem - I think most seniors are single, at least those that need care. Is that true?? ... The majority maybe, well, at younger ages it doesn't have to be the majority. (pause)"*

Technology decisions take precedence

There seems to be a contradiction in first collecting rich stories about people the team members care about and then moving to design decisions that were based on technology and ignore some of the information about users that was gathered. It is also interesting to note that while the information about the 'users' was documented and even got expanded in later meetings, most of the decisions about the interface and choice of functions were not recorded in the minutes, many were not even explicitly discussed, making it hard to clearly attribute the reasons for these decisions.

An example is the choice of the first activity pattern that was implemented *"closing the blinds"*. This pattern first came up in the 5th meeting, and had not been mentioned previously in the meetings with respect to any of the five older people and was not recorded in the minutes until this point. It presumably came from a generalization, that in this part of the world most people have blinds in their apartment that they close at night. Even when it was mentioned, it was not clear it would be done first or that it was particularly simple to implement. At the end of the project, the developer said it was because of the project leader's father. However, this is contradicted by something the project leader said at the 6th meeting: *"My father doesn't put the blinds down."*

Later, the developer acknowledged that technical aspects played a big role in decisions. When asked why certain patterns were selected: *"Well, probably more the pure technical view: which activities could be easily recognized, were primarily decisive for the prototype."* That this makes some sense in this project is supported by the fact that when more advanced (and more accurate) algorithms for detecting patterns were mentioned on two separate occasions, it was decided that these were not really an option in a short project

like this: *"I know some, but they are mostly very complicated, they are doctoral theses... We should just get started."*

Despite choosing functions that were thought to be technically easier, the development was not trivial. In long-term tests, problems often arose, for example, a newspaper deliverer with a broken muffler of a person delivering the newspaper that was mistaken for activity in the middle of the night.

But looking back, the project leader recognized they could have put a stronger focus on user issues: *"I should have been even more stringent or strict about the use cases and I should have forced [the developer] in fact to have a real table of these use cases and all the rules that follow from them and really have an online picture of which of these we have now."*

5.5.2 The privileged developer: proxy and carer

The team used their own parents and grandparents as exemplar users. Although this happened in part because the user organization dropped out, it meant that the team was actually a key user group - the carers who would actually get the messages. The team did not acknowledge explicitly that they too were users, but were now in a privileged position: they could mediate the representation of their relative, could add their own needs as informal carers that may not be desirable to their relatives, and decide which functions would be implemented. These aspects are explored below.

The wishes of the unacknowledged users

During the project, a second user group emerged: the relatives caring for the older person. This user group was the one that actually would get the messages, but was never mentioned explicitly, given a name or really described, even though their needs were a key motivation for having this type of system. The importance of the group was mentioned in the 5th meeting by the project leader while recapping the goals of the project: *"There is a relative who has a bad conscience. They have an older person they are looking out for, for whom he cares. ... And this person wants... "*

The concerns of this unacknowledged user group were voiced repeatedly during the meetings, as can been seen from of the previous quotations: concerns about the older person going to bed, eating, exercising, etc.

When describing their relatives at the beginning, three of the four team members mentioned the lack of communication. They expressed the wish that the system could address this by indirectly communicating the status of their relative. For example, regarding Helene: *"She doesn't say much about how she is really doing... she doesn't really have anyone with whom she can talk to about this type of thing... I would like to build up a channel of trust."*

In some meetings, the conflicts between what the older users want and the own interests as carers were made explicit. For example, when the developer says: *"Well, quite honestly, I think it is less important that the relatives feel comfortable, than that the older people have a certain sense of security through the system. That's what's important*

to me personally... Though personally I would be glad, if she [his grandmother] would actually use it later." The adviser who was interviewed after the project did not see a conflict: he saw see himself primarily a caregiver and not as the son of a user. Hence, he may have given his own interests priority.

The developers as privileged users

As caregivers for the users described, the team members were actually direct users. Being part of the development team put them in the privileged position to include their needs and prioritize these in the development process. On closer analysis, three people who described an older relatively explicitly mentioned their own needs during the description of the older person: *"For me personally, it would be sufficient if it could just..."*

This had subtle effects. One example is the configuration files. In the prototype a Java-based format was chosen. It was explicitly addressed whether a graphical user interface was necessary for the configuration, but this was then not thought to be necessary, because as one team member said: *"I can handle a config file."* Although this was true of the team, who were also carers, this would not be the case for four of the five older people described, thus making it necessary that this be done by the younger relatives. This made the carers the users, and not merely receivers of messages. They would have information about and control over the settings. In the interview after the project, the project leader acknowledged the problem: *"Well, okay, we, we being the relatives, are also users, right? But we didn't give us names in those use cases, right? We gave the seniors names. We should have done this as well by the way."*

In practice the group of carer-developers decided what got implemented based on their needs in some cases. In the last meeting, Timothy's son came back to a concern about his father going to bed mentioned in the first meeting and suggested a new function to remind his father it was time to go to bed: *"Is the reminder to go to bed a possibility, or do most of you say, I definitely don't want that."* It was discussed briefly that even children do not like to be told to go to bed. In the end, the suggestion was rejected when one team member thought about his own relative *"mine wouldn't need it"*. The majority of the team agreed, and the function was not included.

Later the developer conceded: *"At the beginning, it wasn't clear to me to what degree (we are also users), although unconsciously it played an important role."* As mentioned earlier some advisers saw themselves primarily as users, while others saw the older people as the users of the system, even though at this point there was no user interface, but only sensors, for them to interact with.

5.6 Additional information about the project

There are a few topics beyond the scope of the case study that will be touched on here, including first hand experience of being a tester and how the development continued after the part of the project studied.

First hand experiences as a tester

During the project, I was asked to work as a tester. This entailed putting the system in my home and reporting on my activities, so that my reports could be checked the events and alarms being generated. The position of the tablet was directly on our dining room table, in order to be able to hear sounds from throughout the house and also so it could be close to the power outlet.

My understanding of the system was better than most users would have. For one thing, I have a technical background; for another, I was involved in the development, so was well informed about what data was stored only on the tablet, and which data was passed on. Furthermore, I was supposed to check if the logs were correct during the first few days, so that I could even examine the data that was being generated. The first day, I had great fun testing out various things.

However, despite my understanding of how the system worked, at first I felt very uncomfortable with it running. It felt as if someone were watching me all the time. I had a heightened awareness, for example, shutting the door to the toilet when I was alone, or turning on the light, so it would recognize I was up. And when I walked by, I was very aware of the tablet and frequently noticed the LED. Eventually this gave way to sudden moments of awareness, being glad that a certain image wasn't going out.

In just a few weeks, this heightened awareness went away. I almost forgot it was there, and was sometimes surprised when I would get a query from the developer. At this point, it also became more difficult to support the developer - when I was asked what may have happened at 3 AM (in the morning), I no longer had any idea, whereas previously I was conscious when there was a change from my normal routine and made a mental note of it.

There were a number of interesting problems that related to the reliability. While it recognized everyone in the team - it did not recognize my husband as a "person" when he went by. He seemed to find it somehow distressing - I later caught him testing it in different lighting situations and from different angles to see if he could get it to recognize him. A further problem was when there was a series of false alarms every morning around 3 AM. Neither my husband nor I could remember getting up or hearing anything. When the false alarms caused by the broken muffler of the newspaper deliverer mentioned previously started, I tried to stay awake to find out what it was. Later, when false alarms started coming early in the morning (5 AM), just before the interval I had set for "normal" getting up on weekdays, I again had to try to find out why. Luckily, I soon realized that was because the sun had shifted and was now hitting the tablet, triggering a signal that I had turned on a light and made no further sounds. Another cause of false alarms was when my husband and I stayed up late and watched two movies in a row, thus going outside the period of time I had configured for when we were normally awake. In cases like this, I felt embarrassed when I had to explain to the developer and almost felt like a naughty child who had stayed up past its bedtime. But on the other hand, I also didn't think of it at the time, so even if there had been a button to "stay up longer", I would not have remembered to press it.

My experiences were key for the development, because none of the other people

involved in the project kept testing as long.

Later phases of the project

As with most projects, developing the prototype or proof of concept was just the first step to having a marketable system. In this case, the developer left the team to work on another project and the project was postponed.

Approximately nine months later, additional funding was secured for *News of Kin* - this time through a grant for women in technology. Another computer science student was found to continue the project for an additional three months. Her goal was to develop a user interface for the configuration and to improve the sensing of patterns. Immediately after she started, tests were again started with team members and researchers, and continued during the entire three months. During these tests, some problems that were encountered included differences between where the sun came up as the summer progressed or differences between whether the window was open. Once sufficient reliability had been gained, tests with older people were planned, but in practice it was hard to find many people willing to participate. By the end of this funding, the application seemed to sense patterns reliably. But when funding ran out, once again the developer left the team.

Eleven months after this, a prospective partner company was found, who was considering investing in order to branch out into this area. The prospective partner company wanted tests with ten people for ten days to prove the potential of the system before investing. Although ten people were found to test, due to small technical issues, some participants had to drop out, e.g. one user had an old tablet with insufficient memory and an old version of the operating system, and another had forgotten to update the e-mail address entered during an earlier test cycle. As a result, the prospective partner company was not willing to invest in *News of Kin*. Shortly afterwards, the development was stopped, and the company stopped *all* activities aimed at older users, both the *News of Kin* sensing app and the existing product for communication that had been running for more than 5 years.

In the end, it was not possible to get enough funding to tide the company over until the products were commercially viable.The company was small and did not have resources to continue. The project leader of this project, who was also CEO, now works in a position not related to development, sensors or older people.

As a participant observer of the development process, one faces a dilemma. One may see some potential problems, but in the interest of observing, does not intervene if not asked, for example, suggesting the team to ask their older relatives to verify conclusions made about the older relatives during the discussions, e.g. where to put the tablet, checking aspects regarding their routines. Other problems, such as the privileged role of the developer-users, were not clear at the time, but were only identified after analysis and more distance from the project. In retrospect, there is a sense of sadness, of wasted effort. Based on conversations when meeting the team members later, many of the people involved asked themselves what they could have done differently - and whether it would have made a difference.

5.7 Discussion

This case study followed the development of a sensor-based AT system for older people, by observing/participating in project meetings, looking at the documents and interviewing participants. By doing this, it was possible to see how the user-centered process developed in practice in this specific case, and found aspects that could not be identified by documents alone.

As described above, there were challenges. Even though real users were considered by proxy and rich descriptions were recorded about them, the following was observed:

- Aspects about the older users and their lives that were relevant to the system "disappeared" as the project progressed.
- The younger relatives, who as informal carers were also users, were not acknowledged explicitly, although in practice their needs often dominated the discussions.
- The functions chosen for implementation were in some cases based on generalizations (e.g. the blinds) and technical limitations, rather than the detailed information collected about the users upfront.
- A user interface was not developed for the older users - their interaction was limited to a more passive role of being sensed.
- In the end, funding determined whether the project could be continued.

These will be discussed in more detail with the results of the other studies in the discussion in Chapter 8. However, it is still worth putting these in context here.

When working with sensors, the word 'users' takes on a different meaning. Where in other contexts, there are concerns about whether users are considered as complete people or only in terms of their system usage, with sensors the usage can be active or passive, and so it is also important to consider the type of system usage they are being considered in relation to. Although the team talked about their older relatives as the 'users', they were treated as signal generators. This is not isolated to this project or older users - in other sensing projects those being sensed may even be referred to as "objects" (Cucchiara et al., 2004). Here the active users were the younger relatives receiving the messages. In the end, the system was not tested with older people, the passive signal generators. This would have been important: to check the patterns were appropriate and that it worked in practice.

The project leader had a desire to help older people and applied methods recognized as UCD practices (Vredenburg et al., 2002). The personas, usage scenarios, iterative design and early testing provided valuable information for the development team. In this project, the user-centered *humanist* approach and the technology-centered *modernist* discourses of Greenhalgh et al. (2012) were not really at odds with each other. Instead, the stance taken by the team changed as the project progressed. There were some conflicts, such as the discussion about whether it was about the relatives feeling comfortable or how precise the algorithms should be, but generally the project started *humanist,* i.e. with a user-centered

discourse, and ended up *modernist*, i.e. technology-centered. This happened in two ways. First, the rich pictures of the older people were reduced to sense-able activities, losing the sense of the whole person. At the same time, the developers 'privileged' position gained importance, with the stories about the older people being replaced by their own viewpoint. In the end, this meant that the person was viewed in terms of the system - and in the end became a passive user being sensed, rather than being also an active user, interacting directly with the system. Although it seems surprising, that a system would in the end not have an interface for the people considered the users, something similar was also found in a small study done with students (see Appendix F). From the data, it seems likely that the changing discourse relates to the sensor-based technologies that were being used: the users who were the focus of the project were only monitored and so not (active) users at all, moreover, the difficulties reaching the reliability needed for monitoring distracted from other concerns.

Perhaps as part of this, as described elsewhere with personas (Friess, 2012), one 'persona' dominated: Timothy, father of the project leader. Although he and the others were at first considered as a complete person, as the project progressed he was not mentioned, but only represented by scenarios of how someone could be sensed. Since he himself did not use the blinds, this particular scenario was useless to him, but in the country where it was developed widely applicable, as were the scenarios of people walking by the tablet or opening doors.

Although it was not one of the dominant themes, funding had an impact on the project. The period for which funding was very short, and the team felt under pressure: "*We should just get started.*" In practice, this may have also influenced the decision to take easily sense-able patterns, rather than those suggested more directly by the exemplar users. Even selecting easily sense-able patterns, the money ran out before conclusive results regarding the reliability were available. The team may have also felt under pressure to produce an innovative solution, as is indicated when they mentioned the *"state of the art"*. This may have related to the fact that funding programme focused on innovation and they did not want to affect their chances of getting the funding paid out - or of getting further funding in the future.

5.8 Summary

This study set out to look at one specific project aimed at developing a sensor-based monitoring system for older people, which was being done by a company classified as a SME. Qualitative methods were used to study the project in detail. In this case study, the technology-centered view gradually took over from the user-centered one. The older people who were initially considered in detail, were gradually replaced by the signals they generated. At the same time, the wishes of the carers, such as the developers were for the older people considered, were given priority. Through the meetings it was possible to understand how this happened, how the technical difficulties recognizing the patterns reliably and the time pressure imposed by the funding contributed. These results point

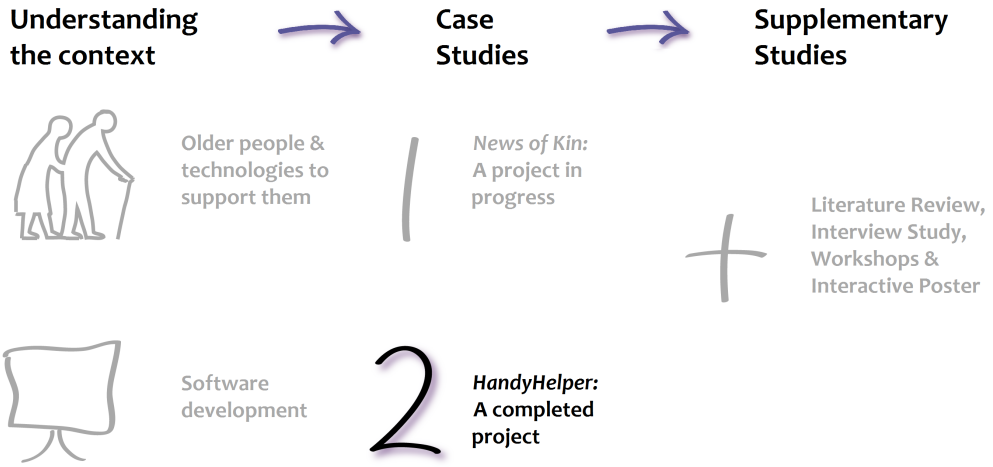
to some possible pitfalls when working with older users and sensors, even when UCD is applied, that may also be relevant in other projects of this type.

The findings demonstrate some of the challenges for a user-centered design process when working with sensor-based systems and older people. The results show how the design process itself could contribute to a telecare system not being adopted by older users, as their needs were forgotten and technical concerns and the wishes of carers took over. In this project, techniques to help keep the 'user' in mind may have been helped, something that will be discussed further in the Discussion in Chapter 8.

The next chapter looks at Case Study 2, a retrospective study of a larger project from its conception to the first installations.

CHAPTER 6

Case Study 2 *HandyHelper*: A completed project



To further explore what occurs during the development of sensor-based monitoring systems for older people and acquire information about the entire process, the development of a larger system incorporating sensor technology was studied retrospectively. Since the goal of the research was to explore the issues that arise during development that may contribute to less than successful outcomes, an important factor in selecting the project was that it was known to have not succeeded. Although the company got input from older people regarding the system during the development, reports from people who had seen the system indicated that they thought the problems related to usability, which also rendered it suited for this research.

The system and case study is referred to here as *HandyHelper*. The development included a number of steps or phases, that are also given names later. The company

responsible for development was located in the EU and received funding from an AAL-specific national funding scheme for one phase of the development. The goal of studying the development of this system was to identify some problems they encountered that may have contributed to the system being withdrawn from the market prior to completion - it considers the design methods used and also the broader picture. Thus, although it supported gathering data relevant to all research questions, since it gave information about a wider time frame, it was particularly valuable for RQ 4.

The case study and key findings in this chapter have been published in a peer-reviewed journal specialized on accessibility and HCI (Hallewell Haslwanter and Fitzpatrick, 2017b), and section 6.6 was published in a reviewed position paper in a workshop related to e-health at an HCI conference (Hallewell Haslwanter and Fitzpatrick, 2016b). As with Case Study 1, the direct quotations are the same as in the publications. Furthermore, the structure of the chapter is based on these publications.

6.1 The project

The idea behind the project was financially motivated. The company responsible, here called *GellIT* to distinguish it from the other (unnamed) companies involved, provides Information Technology (IT) services. The company wanted to branch out into new areas. An external IT consultant told them that AAL was an area with promise, and so *GellIT* decided to invest in this new business area and self-financed the initial development. The country in question has nationalized health care. The system aimed at allowing older people to live in their own homes longer, and was intended to be sold to private households. The company started with smart home components, e.g. controlling lights, but soon extended the system with services, e.g. medication reminder. In the end it incorporated features in a variety of categories, e.g. features supporting independent living, increased security and telehealth. Thus, it is can be categorized as the latest generation of telecare systems, as it included services that were focused on quality of life (Turner and McGee-Lennon, 2013). Since the monitoring component incorporated in the system went beyond simple thresholds and included more sophisticated analysis of sensor data to generate alarms, it can be considered the second, more modern generation (Turner and McGee-Lennon, 2013).

The company was, according to the definition of the European Commission (2003), a large company, just outside the range of a SME, with an annual turnover within the range of a "middle size" company with less then €50 million at the time, but with more than 250 employees.

The system was built iteratively, through a series of phases over a period of over four years. At the time each phase was completed, it was never clear which changes and additions would be made, relegating such decisions to the outset of the next phase. Not unlike Case Study 1, the first phase of the development was a proof of concept. After getting positive feedback on this through a show home, the company applied for, and received, funding to support completing a marketable product. Unlike Case Study 1, a working version of the system was developed and sold, but the system was withdrawn

from the market before it was completed, as it was thought it would be difficult for it to be profitable given the costs involved and the prices that could be charged.

The development was much larger than Case Study 1: the first phase included twenty developers, though later phases included just two. In addition, there were two partners who were responsible for developing certain features, as well as outside companies responsible for installing the needed sensors and infrastructure.

Further details are provided below with the chronological description.

6.2 Research methods

This study applied qualitative methods for a retrospective ethnographically-informed study. Since the development has been completed, original documentation served as the primary research source. Data collection entailed finding relevant documents related to the project and company from that time period. The most important were those closely related to the project, and included meeting minutes, technical descriptions of the implementation, two formative evaluations of the project, conference articles written by project participants, newspaper articles, promotional materials from the company and financial reports for the company. In addition, screen shots and lists of functions for various versions of the systems were obtained. General materials that mentioned the *HandyHelper* system were also included, such as reviews of AAL systems, brochures from carer organizations and trade magazine articles about AAL. In total more than 60 documents were analyzed, for a total of over 500 pages of material. For a detailed list of all resources used, see Appendix B - Case Study Materials.

To get more insider information, semi-structured interviews were held with people involved in the development. The five participants were chosen so as to cover all phases and various roles, and to give different perspectives on the development. All people agreed to being interviewed - see Table 6.1 with a list of people interviewed and their role in the project (the phases are described below in Table 6.2). The interviews had a combined duration of 6 hours and 30 minutes. Audio recordings were made of interviews, and notes were also taken. Interviews were supplemented by e-mails to follow-up on details. Signed consent forms were obtained from all people interviewed (see Appendix A).

In keeping with an iterative coding approach, the analysis was started before the interviews, based on the qualitative method thematic analysis (Braun and Clarke, 2006), as described with the methodology in Chapter 4. The analysis was based primarily on the documents and the notes from the interviews, and was first done manually on paper. Where the notes were not clear or sufficient, they were first supplemented using the audio recordings. The analysis helped identify areas requiring additional information to answer open questions or fill in the gaps. The key documents and interviews were later re-coded manually in ATLAS.ti™. This made it easier to navigate the codes, to get an overview, see how the codes were related, which codes were most common in which documents, etc. (see also Figure B.1 in the appendices showing how codes were navigated).

The audio recordings were also used to get verbatim quote later during writing.

Table 6.1: Case Study 2: Interviewees / people involved

Name	Role	Organization	Phase(s) involved
Gabriel	manager	* consultant (1st year) * *GellIT* (2nd - 4th year)	from start until maintenance
Carl	technical project leader	* research organization (2nd) * *GellIT* (3rd & 4th year) * independent (later)	from *Intelli* until present
Anna	carer	municipal care home	*PAAL*
Bill	service developer	another company	*PAAL*
Dan	evaluator of show home	university	show home

In the following, pseudonyms have been used to protect the identify of the people and companies involved. Most of the materials were in German. The original source materials were used for the analysis - any translations needed for presenting the results, e.g. quotations and names of features, were translated by the researcher. Words in *italics* are taken verbatim from the data; an ellipsis (...) is used in places where words have been left away to make it easier to read.

6.3 Chronological description

The development began in 2007, shortly after the EU position paper highlighting the demographics had been published and before the AAL Programme funding programme had been started, and lasted four years. The project was complex and involved a number of phases, different funding sources and a number of partners. A chronological description follows, beginning with the initial development and continuing through the final version (see overview of the phases in Table 6.2). In keeping with the research questions being addressed by the research it includes information regarding the types of users involved and considered in the project and methods used for their inclusion (related to RQ 1 and 3.1), as well as describing difficulties the team faced during the development (related to RQ 2 and 4).

6.3.1 Initial development: Prototype & show home

The initial impetus came directly from the EU report on aging (European Commission, 2006), which indicated the aging population was growing and that the costs to care for them would be increasing. The company set out to develop a product to support older people to live in their own homes longer. Since the company was branching out into a new area, they self-financed the first phase. The initial team had more than 20 developers, thus being relatively large (see Ambler, 2010). Gabriel was employed as an external consultant to manage the development of a working prototype. The focus was

Table 6.2: Case Study 2: Phases of the development

Phases	Year	Some new features	Partners & funding	People
Initial development: prototype & show home	1st	* TV & remote interface * turn electricity off * water stop * medication reminder * missed calls	Independently funded * *GellIT* developed * municipal support for show home * university for evaluation	Gabriel Dan
First version on market	2nd	* stove reminder * blood pressure monitoring	Financed by company	Gabriel
Intelli project: adding intelligent monitoring	2nd	* activity monitoring * "all clear" button	National AAL funding * *GellIT* * research organization	Gabriel Carl
PAAL project: adding services, plus pilot study	3rd	* grocery shopping service * communication service * planning field trips * organizing cleaning	National AAL funding * *GellIT* * company partners * one university partner * municipal care home	Gabriel Carl Anna Bill
Final version: *Thornhill* care home	4th	* tablet interface * improved maintenance * calling the lift	Financed by sales (*GellIT* alone)	Gabriel Carl
Maintenance	later		Financed by monthly fees * *GellIT* * consultant	Carl

exploring the technical possibilities. Users were not included in the development of this first prototype - the basic goals were taken solely from the EU report.

According to the project manager, Gabriel, in just a couple of months a first prototype was running. The resulting version included features aimed at increasing security using sensors, e.g. to check if windows were open and warn people when leaving, and some services to support people in everyday life, e.g. reminders to take medication (see Table 6.3 with a list of some of the features included in this version). The user interface consisted of a remote control for input and a TV for the display. Gabriel had the first prototype installed in his home, so that he could test it. Once it was clear it worked, the new business area was officially launched and Gabriel was hired by the company to continue the development.

Next a show home was set-up, where it was possible for the general public to come and see the system working. A press statement claimed 500 people visited the home in the first months it was open; overall, the project manager estimated that 1000 people visited the show home during the one and a half years it was open. This was interpreted positively

Table 6.3: Case Study 2: Examples of security features and services in show home version

Security	Services
turn electricity off	automated lighting at night
water stop	phone book
fire alarm	medication reminder
window alarm	ordering meals on wheels
	missed calls

in the team: it indicated a high level of interest in the system and also generated lots of publicity. In retrospect, the project manager remembered, however, that it was difficult to explain to older people what the system did, even at the show home: *"I remember when I started with the topic, it was hard for me to grasp it ... If I involve someone and they explain what it is about, they can't articulate it, because they don't understand the topic. How can someone develop it who can't articulate what it is about?"*

In addition to having people look at the system, a more formal evaluation was done in the show home in order to investigate the needs of older people. The evaluation was conducted in the show home by a local university, lead by Dan. The costs of the evaluation were covered by a grant from the university. In all, almost 100 people from the ages of 55 to 90 were included in the study. The results include both quantitative and qualitative data. The results showed a great diversity among potential users, for example, whether people lived alone or with family, experience they had using computers, whether they had physical and cognitive limitations, etc. Also the opinions of the participants on the system were very diverse. Generally, people reported preferring the TV remote to control the system, but many also thought it was difficult to use. Although the response was generally positive, some of the younger people (under 60) thought it was too soon for them to have it, while some of the older participants (over 80), felt it was too late for them: *"It doesn't pay off 5 minutes before dying!"*. Generally, the security features were rated most important, but some services for "convenience" were also rated as important to more than half of the people, such as an easy way to returned missed calls. The report also included suggestions for additional services that might be useful, one being a way to shop for and order groceries. Regarding costs, approximately 40% were willing to pay at most €50 a month. The most frequently voiced concerns about the system were costs, followed by usability.

One and a half years after starting the development, the company had the first version ready for sale. The company did not have established sales channels, and only a single system was purchased - and this was purchased by an assisted-living facility and installed in the home of an older man to test the potential. The evaluation was positive and lead to a short report on TV about it. The first user said: *"It is unimaginable to be without a computer, Google and search possibilities. And now this is a sensible next step. The system is so simple to use that with the user handbook after a short introduction everyone can use all the features."*

6.3.2 *Intelli* project: Adding intelligent monitoring

With the global financial crisis of 2008, the general market situation changed greatly. *GellIT*, like many others, was experiencing financial difficulties. The company applied for a national grant for the development of AAL. The consortium included only *GellIT* and an academic research organization. The goal was to add intelligence and enhance security in order to more accurately determine if there is human activity in a flat. Here it is referred to as the *Intelli* project. The choice of focus was based on the university evaluation in the show home, because it indicated less than 25% of people interested in the system lived in an assisted-living facility where someone checked on them regularly. Through the partner for the grant, the company gained access to valuable skills regarding pattern recognition in sensor data that they did not have in house. At the same time, they were able to halve the internal development team to ten people.

The goal of the project was to collect data from the various sensors and to add movement sensors, for example, on light switches or frequently used appliances like the refrigerator. If no activity was detected for a certain time period, an alarm was to be triggered. In addition, a green button was provided in the flat that allowed the person to cancel the alarm before it was sent to the carers or emergency services who received and responded to the alarms. The challenges envisaged were of a technical nature, e.g. generating profiles from sensor data, rather than aspects related to understanding the user needs, since these had been explored in the show home.

In the first publication about the project, the focus was clearly on assisted-living facilities, rather than the private homes on which the company first focused. In an interview, the technical project leader, Carl, said this was for practical reasons: individual homes are diverse and so it is more complex to install the systems, furthermore there is greater distance between them, increasing the effort to maintain the systems. To ensure the new intelligence features worked reliably, the system was installed in the home of an older family member of a team member, enabling the team to do testing over a period of several months. Furthermore, the intelligent monitoring was tested in two assisted-living units as part of the pilot described below.

6.3.3 *PAAL* project: Adding services & pilot study

Shortly afterwards, but overlapping with the *Intelli* project, a second national research grant for the development of AAL was secured by *GellIT*. This project, called *PAAL* here, was to integrate additional services, and to pilot the system. The pilot was to take place in a new assisted-living facility being built by a municipality, which also provided further financial support. The project was funded for twelve months, including an eight month pilot of the system for the purpose of evaluation, during which the system would be available at no cost to the 25 residents who were willing to participate.

In addition to *GellIT*, the consortium included 9 partners from a number of different areas (see Table 6.4). One partner was responsible for a market analysis, in order to identify which services the future residents actually needed and wanted. Two companies were to develop additional services - the results of the pilot would decide which of these

Table 6.4: Case Study 2: Consortium for *PAAL* project

GellIT	Partners
* Project management	* Marketing specialists
* Develop user interface	* Service developers (2)
* Develop server	* Specialists in social policy
* Maintenance	* Carer organizations (2)
	* Emergency services
	* Municipal services
	* Installers of infrastructure

would be included in the final version. Further partners were responsible for installing the needed technical infrastructure. Others were to liaise with the older people during the pilot: facility management, carers and emergency services. An evaluation from a university partner was also planned, this time from the point of view of social policy. Looking back, Bill, a service developer, thought that the *PAAL* project was managed well, and attributed this to the fact it was managed by a company and not an academic partner.

The market analysis included face-to-face interviews with eleven of the 25 future residents who would have the system installed and some of their relatives. As with the evaluation in the show home, it underlined the diverse needs of the people who would be using the system. People generally agreed on the importance of security and social contact. But the future residents said that many of the features they were asked about were *"not needed yet"*. Still people said they liked knowing they were there for later. One example are the responses to the grocery shopping service suggested during the show home: these ranged from *"I think I will use that"* and *"Good to have such an offer in case it is needed in the future."* to *"We don't need that."* The report also concluded: *"people are afraid of high additional costs"*.

The results of the market analysis were provided to the partners, including those developing services. However, Bill, a service developer, said that *GellIT* did not allow the partners to talk to the future residents and their families personally. Although the service developers had experience developing for older people, Bill found this frustrating.

Given this situation, the team thought the input from the expert group was most valuable, something mentioned by both Gabriel and Bill. This expert group included carer organizations, emergency services, local politicians and computer scientists. Generally, the carers were not very interested in technology, but the meeting minutes indicate that the partners providing care-services saw the benefits of this type of system. The meetings also helped to gain information about the processes followed by the carers, for example in emergencies, which were consequently considered in the design. Furthermore, the participants from care organizations explained the diverse needs of the older people that they supported. Based on the input from the expert group, a few functions specifically for carers were also planned, e.g. to help plan field trips by allowing the residents to sign up using the system. Table 6.5 gives an overview of a selection of the many features

Table 6.5: Case Study 2: Examples of security features and services in pilot version

Security	Services
turn electricity off	automated lighting at night
water stop	address book
fire alarm	medication reminder
window alarm	ordering meals on wheels
stove reminder	missed calls
activity monitoring	*blood pressure monitoring*
"all clear" button	*grocery shopping service*
	communication service
	planning field trips
	organizing cleaning

in the pilot version, with the functions that were added after the show home shown in *italics*.

At the time, having a pilot in a new facility seemed ideal, but in practice proved somewhat problematic. When it opened, there were technical problems related to the technical infrastructure and its instability that increased the overall effort. Furthermore, a large number of residents moved in at the same time who needed support. These people were faced not only with learning this system, but with a whole set of new appliances. Thus, it was decided to wait before introducing the *HandyHelper* system, shortening the pilot from eight to six months. Bill, a service developer, felt that the support for the older people regarding the system was insufficient - there was only a single training session. But a technician was on site once a week for several hours. Unfortunately, due to the delay starting the pilot, the carer was on vacation the first couple of weeks of the pilot. This was a problem, as she had received training, thought the system provided valuable features, found it easy to use, and had also gained a level of trust with the residents: *"some people still remember (that I went on vacation then)"* even though the technician who gave support had good rapport with the residents. Also Bill, a service developer, remembered that the substitute carer that was there when the pilot started was not interested in the system. According to Gabriel, the project manager, the families of the residents apparently also did not provide much support, and in some cases even discouraged the older people from asking their families for help again by saying *"if you don't understand this, you really are old"*. In practice, the technician was often asked to help the residents with other things, e.g. changing light bulbs. The support costs mounted.

There were a number of usability issues. Because the remote control for the TV was also used for the services, an additional button press was needed just to turn on the TV. The services were rarely used, even ones that were suggested by the evaluation in the show home and confirmed by the market analysis at the beginning of the *PAAL* project. Many residents were also disturbed that an LED light was on all of the time. Some were just disturbed by the light in the dark, others worried about the electricity costs, while

others said it reminded them of the sensors *"watching"* them. Some even unplugged it. Due to this, the technician put tape over the LED, which reportedly *"solved"* the problems - or at least stopped the complaints.

The only academic partner did a qualitative scientific evaluation of the changing living situation after moving to the assisted-living facility. This included impressions about the system, but was not restricted to this aspect and also included aspects of how the life changed more generally, e.g. the amount of stress. It was based on interviews conducted before the people moved in and again four months afterwards. It included sixteen residents living in twelve of the 25 units with the system. Again, the participants were very diverse: from 60 to 85, living alone or as a couple (hence more residents than units), with a wide income range and different physical and cognitive limitations. There were also differences in how they felt about the idea of the system and how this changed after they moved in. Some people rejected the system outright, others just didn't bother with it, others tried and were frustrated with how complicated it was. The evaluation report concluded that better support would have been needed, something Anna, the carer, also agreed with. They also concluded that future residents should have been included during the development, to help ensure it was suited to their cognitive abilities and to increase their motivation to use it. Interestingly, the security features were still valued in the assisted-living environment, but the personal advantages of many of the services was not clear to the people in the evaluation. As an example, the grocery shopping service mentioned earlier was not used - having recently moved in, the residents enjoyed walking to the nearby shop and running into people they knew from before.

Further interviews were planned for the evaluation twelve months after moving in. By this time, the project was over and the free trial period had ended. When asked, the residents were not willing to pay the price. This was only slightly lower than what they had to pay for the (subsidized) carer in the facility, and most had not used many of the services (yet). Both Bill and Carl reported on problems with people using the menus: it related to fact that the 80 year olds *"were not used to using a menu on the TV... even this simple extension was so new to them, they didn't grasp it."* In the evaluation study a number of people reported being overwhelmed with the number of services available in the pilot. In the end, the control consoles for the system were removed from all units. The security features that ran independently and would be costly to remove, e.g. sensors to see if the stove overheats, were left in place, but were not supported.

6.3.4 Final version: *Thornhill* care home

During the time that the pilot was still running, *GellIT* won a contract to install the system in another new, more exclusive assisted-living facility (called *Thornhill* in the following). For this, the system was completely re-designed, what Carl, the technical project leader, referred to as generation 2 of the system. The changes were based on the experiences from providing support during the *PAAL* pilot, but did not consider the evaluation results mentioned above. The system was decentralized to make it more robust, both to be less sensitive to infrastructure problems and also to allow remote maintenance. In the interview afterwards, Carl, the technical project manager said this was necessary,

because the academic partners in the *Intelli* project had not considered these aspects sufficiently when developing the monitoring part of the system. Furthermore, based on observations the technical project leader made during the pilot, the user interface was also changed. This included adding a service for calling the lift and switching the user interface from TV remote to a tablet interface. When asked about the evaluation results from the *PAAL* pilot and why they were not used, Carl did not specify a reason merely stated *"there was no communication from them"* - certainly the final report was completed after the development for *Thornhill* had been started.

Changes were also necessary to adjust the system to the care processes at the new facility. At this facility, the carers had less contact with the residents, making some of the services superfluous, for example, the service for planning outings.

For these changes, the team included only two developers at *GellIT*. Since the new facility was far away from the one where the pilot was done, there were also new electrical contractors responsible for installing the needed infrastructure during the construction. By the time the building was ready, the tablets that had been shown to the future residents were no longer available - and the choice of the new tablets was limited by the budget that had been set when the project was started two years previously.

The introduction of the system was followed by a sociologist, who evaluated the user acceptance. Again there were initially technical problems with the infrastructure and usability issues.

Perhaps due to the experiences in the pilot, the pricing was handled differently here. The costs of the system were planned to be included in the price of the assisted-living facility, but being private rather than being run by a municipality, it was also a more exclusive facility.

Shortly after this, the *HandyHelper* system was withdrawn from the market, even though they reportedly had a number of care facilities interested in the system, and also were a partner in an approved AAL Programme funded project. Gabriel indicated that the decision was made before the development was actually completed. According to the technical project leader, this decision related to the long lead time from the time the project was authorized to when it was actually installed and paid for, in this case well over one year, which would be a problem with care homes more generally. Furthermore, it had proven difficult to find electrical contractors that had the necessary know-how to install the needed infrastructure, which was a serious problem since reliability was key for the security features. The infrastructure problems experienced in both care homes were time-intensive to diagnose and fix. Older people were not willing to pay much, so many systems would need to be sold in order to cover the real costs. And with the problems finding reliable electrical contractors, it would also be difficult to provide the needed support over a larger geographical area. The company instead expanded into related technology aimed at young people buying new homes.

6.3.5 Additional information about the project

It has been a number of years, since the development was stopped. The system in *Thornhill* is still running - and still under warranty. Despite the initial complaints, both

the security features, i.e. the intelligent monitoring features that determine whether the person is active, and the services, e.g. calling the lift, are still used. Carl, who handles the maintenance, reported that people sometimes forget to check themself "out" before going on vacation, and that he did this remotely to prevent further alarms. Since the tablets are in constant use, the original tablets recently had to be exchanged. Since the system is now in regular use, despite the many initial complaints of older users, the project manager, Gabriel, felt that the importance of usability is overemphasized.

Looking back, the people interviewed do not agree on the source of problems. Gabriel, the project manager said *"it is not age related ... it is more a matter of character ... with technological innovations ... you always have 15%-20% that refuse to use it"*. During the project, he had seen many older people who were excited about the technology. He thought that the security features were most important, and that other functions could be added later. For him, the problem was just the fact that it took too long before something was sold. Anna, the carer who worked in the care home during the pilot, thought the services were important. She felt the services that were available during the pilot were of great interest, and thought it was a shame that the system was no longer available. She felt the difficulties related to the computer experience of the older people "*This generation is pretty far away from computers and electronics*". She added, that the tendency of older people to be frugal was also an issue. Dan, the evaluator of the show home, felt many of the problems could have been avoided. Many of the problems, both regarding the costs and usability, were clear already during the evaluation of the show home. Thus, he feels that a great deal of public money was wasted by ignoring these. Carl, the technical project leader, felt that having academic partners had contributed to the problems in the pilot, as they had not sufficiently considered aspects, such as the aforementioned robustness and remote maintenance, which increased the amount of support required on site.

Many of the people interviewed said that based on their experience, funding programmes are valuable if companies want to invest money in new areas, such as AAL. Particularly Gabriel, the project manager, saw advantages: they found good partners through the grant consortia and the additional effort for coordination and administration required was relatively low. Bill, a service developer, felt that grants were useful, but thought the criteria were problematic and did not necessarily lead to the right partners being included, for example, the requirements to include a certain number of partners or partners from certain countries. He also felt it could complicate the development, if one partner collected the information and requirements from the users, and the others did not have direct contact with the users, as happened in two projects in which he had been involved. The technical project leader, Carl, saw both advantages and disadvantages: it broadened the expertise, but added overhead e.g. for implementing services that were never used.

Interestingly, the *HandyHelper* system continued to have an impact, even after the development was stopped. While the system was being re-designed for the *Thornhill* version, the version that was piloted with *PAAL* was installed in one unit of another assisted-living facility to evaluate the potential for their own facility. The outcome of

Table 6.6: Case Study 2: Themes identified

Theme	Impact
Features: security & services New area, esp. relating to security Usability, esp. relating to services Problems related to having older users	*Affect methods applied*
Budget and need for profit Evaluation and getting feedback Technical aspects, e.g. maintenance	*Effort to get it working*

their evaluation was positive, however, by this time, the system was no longer available. Thus, the facility copied the system. Even later, social ministers from another state visited the *Thornhill* facility to see the system, which demonstrates that it was still seen as a good example of an AAL system. Bill, the service developer, felt that even at the time of the retrospective study, that there was a real need for this type of system and felt the *HandyHelper* was one of the best two systems of its type. He said that he had recently tried to find another system like it for his own father, but could not find any for sale.

6.4 Results

This section presents the main themes of the project that were identified by the analysis. One of the main themes, was that the system was innovative at the time. Less prevalent, but still a major theme, was that people involved in the project expected to have problems due to having older users. These themes were in the interviews, but also the documents about the *HandyHelper* system. The main themes are shown in Table 6.6. As shown there, the themes were grouped according to the impact they had on the development: the methods applied and the effort to get the system working. These are described in greater detail below. Then, the challenges and underlying assumptions will be discussed.

6.4.1 The methods applied

When the *HandyHelper* system was started, it was difficult to know what features were needed, as this type of telecare monitoring system was very new at that time. Usability was also an important issue given that it was aimed at a very diverse group of older people. The following section looks at the methods that were used to address these challenges, whether these stand up to the "standards" of the time, and also how well these worked.

Using the description of UCD as "the active involvement of users for a clear understanding of user and task requirements, iterative design and evaluation, and a multidisciplinary approach" (Mao et al., 2005, p. 106), the project applied user-centered design. To understand the needs, developers got input directly from the different stakeholders

through several methods at different times during the development, including both of the main user groups: the older people and the professional carers, who received the alarms and also had a few special functions, e.g. for planning field trips. This included the show home for older people early on, as well as meetings with the carer organizations during the development. The future users were also asked for input about features during a market analysis before the development for *PAAL*. The project included several iterations, each with some type of evaluation at the end. Older people were included in all evaluations, and carers were included in the final evaluation during the *PAAL* pilot. Using an iterative process and evaluations with the different stakeholders allowed suggestions to be implemented. Even looking back, three people interviewed, Carl, Bill and Anna, specifically said they thought the methods were good, including the way input was collected from users. Despite this, older people thought the system was not easy to use, and also not useful enough to be kept at the end of the pilot.

One problem could be that the requirements used for the first prototype did not come from users - instead these were taken from the needs described by the EU position paper. But the requirements for subsequent iterations were developed with user input. And as Gabriel, the project manager, pointed out, reducing the amount of requirements analysis before the initial development, helped to get the system up and running quickly, so they could get user feedback as soon as possible.

The user needs analysis for the next version was based on feedback on this prototype. One hundred people older people were included. Gabriel, the project manager, mentioned the difficulty of explaining what the system could do, even in the show home. Using the show home supported older people giving meaningful input, as they could see some of the possibilities. In practice, some of these suggestions were acted on, as can be demonstrated with the grocery shopping service and also the intelligent monitoring feature. However, the most successful feature, calling the lift, was not identified through a formal evaluation, but was something Carl, the technical project leader, thought of based on his regular visits to the pilot site. More generally, interviews are thought to more effective than using prototypes to discover system requirements for software products (Keil and Carmel, 1995).

The evaluation methods stand up to standards recommended in the literature, e.g. (Barlow et al., 2007). For the evaluation in the show home, a combination of qualitative and quantitative methods were used with a relatively large number of people. This evaluation was done early in the development and considered both the functionality and design, including the preferred interface technology. Barlow et al. (2007) do not specify the length of the time needed for evaluation, and Peek et al. (2014) found many evaluated the acceptance of these types of technology before it was even installed in the homes of the users. A longitudinal evaluation of a system of the same type found that between two and eight months of usage, the main differences were that the people already using the system used more features, thus reducing the number of features not used at all (Spellerberg and Schelisch, 2009). Thus, after the six month pilot of *PAAL*, it may have been too early to determine which features were not needed, however, it was long enough to provide feedback regarding acceptance and about the features that *were* used.

However, Dan, the person doing the evaluation at the show home, was critical that the comments about usability and pricing were not given sufficient consideration. This is supported by the fact that these aspects were identified again in the evaluation report after the pilot. It cannot be due to lack of trust in the evaluation alone, as the market analysis at the beginning of *PAAL* also mentioned these aspects. Furthermore, it can be faulted that the results of the evaluation report of the pilot were not used for the re-design. The focus of the re-design for *Thornhill* was primarily technical. Although in the long run people did adopt the system, there were again initial problems with the usability in *Thornhill*.

The stipulation from *GellIT* that the service developers should not have direct contact with the older people, did impede their ability to apply UCD for these services in the *PAAL* version. The grant funding the project supported innovation and favored a large number of partners, making it impractical for each of them to talk to the future residents individually. Instead, they relied on the analysis results provided to them, and were also involved in the meetings with the experts and stakeholders, which included care providers, but no future residents. The documents indicate that it was in these meetings that the functionality was set, and show that some decisions were directly based on the input of the care service providers.

6.4.2 The hidden effort to get it working

It took a lot of time and effort to get the system working in the end. The first version was up and running quickly. But in the *PAAL* project, there were problems with the infrastructure, and a great deal of support was needed for the older people. The effort was so great that in the end the company stopped the development.

The pilot for the *PAAL* was six months and included a large number of older users. This seems long, but the evaluation report recommended another round of evaluation interviews later to see how the usage changed. This was especially important, since during the market analysis some of the features were considered to be of interest for "later". The residents had just moved in when the pilot started, and had to decide whether to buy the system before many of these features had been used or needed. Others have also reported that the usage of the system changes over time, with additional features being used (Spellerberg and Schelisch, 2009). But even with older users it could take years - or a sudden accident - before some of these features they said they wanted, like the grocery shopping service, would be needed.

Finally, there was the issue of support. Although the older people got a training session, in practice they needed a lot of additional support. Without support from family and carers to help answer the questions the older people had about the system, the burden fell on the company. In this case, the burden was increased, as people also asked the *GellIT* technicians for help regarding other devices, further increasing the technical support costs of the company. Even if Anna, the carer, had not been on vacation the first weeks after it was introduced, in practice, staff in care homes do not usually have time to take over the training of the older people (Dale et al., 2016).

6.5 Discussion

The *HandyHelper* was an early monitoring system for older people. Although *GellIT* succeeded in developing a working system for people living in assisted-living facilities, marketed and even sold it, the system was removed from the market after a short time. Thus, it did not reach either the goals of the company: to support people living in their own homes, and to branch out in to a new area. The case study aimed to exploring the issues and challenges, developers face during the development that could have had an impact on the success.

The system did fulfill at least two of the goals of AAL: enhancing security and supporting people in their everyday lives. Thus, it may have supported the people using it to live in the assisted-living units longer before moving to a higher and more expensive level of care. But the company could not turn this into a commercial success.

The situation was very complex. There were, as perhaps everywhere, aspects that could be criticized or improved. But there does not seem to be an obvious single mistake. Perhaps surprisingly, having older users, who are diverse and lack computer experience, may have contributed, but was not the main issue. The complex sensor technologies presented challenges, but in the end problems with the infrastructure were more important. Thus, it is important to consider the underlying tensions, as these might also be a source of difficulties in other projects developing this type of technology:

1. The meaning of 'the user' changed in subtle ways, as the target group was changed from private homes to care homes. Thinking of them just as 'users' concealed these.

2. It was difficult to get meaningful input from the two main user groups with their different experiences and goals: a) the diverse group of older users and b) the carers.

3. It was difficult to balance the usability required for the services and technical reliability required by the security features, especially as these can take additional effort and there was a strong need to make a profit.

4. The funding allowed partners with know-how needed for the innovative technology to be included, but at the same time, the funding increased the effort, e.g. overhead for grant administration, coordination between partners, implementation of additional services.

5. There were trade-offs with how long to evaluate a system: the pilot had to be long enough to get meaningful input, but not so long that the older people forgot the benefits of additional security provided by the monitoring functions.

These are described briefly below. These points, and the implications that arise from them, will be discussed in more detail with the results of the other studies in Chapter 8.

The project set out to support older people living independently, as illustrated by the people included in the show home evaluation, but the target group was changed due to initial difficulties. The poor sales initially came at a time when the company was coincidentally experiencing a financial downturn in their core business. This led to *GellIT*

focusing on assisted-living facilities like the one that purchased the first system, where they found it easier to get input from professional carers. The strategic shift changed the notion of who the 'user' was, from someone in their own home to someone in a new assisted-living facility, and the situation they were in, which in turn had implications for the development. Thinking of them simply as 'users' or 'older people' hid some of the subtleties that were relevant to the choice of functionality. They are not alone in this, even the 2006 EU policy document (European Commission, 2006), makes use of terms like "people" and "elderly individuals", which support the impression that 'older people' using AAL are a homogeneous group.

When there are two user groups, here the older people and the carers, there is always an issue of how to balance their influence. Although the show home was designed to get input from a broad group of older people, the people who visited did not represent a cross-section of the entire target population. Carl, the technical project leader, thought the visitors to the show home were more innovative than the average - they certainly had more computer experiences and fewer disabilities when compared to statistics from the time (Leitner and Baldaszti, 2008; United Nations Economic Commission for Europe, 2015). Despite this there were still difficulties explaining what the system did. Although other projects have successfully used a participatory approach with older people (Lindsay et al., 2012), the researchers involved specifically mentioned the difficulties of working with intangible concepts with older people. Furthermore, the show home also illustrated the difference between what people say and what they actually want or do, and highlights the ways in which life context matters for this as well. Having a person already living in a facility evaluate a system over a longer time seems it could overcome the problems of having new residents, i.e. people who are still capable of living independently and do not yet know what they will need in their new situation. But the person testing the first purchased version knew Google and seemed unusually experienced with technology. In was easier to work with professional carers in the expert groups, and their input was thought to be considered particularly valuable, but even the carers were susceptible to stereotypes about older people, e.g. Anna's stereotype about older people being frugal. Using carers instead of the older people is not unusual, even in other areas surrogate users may be used, i.e. including other stakeholders instead of the end-users (Lievesley and Yee, 2007), and with older users it is actually recommended to find ways to limit the active involvement required from them (Thimbleby, 2008). This can be problematic as carers may put a higher value on safety, whereas other aspects, such as appearance, may be more important for older people (Dahl et al., 2015). Furthermore, certain services suggested by the carers in the facility could be considered almost coercive for the older people: for example, a function Anna mentioned that would have allowed carers to push a button and check whether a person was there. Older people are generally concerned about their privacy (e.g. Wagner et al., 2012) - it may be more of a concern in a situation, like this, in which residents had just moved to a care facility and were not used to be being monitored by carers. This tendency to add functions giving more control to carers has been reported elsewhere (Draper and Sorell, 2013). The pilot served to gather valuable input from the point of view of older people on the functions chosen, but had its limits

in practice, as the differences between how care was organized from one assisted-living facility to another changed the services that made sense.

One of the major tensions related to the fact that both security features, such as a water stop or activity monitoring, and services were included, for example the photo album or grocery shopping service. It can require extensive testing to ensure systems like this have the needed reliability and usability (Wagner et al., 2012, p. 32-33). The security features in *HandyHelper* required little interaction from the older people, but needed to be reliable, as each alarm required something be done by a carer or the emergency services; the services needed to be usable, as they were used on a daily basis - even just to turn on the TV. Since someone had to respond to the alarms, the security features required the inclusion of additional stakeholders in the expert group, each of which had their own additional requirements due to their processes. These people answering the alarms became the users who interacted more directly with the system features. On the other hand, the older people, became indirect stakeholders with regard to the sensor-based monitoring features, something described also elsewhere (Friedman et al., 2006). For the older people, it was the services they interacted with directly. Adding more services made the system more useful, but also less usable, a trade-off mentioned also by Norman (1988). Due to the number of features, scrolling was needed, which made the system more difficult to use. For the services, more training and support may have been able to encourage a more positive view of the overall system (Sallinen et al., 2015).

Another tension was the funding. Funding provided money which was essential, but added complexity both in the project structure due to new partners and in the system through the increased number of services. The conditions of the grants required innovation to be added in each phase and introduced additional reporting and deadlines. At the same time, the grants provided access to partners who were crucial for getting the monitoring features working. But systems like this are also associated with long-term costs for the users. For this system, in addition to the costs for the internet connection required that was €20 a month, the company needed to charge at least €30 in addition. Current subsidies in the country studied mean the cost of having a professional carer who comes by once a day costs just €70 a month. This could even discourage investment in technology, especially since for the technology an initial investment is usually required and it is difficult to predict how long it will suffice.

A smaller issue was the length of the pilot. Due to the funding it was not only possible, but even financially advantageous to run a long pilot, as funding was received for this. This enabled the older people to have *HandyHelper* system installed and allowed them to use it for free during the pilot. Initially the new residents said they would be willing to pay for additional security. But over time their awareness moved away from the security features mentioned in the initial evaluation, and they focused instead on the services, which many did not use. In the end, this influenced their decision not to buy the system. This could indicate benefits of a shorter pilot, while people still remembered the benefits of the additional security. On the other hand, in order to understand the long-term needs and demonstrate the value of the system as suggested by other projects (Spellerberg and Schelisch, 2009), a longer pilot may have been beneficial. Certainly in

this case, the six-month pilot here was long enough to realize that changes for providing remote support were necessary. Although more recent publications suggest that the technical changes made for *Thornhill* are widespread (Doyle et al., 2014), since this was an early project, the importance of remote maintenance may not have been clear at the time. Instead, not incorporating remote maintenance may have related to having an academic partner, who as the technical project leader indicated, considered only the algorithms and not the long-term usage.

6.6 Understanding the underlying assumptions

In order to gain insight into some assumptions behind the issues identified, the project was reflected on using the critical incident method (Flanagan, 1954), which has also been used in health care (Fook, 2007). One critical aspect was the decision about which features to include - having too many features made the system hard to use, made the development more complex, and even contributed to the stipulation that other partners could not have direct access to the older users, aspects which could also have impacted the usability of these features.

The decision about which features to include was based on a number of underlying assumptions, both about the *users* and about the *problem space:*

- An assumption that people could articulate their wishes and needs after seeing a prototype in the show home, even though most did not have experience with technology like it.
- An assumption that older people could predict their needs. The difficulty was that on the one hand, they were living in their homes and would be moving into an assisted-living facility, and on the other hand were subject to changes through the natural processes of aging.
- An assumption that the older user group were in principle a homogeneous group that could be reduced to a single set of needs. Thus, by including a large number of people from 65 to 85 living at home they presumed they could gather the requirements, even for those living in assisted-living facilities.
- An assumption that people visiting a show home represented the larger group. In practice, these people were atypical in that they were mobile enough to visit and were interested in technology.
- An assumption that a eight-month pilot in a new assisted-living facility could provide information about what would be needed more generally, also for long-term residents. The interim report did recognize the problem, but it was not possible to extend the project/funding at this point.
- An assumption that initial concerns about usability and costs that were expressed were exaggerated and that using the system for a few months would be enough to overcome this.

They are not alone in all of these. As demonstrated by the first case study and also EU documents (e.g. European Commission, 2006), as mentioned above, assumptions about having a homogeneous group are more widespread.

Perhaps if developers are aware of the assumptions, they can act to avoid these in the future.

6.7 Summary

This study set out to look at an entire project, to get information about wider issues developers face that could potentially affect the success of the systems. The project included a number of phases, starting with a prototype, then adding more intelligence to the monitoring features, adding more services, and finally redesigning both the technical platform and user interface shortly before stopping the development. The company actively involved older users, but also other stakeholders, both in gathering information about the needs and in evaluating the system.

The findings demonstrate some of the challenges in developing sensor-based systems for older people. The results underline the differences between 'users', for example older people living at home versus those living in assisted-living facilities, older people versus carers. Considering the needs from the point of view of the carers put a focus on the security, but in the end the older people grappled with the usability in everyday use. The results also indicate problems with the funding systems, for example, that by adding more partners to get funding added additional challenges and encouraged the project to include more features, which contributed to making it less usable.

In the end, everyone lost out, as the system was withdrawn from the market; Without the system:

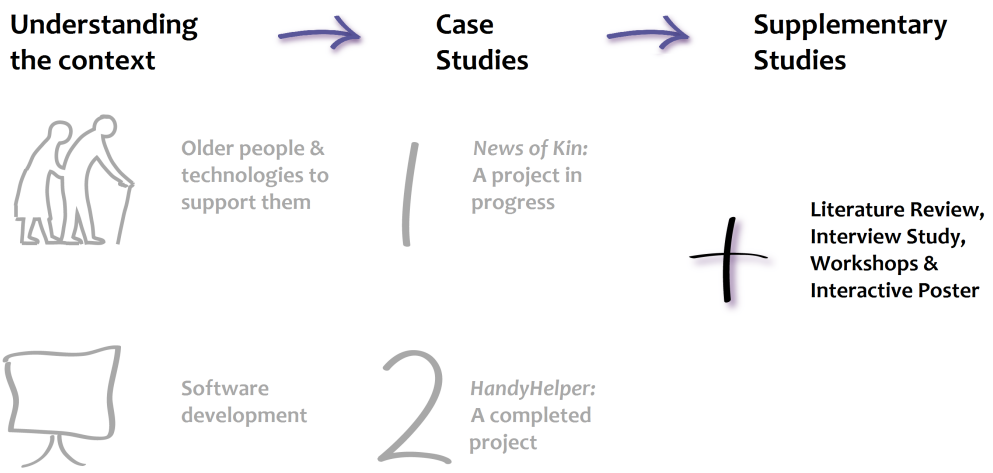
- The older people did not get the additional security that many reported wanting.
- The carers still needed a lot of time to check on people - time that could be used for more valued tasks.
- The company developing the system lost money.

It was a lost opportunity, as the systems installed in the *Thornhill* facility are still running and used regularly and so could provide benefits to other people, as well.

The next chapter briefly looks at the how the results of the two case studies compare, before describing the supplementary studies.

CHAPTER 7

Supplementary Studies



Since case studies are by their nature specific, the next step of the research consisted of further studies to explore to what extent issues identified in the case studies can also be found in other AAL projects. At the same time, these supplementary studies provided information about a wider range of projects and so *extended* the results with new issues. In contrast to the other studies, this part of the research focuses more on individual issues, such as the needs described by the carers being given precedence, that will be built together and put in context in the discussion chapter. Due to this, although they potentially support getting information about issues related to all research questions, they contribute less to gaining insight into the issues.

The supplementary studies include the following investigations:

- *Literature review* of software development, AAL and three projects funded by the AAL Programme of the EU that were conducted in the same time period as the case

studies. This supported checking the choice of the case studies, and demonstrated that the projects chosen were not outliers. It also served as a preliminary check that some of the issues identified have also been reported by other projects.

- *Interview study* to get input by talking to developers of other AAL projects in other countries. This supported getting information about further projects with a monitoring component and services, which were intended for market. The interview format aided in gathering some information about the methods applied, issues encountered and general recommendations from the point of view of the people with experience in developing this type of system, while still being able to acquire information about the context.

- *Workshops* and an *interactive poster* to gain input from a wider group of people about issues in AAL projects. This allowed input to be collected from a wider group to generate new issues and to see which issues had been faced by other teams, as well. Through the workshop it was also possible to get a relative rating of the issues, as well as, some suggestions regarding solutions to some of the issues identified.

Some of these results have been published elsewhere: The results of the workshops and interactive poster (section 7.5) were published in an more abbreviated form in a conference proceedings on pervasive assistive technologies (Hallewell Haslwanter and Fitzpatrick, 2017a); the review of AAL Programme projects (section 7.3.3) was previously published with Case Study 2 (Hallewell Haslwanter and Fitzpatrick, 2017b).

The chapter first presents the individual issues from the case studies that form the basis for the supplemental studies, before looking at the research methods for all of the supplemental studies. Then, the detailed results of the studies are presented: literature review, interviews, workshops and interactive poster. Finally, there is a brief summary. The results are discussed in the next chapter in conjunction with the results of the case studies.

7.1 Isolating issues from the case studies

For the supplementary studies, particularly the workshops, it was necessary to consolidate the results of the case studies and isolate some individual issues identified. In the following, the results from the case studies are summarized to elucidate the issues ultimately considered.

The research focused on companies. In both case studies the goal set by the companies involved was not reached, i.e. to expand the company's product portfolio with a new product that supported older people living in their own homes longer. Thus, neither were a success in those terms, even though both succeeded in developing working systems.

Due to the nature of the project studied and the materials used, the two case studies uncovered diverse aspects that may have contributed to the lack of success. Since Case Study 1 observed a project in practice, it was possible to uncover issues about how the older users disappeared any why developers resorted to stereotypes. There was less

information about these aspects from the materials available for Case Study 2, which was done retrospectively. On the other hand, Case Study 2, the development of *HandyHelper*, provided information about a larger project that extended over a longer time span and included more partners, and therefore could identify additional aspects related to financing.

7.1.1 Common aspects from the case studies

There are aspects shared by both case studies. In the following, these are described briefly. This includes the features included, the users, the tension between reliability and usability, working iteratively, the time required to get the system working and financing the project.

One issue regarded the *features* chosen to be addressed in the project. Security was implemented by both first. Both based decisions on what to include on the input from carers, in one case the relatives and in the other professional carers, even though they first considered the needs of the older people. There was some uncertainty about the features to include. For example, in Case Study 1, the team discussed a feature to remind people to go to bed at length; in Case Study 2, lots of features were included and the decision about which features to include in the final version was to be based on the results of the pilot. There were some surprises about what worked: the grocery shopping feature suggested by older people was not used in practice during the pilot period, and in the final version a feature to call the lift was.

In both projects there was also an issue about the *'users'* and who they were. Both chose to address a broad user group including all older people. Initially both focused on the older people and their needs. However, the people involved fell back on stereotypes of older people: in Case Study 1, the developers, and in Case Study 2, also the carers. For the monitoring part, there were two main user groups: the older people who were being monitored, and the people who received the alarms. Older people and their needs were very diverse. But as shown in Case Study 2, the carers were also diverse and included family members, informal carers, but also emergency services. In Case Study 2, there were also important differences in the care structures even between one assisted-living facility and the next. Perhaps because of the interest of the carers in the system, or perhaps also the fact that they were more like the development team, the development gave priority to input from carers. Neither project clearly identified that there was more than one user group and that each had different needs. Furthermore, in Case Study 2, the people maintaining the system and providing support greatly influenced the final system design, even though they too were never explicitly identified as stakeholders.

Particularly in Case Study 2, there was a tension between making a product that was *reliable* and one that was *usable* for the older people. The simpler Case Study 1 got around this by first developing a separate (usable) solution for the older people and by having the more complex configuration done by family members. In Case Study 2, the lacking usability may also have increased the amount of support required initially. Furthermore, seemingly minor aspects, such as the LED indicating the system is functional being readily visible, proved to have an impact on acceptance by the older people.

In both cases, an *iterative* development method allowing feedback from users was applied using accepted methods of UCD. Having working prototypes assisted in the development. The first version was based on requirements from within the team and was valuable for deciding how to continue. In Case Study 1, the prototype helped to identify problems with the sensing; in Case Study 2, it facilitated getting feedback from older people about the functionality. On the other hand, in Case Study 2, many of the functions people claimed they wanted during the interviews in the show home and market analysis, were not actually used later. Furthermore, although long-term tests were helpful in evaluating the system, in Case Study 1 it proved difficult to find older people to participate in these. In Case Study 1, long-term tests yielded information about the reliability of the pattern detection in a variety of conditions, despite having been done with members of the development team rather than older people; in Case Study 2, the pilot provided information regarding the maintenance, the features used, and the user interface which was used for the development of the next version that ultimately worked in *Thornhill*. However, changes older people undergo may also affect whether certain features would be needed later that were not yet of interest, such as the shopping service in Case Study 2.

It took *longer than expected* to get something working in both case studies. The initial version was developed quickly - in both cases in under three months. Yet in both cases, it took a long time to have something that was mature and reliable enough. In Case Study 1, this was in part due to difficulties reliably sensing anomalies from normal patterns and sending messages; in Case Study 2, it related more to infrastructure problems and having an architecture suited to long-term maintenance needs. Moreover, even when a version of *HandyHelper* was working in Case Study 2, the sales were slow and with care homes there was a long time before a contract was received and the system was actually installed. In both cases, the lack of promise in terms of financial success ultimately led to the end not only of the product, but also the entire business area.

In both case studies issues related to *financing* or funding available had an impact. In Case Study 1 the funding allowed the project to be done, but limited the time available, e.g. for tests with older people. This may also have increased the tendency to choose functions based on the technical feasibility. In Case Study 2 there were also effects from using external funding sources, although these were very different. Here it required the project to include both innovation and partners, which increased the complexity of the project structure and ultimately also the usability of the product. Furthermore, the decision of people from the pilot to discontinue the *HandyHelper* was not so much based on the absolute price of the system, as much as the price relative to that of a subsidized carer.

7.1.2 How monitoring systems are different

The focus of the research is sensor-based monitoring systems for older people. Both systems integrated features using sensors to monitor the activity of older people to help increase security and considered these the key features. In Chapter 2 some challenges related to the systems being studied were identified. These included difficulties with

innovative technology, stringent requirements for reliability and the monitoring features for older people. In the following, these are revisited briefly.

Having innovative technology was indeed a problem for *HandyHelper*. The time getting to market was so long that the company gave up. For *News of Kin* the difficulties related to the complexity of the sensing tasks.

As mentioned above, reliability was a problem for both systems. Reliability is particularly important for the security features that are at the heart of monitoring systems. For *News of Kin,* the problems encountered were in the identification of events, something that was expected. However, it also related to finding the appropriate patterns to identify. For *HandyHelper,* the problems related instead to the infrastructure, which was installed by other partners, something not considered at the outset, but which nevertheless contributed to the overall reliability.

Having older users was not a problem in the way envisaged. In fact, in Case Study 2, the project leader specifically said having older users was not a problem, though the usability of the services was an issue for them. An underlying problem related to the fact that due to the sensors used for these monitoring features, the older people were primarily signal generators rather than real users. The alarms generated were sent to other people, e.g. family members or professionals who cared for the older people. For these features, they, and not the older people, were the real 'users', the one who used the system. Consequently, both projects prioritized the needs of the carers over those of the older people, potentially making the system less acceptable to older people.

7.1.3 Moving to the supplementary studies

The rest of the chapter presents the supplementary studies. For these, the issues identified in the case studies were reduced to single items, for example, *"Reliability - in all situations, over time"* or *"Reliability takes over – but usability important to acceptance"* (see Table D.2 in the appendices for a complete list). These could then be checked in the literature and with people who have worked in the development of similar systems, to see if also others had also experienced them.

7.2 Research methods

Next the methods for the individual studies of the supplementary studies are described. Some of these supported the validity and quality of the research, as was described with the overall research methodology in section 4.5.5. Table 7.1 gives an overview of the studies and their application. A check mark ✓ indicates the primary purpose - if the check mark is in parentheses () it means that this was a secondary goal. The columns of the table are explained below:

- *Member checking* refers to having people involved in the case study review the results (Braun and Clarke, 2013). This was done to allow people involved in Case Study 2 to check some of the issues identified by the researcher. With relation to

Table 7.1: Overview of the supplementary studies and their purpose

Study	Member checking	Compare to literature	Check attributes	Gain support	New Issues	Solutions
Literature review		✓	✓			
Review of *AAL* *Programme* projects			✓			
Interview study				✓	✓	(✓)
Workshops	(✓)			✓	✓	✓
Interactive poster				✓	✓	

the validity and quality, this supported the point *checking back* described with the methodology.

- *Compare to literature* refers to checking whether the issues identified have been reported by others working in AAL and described in the literature. This acted as a first check before continuing to the other empirical studies, and supported the *credibility*.

- *Check attributes* refers to whether the case studies were a good choice, for example whether they had features common to projects more generally. This supported the *ecological validity*, the relationship to the "real world".

- *Gain Support* refers to checking whether others have also faced some of the issues identified in the case studies. This also supported the *ecological validity* and the *transferability* described with the methodology.

- *New Issues* means that people could add new issues and as such generate additional data to *extend* the results to a broader range of projects and countries.

- *Solutions* means that people also contributed recommendations or proposed solutions to some of the problems experienced in AAL projects, which supports moving forward from problems. These suggestions could be applied by others in the future to help address some of the issues identified.

7.2.1 Methods for the literature review

It was important to check the results with existing research before continuing with further empirical studies. This included checking whether some of the results had also been reported by others, and hence might be representative of problems faced more generally, and inquiring to what degree the case studies represent the "real world", for example by checking that they used similar methods to other projects of the time.

Review of software development

Some of the aspects that were thought to be important were first checked to the literature. To this end, literature was collected and read. It is not unusual that in qualitative research the literature is only examined in more detail after the studies in order to have a more open approach (Braun and Clarke, 2013).

First a literature search was done for information about software development practice, particularly those aspects that could point to weaknesses or atypical features of the project: what methods were applied, team size, number of iterations, delays. The starting point was the digital library of American Association for Computing Machinery (ACM) (ACM, 2016). The search was expanded until some information could be found.

In a second step literature on projects developing AAL technology, systems to support older people and monitoring technologies were searched for more generally, for example, through Google, the digital library of the ACM, searching for articles referenced in previous articles, searching for further articles by the same authors, searching for further articles in the portals where articles were found, and searching again with terms found in other articles. In all over 75 articles were examined, including review articles and reports on specific projects from Europe, the United States, Japan and Australia. It was not an exhaustive search, but gave an indication of whether some of the issues had been reported in other projects before the studies that checked empirically whether others had experienced similar issues. Many of these articles are also included in the literature review in the beginning of the thesis.

Review of AAL Programme projects

Since the AAL Programme of the EU has funded a large number of development projects and stipulates that certain deliverables be made available publicly, this was thought to be a good source for getting more detailed information about contemporary projects. Furthermore, these projects promised a certain level of quality, since they had competed against other projects to get this funding.

The review of projects financed by the AAL Programme was done primarily to check the quality of Case Study 2, for example, if the methods applied therein were state of the art, and if possible, also whether any similar issues were encountered. As a reminder, Case Study 2 started at the end of 2007 and continued for over four years. Since Case Study 1 did not include a consortium and was much smaller than projects funded by the AAL Programme, a comparison with projects of the AAL Programme would not make sense.

For this review, projects from the AAL in the same period of time as Case Study 2 were chosen that had similar attributes. The time period is relevant (Flick et al., 2000), as projects done later may have benefited from knowledge and experiences that were not available to Case Study 2. For this purpose, the catalog of projects from the first AAL (Joint) Programme which ran from 2008 and 2013 was used (AAL Joint Programme, 2013a). Since international partners are required to get funding, all involved multiple countries. A selection was then made for projects that had similar attributes. Based on

Table 7.2: Review of AAL Programme projects: Projects considered

	Features included	Target health issues
Project 1	security & services	mild cognitive impairments cardiovascular problems diabetes
Project 2	security & services	Alzheimer
Project 3	security & services	dementia

comments made by people interviewed for Case Study 2 about how they thought the project was run differently because a company ran the consortium, it was reduced to projects where the consortium was headed by a company. Furthermore, since the research focuses on monitoring systems based on sensors and some issues identified related to this aspect, only projects including sensors for monitoring were considered. Finally, in order to get complete information, the project had to be completed at the time the analysis was done. Only three of the 119 projects in the catalog fit all criteria (an overview is given in Table 7.2 - more details about the projects studied are provided with the results). All of these were then studied. Unlike the case studies, these three projects were aimed at a narrower group of older people, e.g. only those with dementia or certain health issues (but not both). However, all health issues targeted are things experienced by a large number of older people, and so would also be present in the general older population, especially since projects 2 and 3 included only people who were either living in their own homes or in assisted-living units, like those in the case studies.

For information on the projects and their development, the available deliverables were studied (AAL Joint Programme, 2013b). In addition, internet searches were done to see if a web site about the project was still available and whether articles, patents or products could be found. Since the goal was to gain information about the development of the project, the focus was put on the deliverables. Through these it was possible gain access to information about the methods applied in all projects. A complete list of sources used is provided in Table E.1 in Appendix E - Review of similar AAL Programme Projects. Note that since all of these sources are deliverables to show the funded work was done, the results may be presented in a way to make their results more acceptable.

Since, with the exception of one project, little documentation could be found and hence did not give a full picture, a thematic analysis was not done. The analysis instead focused on those aspects that could be reconstructed:

- which features were included in the final system,
- the devices for user interaction,
- how and in which phases were users involved in the development,
- which user groups were included,
- user support that was provided,

- length of the pilot,
- problems encountered,
- etc.

Much of the analysis was done using tables. After all projects had been prepared this way, some information was found that was available for one project, but not others, for example about user support. An attempt was then made to fill in the gaps for these projects by reexamining the documents and further searches. After these were completed, in a final step the aspects that had been collated were compared to Case Study 2.

7.2.2 Methods for the Interview Study

In order to include a wider range of projects and extend the results, people involved in the development of AAL systems were interviewed. These aimed to gain information about further projects, the methods they applied, the issues they faced, and what recommendations they had for others developing AAL systems. A focus was put on finding people like those from the case studies, i.e. people who worked in companies and projects that included monitoring technology based on sensors. The goal was to include several interviews with people working in companies in other countries. Since getting input from other countries was a goal, an attempt was made to include one from southern Europe, one from northern Europe and one from central Europe, and also at least one from a larger country with access to a larger market, and one from a smaller country more similar to the one where the case studies were located. Overall, four interviews were held, with people from four different countries, of which two were with people who worked in companies (information about the participants is provided with the results in Table 7.6). Three other people from companies were contacted, all of whom said they were in principle willing to participate: two could not participate because of a stressful project phase during which many customer visits were necessary, which lasted several months; the other did not receive permission from his company.

In order to make it easier to compare the results, semi-structured interviews were chosen. A list of questions was developed in advance (this is provided in Appendix C - Interview Study). An effort was made to ensure that the topic of each question was touched upon, but the questions were not always asked explicitly, asked in that order or in exactly that wording. All interviews were audio recorded. Signed consent forms were obtained (see Appendix A). If possible, the interviews were done in person, otherwise they were held as video conferences using Skype™, the modality and length of each is shown in Table 7.3.

For the analysis, each interview was first transcribed (see also Figure C.1 in the appendices showing the transcription). A selective coding was done based on the transcripts to identify specifically issues they faced and recommendations from them - both those mentioned explicitly and implicitly. Afterwards the interviews were analyzed to see if similar issues occurred in either the case studies or other interviews. To simplify this last step, the interviews were re-structured into a description of the project, the methods

Table 7.3: Interview Study: Interviews held

	Modality	Length
Interview 1	in person	25 minutes
Interview 2	video conference	70 minutes
Interview 3	video conference	65 minutes
Interview 4	in person	70 minutes

applied (also with regard to RQ 3.1), the problems encountered and recommendations, since the questions were not asked in the same order and the answers to some questions were contained within answers to others.

Note that one of the interviews and some of the additional materials from the projects described in two of the interviews were in foreign languages, which are not specified here to maintain the anonymity of the participants. A full translation was not done - the English description of the project, issues and recommendations were developed by the researcher based directly on the original source materials.

7.2.3 Methods for the Workshops and Interactive Poster

In a final step, input from a wider group of people working in AAL development projects, including those not including sensor technology, was gained through two workshops, followed by an interactive poster (see Figure 7.1 [1]). These were used to collect further issues, and also to check whether issues from the case studies had also been encountered by others. Rather than having the researcher doing the study rate the issues, this was done by the participants. For both the workshop and the interactive poster, the rating was like that suggested for software project risks (Tiwana and Keil, 2004). It was based on: a) how *important* these were thought to be to success and b) whether these were in or outside their *control* in projects. Literature supports that it is key to consider those issues over which project leaders have some control and hence could possibly prevent in the future (Tiwana and Keil, 2004, p. 77).

In addition, in the workshops, participants grouped the issues identified, and developed solutions to some of the issues identified.

In the analysis, a focus was put on issues faced by multiple projects. In the following the methods for the workshop and interactive poster are described. Since a novel format was used to identify the key issues in a short amount of time, the individual steps to gather information from the experts are described in more detail.

The workshops

Two workshops, referred to as workshop 1 and workshop 2, were held using the same format. An overview is given in Table 7.4. Workshop 1 was held in conjunction with

[1] The figures in this section have been published previously in Hallewell Haslwanter and Fitzpatrick (2017a)

Figure 7.1: Workshop and Interactive Poster: Process

Table 7.4: Workshops: Overview of workshops held

	Conference	Modality	Participants
Workshop 1	Austrian	by invitation only	5
Workshop 2	international	open	9

a meeting of *AAL Austria*, a non profit group that supports the growth of AAL. This meeting was held in conjunction with the conference IMAGINE. Nine people from Austria were invited, of which four took part in workshop 1 and one further person asked to join on the same day. Workshop 2 was held as an official workshop at ICCHP, an international conference on assistive technology (Hallewell Haslwanter and Werner, 2016). It was advertised through the conference organizers and the mailing list of *AAL Austria*. In addition, people who had been invited to the first conference and who had asked to be contacted should another workshop be held were informed about workshop 2. The conference had an estimated 600 visitors (icchp, 2016). One of the many tracks was on AAL, which included twelve papers (Miesenberger et al., 2016). Nine people took part in workshop 2, including three of the people invited for the first conference, of which two had been involved in Case Study 2. All but one of the participants were from Austria, the other was from Italy.

Since the quality of the results depended on the range of experience people had in AAL, the goal was to include people who had experience in projects developing AAL technology. This included people who had worked on projects funded by grants, people working at companies, and people who had worked on multiple projects over a period of a number of years. In order to cross-check the results of the case studies, people involved in the case studies were also of interest. Together the participants of the workshops covered the different aspects they aimed to cover. The participants included people who worked at different universities, a research organization, a large international company and two start-ups, and so included practitioners, as well as researchers. The backgrounds of the workshop participants included computer science, electrical engineering, business, health care, human service and management sociology. All people had worked in at least one project related to AAL for a couple of years; one participant had worked in the development of AAL for eight years and been involved in a number of different projects,

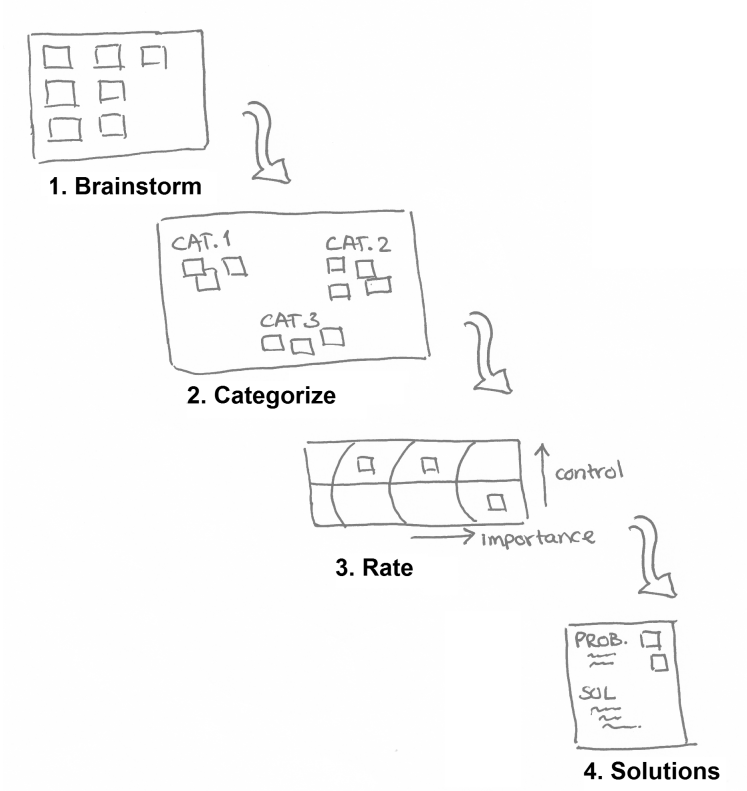


Figure 7.2: Workshops: Steps used (previously published)

and so was involved in some of the early AAL projects. The participants had experience with a wide variety of funding sources, including the AAL Programme of the EU, the Austrian national funding *benefit*, other funding sources and also commercial funding from a company. Details about the participants, including their type of organization and their focus or discipline, are provided in Table D.1 in Appendix D - Workshops and Interactive Poster.

The workshops consisted of four steps (see Figure 7.2):

Step 1 entailed brainstorming to identify issues people had encountered. To give people a common starting point, a quick introduction was given. The participants were asked to work in pairs to first discuss their personal experiences and identify issues. Each issue was to be written on a separate sticky note and put on a sheet of paper. Different colors of paper and pens were used, so as to be able to identify which pair had come up with the issue during the analysis.

Step 2 entailed categorizing the issues. The pairs were joined into bigger groups of four or five people to promote discussion. The participants were asked to go through their issues and discuss them. During this activity they were also supposed to identify duplicates, add additional issues, group the issues by moving the sticky notes to a new sheet of paper, and name the groups or categories of (an example is shown in Figure D.1

Figure 7.3: Workshops and Interactive Poster: Rating issues based on importance and control over them

in the appendices). During this phase, they were also given a list of issues from the case studies, and told they could add some of these if they had also experienced them, but did not have to. The complete list of issues provided to them is given in Table D.2 in Appendix D.

Step 3 entailed rating the issues. For this step, all people worked together and used a poster mounted on the wall. The participants were asked to position the sticky notes on the poster based on their rating. As described above, the rating was based on scales of the perceived importance to "success" (position on the x-axis) and the degree to which the issue was in their control (position on the y-axis). The dimensions were labeled on the poster and explained (the poster from workshop 2 shown in Figure 7.3 - the labels have been enlarged here to make them legible): lines clearly denoted areas that had the same rating, i.e. how important (3 levels, not named on the poster), and "in" or "outside" their control. The term "success" was not explicitly defined. The perception of success varies, but often relates to having a working system and a satisfied customer and not only whether the project is on time and within budget (Berntsson-Svensson and Aurum, 2006).

Step 4 entailed discussing solutions, similar to the "fantasy" phase in future workshops. For this, people worked in new groups of two to four people. Participants were asked to select one issue or several related issues of interest to them. First they were asked to describe the problem and then explore possible solutions. The results were to be drawn on a new piece of paper. Afterwards, these were presented to the whole group. Any comments made during the discussion were added to the page by the researcher at the end of each presentation.

During the workshops the researcher went around and took notes on what was said by the participants. Photographs were taken after each step to record the intermediate results. Signed consent forms were obtained from all participants in order to record the sessions and also to publish the results (see Appendix A).

The interactive poster

The interactive poster aimed to get input from a wider group, including different countries. To this end the poster was submitted to (and accepted at) the annual conference of the AAL Programme conference, the AAL Forum (Hallewell Haslwanter and Fitzpatrick, 2016a). The format of the poster resembled that for the workshop (see also Figure D.2 in the appendices showing the poster). However, for the conference the poster was pre-populated with a series of issues that had been identified through the case studies and workshops. The complete list of these issues is provided in Table D.4 in Appendix D - Workshops and Interactive Poster.

People could interact with the poster in two ways: they could add a sticky dot next to an existing issue to indicate they had also experienced this, or they could add new issues (see Figure 7.4). New issues were to be placed on the poster according to the rating, like in step 3 of the workshops. Instructions and materials for participation were furnished, so that people could participate at any time during the two days of the conference. According to the conference organizers, the conference had approximately 700 participants and 40 exhibitors (AAL Programme, 2016).

The researcher tried to be close to the poster to encourage people to participate, and thus could get information about some of the people who participated and also gain additional information about the issues people added, which supported identifying whether issues were duplicated during the analysis. At least sixteen people from at least nine European countries were observed participating by the author (a list of the countries is provided in in Table D.3 in the appendices), with many more looking at the poster since it was conveniently located next to the lunch area. Through the poster, the expertise of the participants from the workshops could be extended to include someone from gerontology, as well as people who worked for funding agencies and thus offered a different perspective. Since the conference was related to the AAL Programme, several participants had been involved in projects funded by this programme. The projects that were mentioned were also very broad, including projects with monitoring features like those studied in the case studies, apps, platforms to integrate services, robotic systems, and solutions to support older people working longer.

Putting the poster at a conference ensured people with experience in AAL were included. Issues with dots next to them were ones experienced by more than one person. However, since there was no control over who participated, having no dots does not mean that no one has this issue, only that people who participated had not experienced it. Similarly, having the highest number of dots does not indicate that the issue is most common overall.

Analysis of the workshops and the interactive poster

Thus, the *workshops* helped ensure that participants with a broad range of experience had been included and went into more detail; the *interactive poster* reached a more international group of participants. The analysis of the issues was done together.

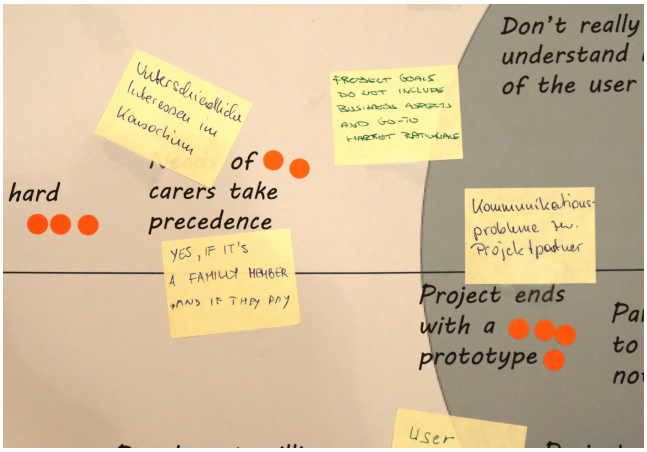


Figure 7.4: Interactive Poster: Contributing through 1) red dots to support other issues and 2) sticky notes containing new issues

All issues and the ratings were entered into Excel^{TM}. First the items were ordered by putting all issues from each workshop group and the poster in a separate column, grouped by the categories. For each issue, the original text, category and rating were included. For the dimension *Importance*, the three levels mentioned above were distinguished: the most important (1) being those in the darkest band on the right and the least important (3) in the palest region at the left (see Figure 7.3). For *Control*, during the analysis it was only distinguished if the issue was in (1) or outside their control (0), i.e. above or below the horizontal line in the center of the poster. The issues were left in the categories as this could give additional information about what was meant by the respective issue. Keeping each source in a separate column supported going back to the notes, photos and audio recording. In practice, each of these sources was used at least once.

The focus of the analysis was discovering issues that were supported or duplicated by another person. First items marked as duplicates by the participants were marked using coloring and notes. The resulting lists were then searched to find issues that clearly matched issues on list from the case studies, and again marked. Finally, the issues were read and re-read in different orders to search for further duplicates between the different columns representing the different sources. Some of the issues, both from the workshops and the interactive poster, were in German. These were translated by the researcher for the final list.

At the end, a list of issues that had been "supported" was made. The rating was then set. If different ratings were given to the issue in different columns, the ratings were averaged and then rounded up.

Afterwards, the categories from the workshop participants were compared to look for similarities and develop the final categorization. This was done both by looking at the names and issues in the categories from the participants. In some cases, the original posters and photos of the intermediate results were re-examined to see if additional

clues could be gleaned regarding what people presumably meant. The individual issues from the poster were also examined to see if the new issues fit into the categories which emerged from the workshops.

The solutions were re-drawn and summarized.

Two people who were involved in Case Study 2 took part in workshop 2. This was planned for *member checking*. However, because of this, the issues that these people confirmed from the case studies were not considered "supported", unless another participant also supported them. To support their issues being identified, different colors sticky notes and pens were given each pair during the brainstorming in step 1, the results were photographed after each step, recordings were made at each table, and the researcher was close by. The issues confirmed by these case-study participants are listed explicitly in the results below. Note that no one from the development team of Case Study 1 participated - the member checking for that project was done through the final interview with the project leader.

In sum, the empirical studies in the supplementary studies complemented each other and served to provide additional issues and to check whether others had experienced similar issues, and as such served both to *extend* the results and support the validation.

7.3 Literature review

The first of the supplementary studies aimed to check if others had reported similar issues and to check whether the projects in the case studies had attributes similar to those of other projects. This was done by a literature review and a review of projects financed by the AAL Programme of the EU in the same time frame. The results are summarized in the following.

7.3.1 Review of software development

In the following, some results were checked against the literature. Since the projects are not success stories, it is also important to consider if the development practices were in line with the "norm" at that time. Otherwise the problems may have just resulted from bad practices and not be relevant for other teams using better methods. The results established that the team structures, development practice, methods applied and even the delays encountered in the case studies were not unusual.

Team structure and development practices A study of development practices in 2010 found that project teams are shrinking (Ambler, 2010). It also found that projects are generally most successful with small teams (1-10 developers). The team size for Case Study 1 was definitely below the average, however not an outlier: 28% of projects have just 1 to 4 developers (International Software Benchmarking Standards Group, 2012). The team size in Case Study 2 varied from small to large depending on the phase, so little can be said. Particularly in the first phase, the number of people in the team was above the average size, with 20, as only 44% of teams have 9 or more developers (International Software Benchmarking Standards Group, 2012). Having some team members in another location is also not unusual - even many years ago, 55% of projects had at least one team member in another location (Kinney and Panko, 1996).

Besides agile, iterative is perceived to be the most successful model of development (Ambler, 2010). While both case studies were iterative, since contents of the iterations were flexible and the working style was highly collaborative, Case Study 1 was closer to agile (e.g. Sommerville, 2007). With eleven meetings in three months, Case Study 1 had more meetings than the average (16.5 meetings in 6 months) (Kinney and Panko, 1996).

The incorrect estimates regarding overall effort, as evidenced by the delays in getting to the pilot in both case studies, is also not exceptional (International Software Benchmarking Standards Group, 2012). This same study found 60% of projects underestimate the effort - sometimes up to a factor of 20 times the original estimate. This is especially the case when new technology is involved or the users have a large diversity - both of which were the case here.

Thus, based on these attributes, the projects should have had an advantage by working iteratively, and Case Study 1 should have had an advantage by having a small team and lots of meetings.

UCD practice Both case studies used methods recognized as UCD practices (Vredenburg et al., 2002), even though the teams did not include usability specialists. Looking at the state of the art of UCD a couple of years before Case Study 2 was started (Mao et al., 2005), the techniques used are ones applied in other areas. This study found user requirements analysis, iterative design, user interviews, prototypes without user testing and usability evaluation were thought by practitioners to be some of the most important methods; iterative design and usability evaluation were among those that were most commonly applied. Based on this, each case study used methods considered both important and applied frequently in practice, but like most projects did not include users in all stages. In line with current practice (Lindgaard, 2014), both did user-based testing in the field before the system was completed.

For the development of the smaller *Next of Kin* system studied in Case Study 1, user requirements analysis, iterative design and prototypes without user testing were used. Several team members felt field studies, which they knew from previous projects, were less valuable than the detailed knowledge team members could provide about their families. Furthermore, tests with users were planned: they were not performed during the first phase due to technical problems, but were done during the final development.

For the development of the more comprehensive *HandyHelper* system from Case Study 2, iterative design and user interviews were used. Furthermore, tests and interviews with users were carried out during the pilot.

Thus, even though participatory methods were not used, it was in line with standard practice in companies at the time.

Similarity to other projects developing AAL systems That both case studies integrated the users in some form during the analysis and/or test was in line with the majority of projects of the same time funded by the AAL Programme (Busquin et al., 2013).

In terms of features, this research focused on systems that included monitoring. *Next of Kin* from Case Study 1 was to be integrated with an app featuring communication services; *HandyHelper* from Case Study 2 integrated services including smart home features, information services, communication services and health monitoring. A study of funded projects developing AAL technology that had Austrian involvement (Geyer and Good, 2016, pp. 19ff), showed that 25% of those projects funded by the AAL Programme of the EU included activity monitoring, 34% information services, 28% communication services and 17% health monitoring. Furthermore, of those funded by the Austrian funding programme *benefit*, health monitoring features were most common, followed by activity monitoring; smart homes features were in fifth place. Thus, the features integrated were ones that were thought to be important in projects developed in Austria with funding specifically aimed at developing AAL technology.

Neither of the case studies was funded by AAL Programme. Since projects like the ones studied may fail before they are successful on the market, in the end, it is not possible to know what proportion of the projects developing AAL technology actually have AAL Programme funding. Both projects did have some sort of funding and people

working in both case studies had previously been involved in projects funded by the AAL Programme. The company involved in Case Study 1 was a SME, which are the focus of the AAL Programme funding. However, the phase studied did not meet the criteria of the AAL Programme in terms of having three European partners (AAL Programme, 2017). There is, however, an indication that despite the stated focus of the AAL Programme of getting systems to market, many are actually research based (Geyer and Good, 2016).

7.3.2 Review - Checking issues

The review of literature about AAL showed that a number of the individual aspects found in the case studies were also reported in studies published by researchers, and indicated that the findings were not unique artifacts of a single project, but had also been reported by others. However, since the research was exploratory, it is not surprising that the case studies also identified further issues that were not mentioned elsewhere. Since these sources were mentioned in the initial theory chapters in more detail (chapters 2 and 3), and the issues were checked empirically, only a brief overview of the results is provided here.

- *Costs* were also found to be an issue for other systems for older people (e.g. Blythe et al., 2005; Eisinger and Eisinger, 2011; Peek et al., 2014).
- *Usability* was found to be an issue with systems aimed at older people (e.g. Blythe et al., 2005; Eisinger and Eisinger, 2011; Peek et al., 2014).
- Functions were also included in other systems that gave control to carers and threatened independence (Mort et al., 2013).
- Discussing intangible concepts, such as sensors, with older people was also found to be problematic by others (Lindsay et al., 2012).
- People may say features are of interest in a show home, but still not necessarily want them for themselves (Eisinger and Eisinger, 2011).
- Satisfying aspects like functionality and usability, but also flexibility and reliability in the same system may prove difficult more generally (Whitworth et al., 2006).
- AAL products are not getting to market as was hoped (e.g. Geyer and Good, 2016; Busquin et al., 2013; AAL Programme, 2015).

An evaluation study covering a wide range of AAL projects, which included both projects financed by the Austrian AAL funding programme *benefit* and the AAL Programme of the EU, provided evidence that some of the problems identified in the case studies were not uncommon (Geyer and Good, 2016, p. 36):

- Technical problems, as experienced in both case studies, often resulting in a delay of tests with users ($> 53\%$ of projects in this evaluation study)

- Insufficient cooperation between partners, as in Case Study 2 (43% of AAL Programme funded projects; 34% of *benefit* funded projects)
- Organizational problems, e.g. partners canceling, as in Case Study 1 (> 35% of projects)
- Insufficient inclusion of users, as in Case Study 1 (> 23% of projects)
- Insufficient means to successfully complete the project, as in Case Study 1 (> 20% of projects)

Furthermore, some of the other common problems, insufficient coordination (i.e. project management) and poorly defined goals that more than 28% of projects suffered from (Geyer and Good, 2016), were *not* an issue in the case studies, perhaps because as one interviewee from the case studies said, the project was managed by a company. Case Study 2 seems almost exemplary, as it suffered only from the most common problems, despite the large number of partners and high level of innovation.

Looking at these results, the benefits of the case studies are also highlighted, as they provide more insight into why these issues arose and how they influence one another.

7.3.3 Review of AAL Programme projects

Since questions about the methods applied arose in Case Study 2, the development of the *HandyHelper* system, similar projects were examined to analyze whether the methods, technologies, etc. applied were state-of-the art when compared to other AAL projects of the time. The materials available were not sufficient to do an analysis in the same depth as Case Study 2, but provided nonetheless information about the methods used and the design, e.g, user interface technology chosen and features included. If other projects used similar methods and encountered similar issues, it would indicate that the development team was not remiss in its choices and would support that Case Study 2 was of value to study. Based on this comparison, the *HandyHelper* was better than some projects in certain aspects, for example length and number of participants in the pilot phase, worse in other respects, for example by not having workshops with users before starting the system, but generally not an outlier, also with regard to some of the technical problems encountered.

Overview of projects

In the following, the three projects found matching the criteria are described. They are referred to as project 1, project 2 and project 3, respectively, to maintain anonymity, as was done for the other projects studied. Due to the selection, these projects cannot be seen as representative, but only as examples. Each of these three projects lasted 24 months, which is similar to the time for the *Intelli* and *PAAL* phases of the *HandyHelper*, but shorter if the time for the initial development and extended show home are also considered.

Table 7.5: Review of AAL Programme projects: Information about projects studied

	Project 1	Project2	Project 3
SERVICES	scale blood sugar level	reminders call doctor	reminders photo book
SECURITY FEATURES	alarm button medication reminder	bed activity sensor gas leak sensor heart rate monitor	fall detection activity via appliances
USER INTERFACE	TV screen with remote control speech input	TV screen audio	touch screen tablet
NEEDS ANALYSIS	Interviews: 40 patients, family carers and professional carers Use cases	Questionnaires: 300 patients, family carers, professional carers and doctors	Workshops with patients Workshops with carers & experts Show home
EVALUATION		Technical pilot Pilot with subset of data Full pilot: 4 months with users Technical support every 2 weeks	Pilot 1/2 - 8 months with 20 people Interview before & after with users Focus group & questionnaire with carers

An overview of the projects is given in Table 7.5. A description about each project is provided in Appendix E - Review of similar AAL Programme Projects.

Comparison to Case Study 2

In the following, the aspects found are compared to Case Study 2, the *HandyHelper*. This comparison starts by looking at the methods for user engagement and evaluation for each project, and then considers aspects such as the features included, user interface technology chosen and technical problems experienced.

Methods used In project 1 both the user needs analysis and evaluation were less extensive. Like *HandyHelper* the older people were asked to comment on functionality in the first iteration, in project 1 the older people were asked to comment on functions suggested by health professionals. These interviews were qualitative and encompassed a much smaller number of patients than the number of people included in the evaluation in the show home of the *HandyHelper*. Furthermore, results indicate that no new suggestions

for functionality came from the interviews in project 1. In total, in project 1 the number of professional and informal carers consulted during user needs analysis exceeded the number of older people.

Project 2 got input from more people during user needs analysis, but had fewer during the pilot. The needs analysis included a far larger number of subjects than *HandyHelper* (225 vs. 100), and most of these were patients. However, people only completed a questionnaire and did not have access to a system and so may have had a limited understanding. Regarding the pilot, only phase 3 can be compared to the *PAAL* pilot of *HandyHelp*er, since purely technical long-term tests had been done as part of *Intelli* project and also lasted several months. In this way, *HandyHelper* had an edge, as it did the initial tests in a situation more like a living lab. The duration of the "full pilot" was similar, though the number of installations was much smaller in project 2 than in *HandyHelper* (7 vs. 35). This is particularly surprising given the fact that the installations were very diverse and the fact that the system depended solely on sensor input. The evaluation afterwards consisted of a questionnaire and medical tests, rather than the qualitative approach used in *HandyHelper* which also looked at attitudes of the older people towards the system and how these had changed. The documents about project 2 report on technical support during the pilot - what they report is less frequent than *HandyHelper*, but this may have been because it was not needed.

For project 3, which did make it to market, the methods, though not necessarily number of participants, were quite comparable with exception of the initial workshops. Unlike *HandyHelper* workshops were done with users before a version of the system was available. Afterwards, interviews were then done in a show home, as in the case of the *HandyHelper*. For project 3, no information was available about the number of people included or whether qualitative or quantitative data was collected. The evaluation used similar techniques, with both pre- and post-test interviews. In addition, in this project carers were included in the evaluation. Fewer persons were involved in the pilot than in *HandyHelper* (20 vs. 35), but the length of the pilot varied greatly: in some locations the pilot lasted just 1/2 month; in others it lasted 8 months, though this may also include the technical tests of the type done in *Intelli* for *HandyHelper*. It is interesting to consider project 3 in more detail, since it did make it to market, and thus could be considered a success. It is impossible to know what led to the success or how great the success is. It is interesting, however, to note that the application itself and the methods applied were quite similar. The main differences were the initial development workshops and the use of a touchscreen interface. Although a touchscreen was used in the final version of *HandyHelper*, by then the company had already decided to discontinue the system. The initial development workshops were specifically mentioned as being valuable, and may truly have had an impact.

Other aspects In terms of features, again there are some interesting indications. Project 2 included only sensor based security features, and did not say which type of sensors were most valuable. For project 3, the security features were rated highly in the evaluation after four months. Since these were barely mentioned by the people in the

evaluation study after the six month pilot of *HandyHelper*, it would be interesting to understand why. It may also be related to the fact that in project 3, the people were still in their own homes. The evaluation report for *HandyHelper* suggests that people need more information about what benefits the system offers. The only two services mentioned for project 3, the project that made it to market, were the agenda which people liked, and the photo book which they did not. Both of these were included in the final version of the *HandyHelper*.

The user interface technology shows similarities to some of the projects mentioned. The user interface chosen for project 1 was similar to that of the initial version of the *HandyHelper* which consisted of a television and remote control, however project 1 included a speech interface as well. However, project 1 was designed for people with dementia. A study of smart homes done in 2011, found that a large majority older people preferred a television and remote control over a touchscreen (Eisinger and Eisinger, 2011), so they were not alone in making this choice. The final interface of *HandyHelper*, which is still in use, has a touchscreen like the more successful project 3. But since the number of services has also been reduced, the improved acceptance cannot be attributed to that factor alone.

In terms of technical problems, the two projects where information about the evaluation was available do mention problems. Project 2 reported a number technical problems; for example, interference with the speaker systems, insufficient range of wireless components, insufficient battery life, the need for a redundant internet connection and problems with an unstable power supply. Thus the problems related both the infrastructure (range of wireless components) and long-term reliability (battery life, need for a redundant internet connection), aspects that were also an issue in *HandyHelper*. The nature of technical problems for project 3 was not described, only that most could be resolved during the pilot. Since the pilot lasted up to 8 months, it is unclear if these were obvious in a short time.

Conclusions about the comparison to AAL Programme projects In conclusion, this analysis supports the value of the *HandyHelper* case study. The methods applied have similarities to the AAL Programme projects studied. The choice of user interface and success were not outliers when compared to these three projects developing AAL technology around the same time.

The user needs analysis included a larger number of participants than one study, but fewer than another. It is interesting to note, that although the evaluation report of the *HandyHelper* specifically recommended more user involvement as a suggestion for improvement, when compared to other projects developing AAL technology at the time, they were not an outlier. Like *HandyHelper,* in one project, some of the functions were decided upon by other stakeholders before older people were asked. One project studied also used a show home to get feedback. Unlike the others, *HandyHelper* used both qualitative and quantitative methods for user needs analysis. Looking at the evaluation, all projects used a pilot study. The length of the pilot was of a similar length for the two projects that reported having one. The number of people in the pilot was greater than

any of these AAL Programme projects studied. The amount of support they provided was also greater than that reported by the one project specifically mentioning it.

Looking at even just three projects, it is possible to find developers who reported similar problems, made similar choices and some that had less extensive user analysis and evaluation. And with regard to the commercial success, only one of the projects could be found in the internet, so certainly *HandyHelper* was not alone in not having succeeded on the market. Furthermore, the experiences here underlines how difficult it can be to get detailed information about completed projects even if deliverables are officially public, which makes the study of *HandyHelper* very valuable.

In the remainder of this chapter, information collected from people involved in other projects is presented. Unlike the results collected in the case studies, these were not in situ or inductive, but based directly on the input from others.

Table 7.6: Interview Study: Information about participants

		Region	Type of organization	Features
1	Bernhard, CEO	central Europe	small company / start up	* venture capital, regional funding * just starting in AAL area
2	Salvator, developer	southwestern Europe	large company	* AAL Programme funding * trying to go to market
3	Per Ove, technical lead	northern Europe	research organization	* AAL Programme funding * problems getting to market
4	Julien, project leader	western Europe	research organization	* regional funding * planning to go to market

7.4 Interview Study: Looking at other projects

In the following section, the results from the interview study are presented. These helped to get more detailed information about projects not possible from literature.

7.4.1 Interviews - Participants

Table 7.6 gives an overview of the people interviewed. Since there is not an obvious order, they are presented in the order the interviews were done. The questions that guided the interviews and a structured summary of the interviews are provided in Appendix C - Interview Study.

7.4.2 Interviews - Issues identified

The list of issues identified is shown in Table 7.7, with information about where the problem was found. In the table "Int 1" refers to the Interview labeled with "1" in Table 7.6, etc.; "CS1" refers to Case Study 1, and "CS2" to Case Study 2. A check mark (✓) in a column indicates that it that it was mentioned by an interviewee - for the case studies it indicates it was also an issue.

All of the projects discussed succeeded in developing solutions, but have not made it to market, at least not yet. All but interviewee 3 seem optimistic about their chances of getting their system to market, assuming they get the funding needed.

The table shows that there was a diverse set of issues and that all people interviewed had different concerns. Nine of the 22 issues were also identified in the case studies - interestingly most of these were also mentioned in more than one interview. Although the same questions were asked, there was a main topic to which most of the issues relate in each interview: interviewee 1 mentioned several issues relating to implementing a system ripe enough for the market; interviewee 2 mentioned many issues related to diversity of older users; interviewee 3 mentioned many issues related to piloting a system; interviewee 4 mentioned several issues related to the design of the systems.

Table 7.7: Interview Study: Issues mentioned

Issue	Int 1	Int 2	Int 3	Int 4	CS1	CS2
Difference between theory and practice	✓					
Getting funding	✓		✓		✓	
Subcontractors don't do work	✓					
Prototype very far from complete system	✓		✓		✓	
Diversity in Europe, e.g. height of people		✓				
Processes of carers differ		✓				✓
Diversity of older: speed of moving		✓				
Older people forget to charge device		✓				
Appearance affects acceptance		✓	✓	✓		✓
Layout of houses		✓				
Older people don't want to be a bother		✓				
Time for tests short, esp. due to delays		✓	✓		✓	✓
Getting people for long-term tests			✓	✓	✓	
Infrastructure problems			✓			✓
Switch to care home, but different			✓			✓
Communication in team, due to language			✓			
Getting relatives to agree to tests			✓			
Municipalities slow			✓			
Not having common understanding in team				✓		
Privacy concerns				✓		
Hard for users to admit needing help				✓		
Making it too complicated			✓	✓		✓

A number of aspects related to having international projects that was not covered by the case studies were mentioned by the interviewees. These included things such as the height of people, layout of houses and language aspects that affected communication in the team.

There were also some new issues relating to having older users: differing speeds of motion, forgetting to charge devices and privacy concerns, e.g. related to video images even if they were only processed locally. At the same time, it was difficult to get family members of older people to agree that their older relatives participate in the tests that were needed in order to check if the systems worked properly and get feedback from the older people. Moreover, it was mentioned that older people did not want to admit that they really need assistance, which further reduced the number of people available for testing. Even with those people who did participate, it could be difficult to explain the privacy mechanisms, in part because people did not understand the technology involved. A couple of interviewees also mentioned how dependent people became on the systems during long-term tests, which then made it difficult when the project could not

Table 7.8: Interview Study: Recommendations from interviewees

Recommendation	Int 1	Int 2	Int 3	Int 4	CS1	CS2
Can fix hardware problems with software	✓					
Need easy way to distribute changes	✓					✓
Work user-centered and iteratively		✓				
Architecture that allows components to be changed later		✓				
Research literature regarding needs			✓	✓		
Include the user early			✓			✓
Leave enough time to test with users (& iterate)			✓			
Include a designer in the team			✓			
See the user environment personally			✓		✓	✓
Keep it simple: rather fewer functions			✓	✓		✓
Research also other projects				✓		
Include a user organization				✓		
For e-health parts, situate in one context				✓		
Regular meetings with all partners				✓		
Partners that are willing to go beyond minimum				✓		
Structured requirements gathering				✓		

be continued. The fact that municipalities reacted slowly with respect to continuing the systems after the end of projects compounded this.

Two interviewees mentioned how long it took after a working prototype was available. One person mentioned that it took a year just to find people for tests, to train them and run the tests; another mentioned that the prototype was less than two percent of the complete system.

The appearance matters for systems that are installed at home, an issue mentioned in three interviews. In one case, a woman turned off the system and put it in the closet due to the big black cords she thought were ugly.

7.4.3 Interviews - Recommendations

The recommendations from the interviewees are shown in Table 7.8. Most of the recommendations in the table were mentioned explicitly as recommendations, others were mentioned in response to other questions. Here the check marks indicate which interview the recommendation came from, and whether it was something also suggested by someone interviewed in relation to one of the case studies.

The table shows that there were a number of recommendations. Two of these were mentioned by more than one interviewee; four of the recommendations were also mentioned in the interviews from one of the case studies. As with the issues from the interviews described above, there was also a certain focus that runs throughout the recommendations

from each interview: interviewees 1 and 2, who mentioned issues regarding getting to market and diversity, respectively, suggested more technical aspects; interviewee 3, who mentioned issues related to pilots, focused on usability aspects; interviewee 4, who mentioned aspects related to design, focused on recommendations related to project management.

Many of the recommendations concerned getting information about the people who will use the system. People interviewed recommended researching existing literature regarding the needs of older people, ways of including users early in the development, using prototypes to make the system more tangible, leaving enough time to test and iterate, and simplifying the system by having fewer functions. Having the developers see the use environment personally reportedly helped developers better understand the needs and abilities of older users, and in some cases also yielded information about unexpected usage of the system, for example, that people used messages to themselves instead of reminders in order to avoid having to switch screens.

Technical aspects were also mentioned. The recommendations regarding this were closely aligned - it is important to have a flexible architecture. This was thought to help with a variety issues; for example, technical problems, problems with partners delivering components and also problems users have once the system is running.

But also the project environment was important - considering the choice of partners carefully was thought to be important, as was keeping in touch with them regularly. Furthermore, one interviewee mentioned that it makes a real difference to the objectives and how practical a project is if it is led by university rather than a company.

7.4.4 Interviews - Comments

It is noteworthy that the company for interview 1 had quite a few similarities to Case Study 1. Both were small companies, that were using general funding for innovation to extend an existing project with monitoring features. Unlike the company in Case Study 1, the product from Interview 1 was originally aimed at a younger market.

From the tables, it is evident that some of the interviewees and case studies had similar problems, for example, that the effort to get from a prototype to a complete system was significantly greater than expected. Likewise, making a project international, did seem to add complexity. Three of the four interviews mentioned aspects that differed between countries, which complicated international projects. These included aspects about the height of people, language, regulations about who can access medical data, but also other aspects, for example, the fact that in Nordic countries at certain times of year it isn't possible to know whether it is daytime just by looking out the window.

Through the interviews, it was also possible to gain some background information about the issues described. An issue mentioned in both interview 3 and interview 4 related to finding testers. But the cause was not the same: in one case this related to people having dementia and needing the family to approve; in the other case, it related to privacy and aesthetic concerns. In relation to required family approval, getting people from the care home to recommend it helped. The privacy concerns were less easy to address, because even explaining how the system worked, for example that the video

images would be blurred and would not leave the home, did not convince people. The aesthetic aspects could be improved, something mentioned as an issue in more than one interview. But also regarding this, health care professionals and family could have a strong influence.

In terms of function, more than one person interviewed mentioned the tendency to make the systems more complex than the users really wanted or needed. One person interviewed also supported the importance of having developers experience the environment personally, which was also mentioned by people involved in both case studies. Although it was not thought to have been a problem, in interview 3 Per Ove also thought that people were considered differently when sensors were involved.

Then again in the recommendations similarities were apparent - reading the literature, being iterative. Two interviewees also mentioned that they benefited from more structured methods of collecting requirements. Note that although Julien from interview 4 thought involving a user organization was important, this did not guarantee success, as both Per Ove (interview 3) and the project leader of Case Study 1 can attest to.

7.5 Workshops and Interactive Poster: Gathering information about issues from a wider group

Next the issues identified through the workshops and interactive poster are presented. These helped both to support the findings of the case studies, but also to extend the results by collecting issues from a wider group of people. First the issues that were identified and how they were rated are presented. Afterward, the categories and solutions developed in the workshops will be described.

As described with the research methods above (section 7.2), workshop 1 included five participants, workshop 2 included nine, and at least sixteen people contributed to the interactive poster. Most of the workshop participants were from Austria, but covered a broad range of disciplines, organizations and experience in AAL; the people who contributed to the interactive poster came from various countries. For more information, also about the participants, see Appendix D - Workshops and Interactive Poster.

7.5.1 Workshops and Interactive Poster - Issues identified

In total 71 issues were identified by participants in the *workshops*: 23 from workshop 1 and 48 from workshop 2. Some of the provided issues were supported by each workshop. In total, eleven of fifteen issues from the case studies were supported (see Appendix D for the list of the issues from the case studies), meaning that others had also experienced this problem. In addition, five new issues from workshop participants were duplicated by another participant.

Through the *interactive poster* 28 new issues were added (Figure D.2 in the appendices shows an image of the poster after the conference). Thirteen of the fifteen issues from the case studies and workshops used to pre-populate the poster (see Appendix D for the list), and fifteen of the new issues added by participants were supported with red dots (as shown in Figure 7.4).

Member checking results from the case studies

Two people involved in Case Study 2 confirmed five of the twelve issues on the list relating to that case study (see Table 7.9). Although they did not confirm all issues, it is also important to note that no group took more than six items from the list.

Issues that were supported by multiple sources

Removing duplicates, e.g. points from workshop repeated on the poster, though not pre-populated, there were 33 issues that multiple participants had experienced. This included issues as diverse as, *"Don't really understand the needs of the user group*" and "*Communication problems between project partners / stakeholders*". The complete list is provided in Table 7.10 with the rating. The rating was done by the participants, as described in the methods (see also Figure 7.3). In the table, the issues are grouped by categories (described below), and within each category ordered by importance. To make

Table 7.9: Workshops: Issues confirmed by people involved in Case Study 2

Issue
Adding partners adds complexity
Developers not older – fall back on stereotypes
What people say (e.g. show home), isn't necessarily what they do
Finding people for long-term tests
Lots of support needed at start
Change in care makes difference to functions needed

it easier to interpret, issues rated with high importance are shown in CAPITAL LETTERS. Some issues in the list are closely related to one another - they were only combined, if it was certain the same thing was meant, e.g. because it was an item from the list or pre-populated on the poster.

Interestingly, in workshop 1, all issues identified were given the highest or medium level of importance, and none were give the lowest level. This was not the case in workshop 2. This may be due to the fact that participants in workshop 1 were invited and hence people focused on those aspects that were most important - or they may simply have given issues a higher priority. It was a smaller workshop and overall the level of consensus was higher.

7.5.2 Workshops - Categorizing issues and finding solutions

In the following, the results specific to the workshops are described. This includes the categories suggested by participants for the issues identified and the five solutions suggested to address some of the issues identified. These aspects add a layer of meaning to the individual issues: categories help to give meaning to the individual issues by linking them into a bigger context; the suggestions help point at a possible cause, and may help people avoid these issues in the future.

Categorization

To help make sense of the issues and how they are related, the people in the workshops were asked to inductively group or categorize the issues they had and to name or label the categories. This step was important, as the context was less known than in the case studies. The categories which emerged are shown in Table 7.11. The names of the categories shown here were those developed by the participants, the number of issues in each is shown afterwards in parentheses. In one group, one issue was included in two different categories, hence the $\frac{1}{2}$. However, a unified set of categories was needed. Subsequent paragraphs describe how the final categories were determined.

The first step entailed examining the categories from the participants more closely. It is evident that there was some overlap (see Figure 7.5). For instance, "Funding perspective" has certain similarities to "Money" and "Financing" - especially when the individual issues were considered. Some groups had individual categories for certain

Table 7.10: Issues supported by multiple participants through the interview study, workshops and interactive poster

Category	Issue	Importance	Control
Users	Don't really understand needs of the user group	high	in
	Very diverse user group	med	out
	Lots of support needed at the start	med	in
	Finding people for long-term tests	med	in
	Privacy concerns	med	in/out
	Older people don't want to pay for solutions	med	out
	Changing needs of older people	low	out
	Needs of carers take precedence	low	in
Financing	Problems finding funding / financial partners for new projects	high	out
	Partners chosen to get funding, not expertise	high	out
	Adding partners adds complexity	high	out
	Project ends with only a prototype	high	out
	Companies not interested in investing own resources	low	out
	Technical partners want easy funding	low	in
Marketing	Lack of overview of the players / which projects have been developed	high	in
	Technologies not financially supported - carers are	high	out
	Low project impact - business development too late	med	in
	Project goals do not include go-to market rationale	med	in
Product	Technical prototypes too complex for field tests	med	in
	Unproven benefits	med	in
	Benefits hard to prove	med	out
	High reliability needed - in all situations, over time	med	in
	Shouldn't be too obvious, e.g., LED light	med	out
	Maintenance requires special requirements	low	out
	Reliability takes over - but usability important to acceptance	low	in
	Development lifecycles differ - computer vs. buildings	low	out
Project	Communication problems between project partners / stakeholders	high	in
	Product definition driven by research topics and tech push (rather than user input)	high	out
	Still little inclusion of users beyond testing	med	in
	Different interests in consortium	med	in
	Different language of different experts - hard to find agreement	low	in
	Structure & culture of companies differ in consortium	low	out
	Time needed to prove results longer than duration of project	low	out

Table 7.11: Workshops: Categories identified by participants

Workshop 1	Workshop 2, group A	Workshop 2, group B
Funding perspective (8)	Users (9)	End-user / development (9)
Commercialization - Marketing ($7\frac{1}{2}$)	Money (7)	Financing (5)
User perspective	Product (5)	Solutions (5)
Product perspective - Usability ($2\frac{1}{2}$)	Project / Organization (5)	
	Other Stakeholders (3)	

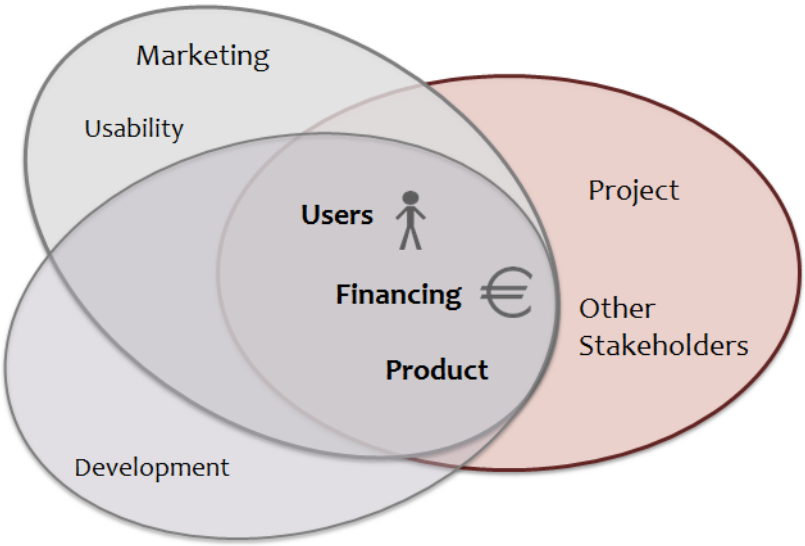


Figure 7.5: Workshops: Categories and overlap between them

things, like "Users", that were only a part of a larger category, such as "End-user / development", in other groups. Similarly "Product" coincides with "Solutions". After separating these combined categories, it was easier to see where the categories from the different groups overlapped. All groups identified issues relating to *Users*, *Financing* and *Product*, which are shown in the middle of the figure. The other main categories mentioned separately were "Marketing", "Project" and "Other Stakeholders". "Usability" and "Development" were also mentioned, but only as part of another category.

Analyzing the issues also helped to find similarities between categories. The issues "Users" from the workshop generally referred to older people, whereas "Other stakeholders" referred to carers, who also used the system, but since there was only one issue supported by more that one participant and it also related to the older users, these categories were combined in the final list. Furthermore, the issues in "Project" from one workshop group closely related to "Development" from another workshop group, for example, users being only included in the test phase, so that these categories were also merged. Similarly, the issues in "Usability" from workshop 1, closely related to those labeled by "Users" in workshop 2, so that these were also joined.

In the end, five categories remained: *Users, Financing, Marketing, Product* and *Project*. All issues from the interactive poster could also be assigned to one of these categories. The issues in the categories, which are presented in the Table 7.10, are described here briefly.

Users included a number of issues, most of those supported by multiple participants were rated with medium importance. This included aspects such as the diversity of the older user group, the fact that their needs change over time, and importance they put on of privacy. It also included issues, such as difficulties finding people for long-term tests, that aggravate efforts to understand the needs of the group.

Financing related to getting funding, most of the issues in it were rated with a high level of importance. Most of these issues related to partners: that having lots of partners added complexity, that they were often not chosen for expertise but to fit the requirements of the funding programmes, and that some did not want to invest their own resources. Although some of the issues were related to conditions of the funding, it was not just about placing blame - there were also issues like *"Unrealistic project expectations/goals"* and the need to take smaller steps, although these were not supported by anyone else and hence not in the final list. These issues in this category were considered to be particularly *important* by workshop participants. In both workshops, more than half of the issues in this category were rated with high importance (all in workshop 1 and seven of twelve in workshop 2). Furthermore, issues from *Financing* also make up a large proportion of those items rated with high importance (eight of thirteen in workshop 1, and all in workshop 2).

Marketing included issues regarding getting to market. This included aspects that teams could control, such as doing the business development earlier, but also aspects that required support from funding agencies, such as getting an overview of which projects had been funded. Although fewer of these issues were supported by other participants, three of the thirteen items of highest importance in the first workshops were from this category.

Product related to the AAL systems. For example, the benefits were thought to be unproven and also hard to prove, or that the systems needed to be reliable in a large variety of situations, and that this often took precedence over usability, which was important for user acceptance.

Project included issues regarding aspects during the development itself. This included some methodological issues, such as insufficient time for testing and that users (referring to the older users) were often not included besides for testing. There were also issues more related to the project structure, such as communication problems between partners and stakeholders, perhaps related to the different interests and different "language" of different experts mentioned in the interview study.

Solutions suggested by participants in the workshops

In order to move towards solutions, the people in the workshops were asked to choose an issue or group of issues to find solutions. In Workshop 1 two solutions were developed, in Workshop 2 three resulted. The results are summarized here, including the category and

rating of the issues considered. Copies of the solutions drawn by the participants are included in Appendix D - Workshops and Interactive Poster.

Solution regarding *Financing* from workshop 1: Several issues were selected and discussed in relation to funding, e.g. *"Unrealistic project expectations / promises", "Little thematic flexibility"*. All issues selected had been rated with the highest level of importance and outside their control. The participants felt additional flexibility was needed, including thematic flexibility during the initial phases to avoid the "tech push" and more flexibility during the development to still allow sufficient time for tests despite delays. Furthermore, additional support or coaching was suggested during all phases: generating ideas, development and market introduction.

Solution regarding *Marketing* from workshop 1: For issues: *"Lack of overview of the players" & "Lack of overview of which projects have been developed"*. Both issues had been rated with the highest level of importance and inside their control. The participants developed a list of the players. This included different user groups, insurers, funding agencies, and the universities and companies involved in the development, among others.

Solution regarding *Financing* from workshop 2: Several issues from this category were selected and discussed with regard to the market perspective. All issues had been rated with the highest level of importance and outside their control. After much discussion, the group concluded that research funding had dried up and that it was a difficult situation for start-ups. Rather than specific AAL solutions, they suggested add-ons to existing products had promise for established companies, such as to a robotic vacuum cleaner. Note that the people who developed this solution were either from a start-up or people working in applied research.

Solution regarding *Product* from workshop 2: For issues: *"Too little value - AAL technologies" & "Benefit difficult to prove"*. Both issues had been rated with medium level of importance and inside their control. First the problem was identified as there being little value in AAL systems, that the value was hard to prove, but also that the needs of older people were not really known. The solution was two-fold: in future projects developers need to do more requirements analysis to develop tailor-made AAL products, and researchers need to develop appropriate instruments to measure the benefit and then do long-term studies to actually measure it. Note that the people who developed this solution were themselves researchers. During the presentation to the group, it was discussed that these problems came about because AAL emerged from funding. The group felt these steps could make the results more market oriented, increase user acceptance, and also encourage investment from users.

Solution regarding *Users* from workshop 2: For issue: *"Developers are young → older people stereotyped"*. This issue had been rated with the lowest level of importance and inside their control, which made it an interesting choice. The solution was using information that *is* available, e.g. from project leaders who are often older, older relatives and information collected about older people by social scientists. To solve the problem, developers should draw on this information, work in interdisciplinary teams and talk to the older people who are the target of these types of systems. Note this issue was on the

list of issues from the case studies, and the person who selected it was someone involved in Case Study 2 *HandyHelper*. During the presentation to the group, the group discussed that "we" (the software engineers and educators) had failed because developers were not sufficiently aware of need to gather information about the users and their needs, and that perhaps forcing people to talk to users or forcing them to use certain methods may make sense, at least in bigger companies.

7.6 Supplementary Studies: Summary

The goal of the supplementary studies was to check the choice of the case studies, identify additional issues, and to check whether the issues have also been faced by other projects. In addition, through them it was possible to see how important people thought each of the issues were, how much control development teams had over them. Based on these, the supplementary studies supported getting some recommendations for future projects. These studies focused more on isolated issues. These issues will be linked and the results discussed in the overall discussion in the next chapter, and only summarized briefly here.

By looking at the practices of other companies both in and outside of the area of AAL, it could be shown that the projects studied in the case studies were in line with projects of the same time in terms of the problems they had and methods they applied. Through the interview study, workshops and interactive poster it was possible to check whether issues encountered in the case studies had also been experienced by other projects. The results showed that other teams have experienced similar difficulties during the development of AAL technologies. The categories, ratings and solutions from the workshops supported seeing how the issues fit together.

In the end, the issues identified could be grouped into five categories. Issues relating to the categories *Financing* and *Users* were identified by all workshop groups and also in the interview study. The greatest number of issues supported by multiple people through the workshops and the interview study related to *Users* and *Product*.

The issues rated *most important* by the participants in the workshops were in the categories *Financing*, *Users*, *Marketing* and *Project*, with most in the category *Financing*. Those rated *within the control of development teams* do seem to be issues that could be fixed, for example getting an overview of the players by creating a list, something that was done for Austria in workshop 1, but needs also to be done for the broader context.

The issues people chose to consider "solutions" for also favored *Financing*, even though these were thought to be out of the control of teams, with two of the five solutions relating to this. The supplementary studies highlighted how important the money issues were to people involved in the projects - both funding/grant and marketing. In Case Study 2, the funding problems that lead to switching from a system for people in their own homes to people in care homes, affected the needs in subtle ways and ultimately may have impeded the success. Furthermore, in Case Study 2, the difficulties and costs associated with getting to market, which also were mentioned in the workshops, resulted in the entire project being stopped. Many of these issues were thought to be out of control of the teams. Additional flexibility in grants was recommended by the workshop

participants to address this - both thematic flexibility in early phases, but also more flexibility with regard to deadlines during the development. This is important, as the interview study also supported the importance of having a long period of testing with users to check results from more than one version, both for usability of the interactive features and for reliability of the security features.

Given the results of the case studies, it may seem surprising at first that issues related to UCD were not widely mentioned in workshops and the interactive poster. At the same time, two of the five solutions specifically mentioned the need to be user-centered and many of the recommendations from the interview study also relate to UCD. The issues pointed to both difficulties being user-centered, e.g., difficulties getting access to older people for long-term tests, and also a poor choice of methods, e.g., *"Technical prototypes too complex for field tests"*, where methods like storyboards described by a participant in the interview study may be more appropriate. Still it has been shown most projects do include users in some way (Busquin et al., 2013; Garschall et al., 2016). However, there are pitfalls to using UCD, especially when working with older people (Lindsay et al., 2012). Findings of Case Study 1 showed in detail how this happened in one specific case. The supplementary studies indicated that although users were included in the development, people involved in projects still felt developers were not user-centered enough. To address this, it was recommended that project leaders draw on information about older people and previous projects that is available, and use the range of user-centered methods that are available. This indicates that teams may need more information about the resources and methods available, or that the information available is not really in a usable form at present.

There were also issues related to the technical implementation and management of the development process. Case Study 1 demonstrated some of the problems, e.g. reliability, with which project teams are grappling could distract teams from the older users and their needs, even if they started working in a user-centered way. Issues such as *"High reliability needed in diverse situations"*, that *"Reliability takes over – but usability important to acceptance"*, underline the fact that also other projects have experienced technical problems and that these may be taking the focus away from the users. However, there may also be aspects of the project structures that complicate the development, such as *"Communication problems between project partners / stakeholders"* and *"Adding partners adds complexity"*, seen in Case Study 2. Project management was an issue, for instance with regard to the issue of communication between stakeholders, and also the recommendation from the interview study to have regular meetings. Since the people involved in these studies have experience and include experts, it may seem surprising they report problems like this, as these seem like basic project management. However, other studies have found that lack of formal project management practices is a risk for software development projects more generally (Tiwana and Keil, 2004).

In the next chapter the results will be discussed to give a more complete picture of the situation and put the results in context, but also describe the contribution and the implications of the research.

Part III

Discussion

CHAPTER 8

Discussion

This chapter discusses the results of all studies. It starts by looking at aims of the research, and then summarizes the findings of the empirical studies. After this, the issues identified are unpacked and described. The results are then put in the context of the work of others. After this, the contribution and limitations of the research are described. At the end, in addition to some advice for developers and project leaders, there are points for future study for researchers and funding programmes that may help increase the likelihood of success in the future. Although the discussion here is new, some aspects have been included in the publications relating to the individual studies.

8.1 Revisiting the research studies

We start by revisiting the research questions behind the research, the design of the studies and then briefly recapitulate the findings.

8.1.1 Research questions and methodology

Due to the aging demographics in Europe there is a need to find ways to support the growing number of older people (European Commission, 2006). AAL is a way of approaching this, trying to address the issues caused by the demographics by providing technology to allow older people to live in their own homes longer (AAL Joint Programme, 2017). Although the development of systems has been supported by different funding programmes in Europe since 2008, systems are only now starting to reach the market (e.g. AAL Programme, 2015). Continued funding is seen as being necessary (e.g. Busquin et al., 2013), so that some funding programmes have been extended, such as the AAL Programme of the EU. Previous research has described the technological possibilities (e.g. Eichelberg et al., 2014), and also investigated user acceptance and barriers to adoption (e.g. Sanders et al., 2012).

This thesis complements this previous research by exploring what happens during the development of AAL technologies to identify issues that arise that could affect the success of these systems, and to understand how these fit together. It is also during the development that decisions are made that can affect the barriers to adoption identified by others. The focus was placed on projects incorporating sensor-based monitoring features developed by companies. This research took the perspective of HCI. The goals were to support practitioners in avoiding these problems in the future and to support researchers in finding more systematic solutions to them.

The guiding research questions were related to the overarching concerns of ***users*** (RQ 1), the ***technology*** (RQ 2), the ***development processes*** (RQ 3) and ***wider issues*** supporting understanding (RQ 4):

- RQ 1: How are stakeholders, including older people, considered and included in the process?
- RQ 2: How does using sensor technology affect the development?
- RQ 3: How is the development done in practice?
  - RQ 3.1: Which user-centered methods and techniques are used?
  - RQ 3.2: How are decisions made during the development about which features to include?
- RQ 4: What other issues arise that could potentially affect the success?

In order to understand what is happening during the development process and what leads to the difficulties, a constructivist approach was taken. To this end, two qualitative case studies were conducted to explore what happens in practice, and to look at what happens in more detail in order to gain understanding regarding how the issues fit together. To get a more complete picture, each of the case studies included different aspects: Case Study 1 was a smaller project based on tablets that was studied during the initial development phase using ethnography to identify and understand the problems that happened in more depth; Case Study 2 studied the entire development of a more comprehensive system with many services retrospectively to get information about a wider range of issues not available through the first case study, such as having multiple partners and the introduction phase. The analysis was based on thematic analysis and identified a series of interrelated issues that could contribute to the lack of success. In a final step, a series of studies was done to get input from other people who had worked in the development of AAL technology. These supplementary studies included an interview study, workshops and an interactive poster to get input from a wider group of people to see what issues they had encountered and to check if others had also experienced some of the issues identified. Through these supplementary studies, it was also possible to have people with experience in the development of AAL technologies rate and categorize the issues, and propose solutions to some of them, which also provided evidence of how the issues are interconnected.

8.1.2 Results of the empirical studies

In the following the results of the studies and the main themes identified are summarized to refresh them in the mind of the reader.

Case Study 1 *News of Kin*

Case Study 1 followed a smaller project done by a company classified as a start-up during the development. It centered on a monitoring system aimed at private homes. Using sensors included in normal smartphones, the goal of the system was to monitor activities in order to determine if an older person appeared to be okay, for example by moving around, and otherwise send an alarm to relatives.

Since the case study followed the development, it was possible to identify themes in the discourse during meetings. The two main themes identified were *the disappearing older user*, and *the privileged developer.*

The disappearing older user was used to describe how the older people were first a central concern, and gradually disappeared from the discussions at meetings and also in the documents. At the outset of the project, five older people were described in rich stories recorded as persona-like exemplar users. In part due to the nature of sensor-based systems, the older people were reduced to sensor generators in the meetings. As the project progressed, stereotypes and generalizations with regard to older people took over from the concrete needs of family members considered at the outset. Perhaps due also to the technical complexity and difficulties, gradually the technical aspects gained importance.

The privileged developer, the second theme, described how the needs of the developers gradually gained precedence over the needs of the older family members. Older family members were used as exemplar users, because the user organization who had agreed to participate canceled shortly before the project started. This made the team members the active users, those receiving the alarms, though they never explicitly described themselves, the family carers, as a user group. Because they were in the team, their wishes were given priority.

Due to technical problems, the system was not tested with older people. After later development cycles the project was abandoned, and so did not meet its goals.

Case Study 2 *HandyHelper*

Case Study 2 retrospectively examined a project that was developed over a period of more than four years. This was a larger smart home system initially aimed at older people living in their own homes. The themes were grouped into the impact they had on the project: *The methods applied* and *The hidden effort to get it working.*

The methods applied included a number of factors concerning getting input from the users and other stakeholders. For instance, including both interactive services and the sensor-based security functions meant that information was required from older people, but also from others who were affected by the system, e.g. the carers and emergency

services who reacted when there were alarms. Since the system was innovative at the time, there was little information regarding the types of services older people might need and want. The first phase involved showcasing a first solution at a show home. In an evaluation study conducted at the show home, the older people came up with a long wish list of functions. Including too many of these then reduced the usability. Usability was important for the services, also due to the diversity of older people for whom the system was intended, some of whom had little technical experience. Due to the monitoring features, reliability was also important. Since monitoring was relatively innovative at the time, new algorithms were necessary to achieve the needed reliability. A six month pilot was held to test the system. Although there were initial problems with the reliability due to the infrastructure, the primary problems related to usability.

The hidden effort to get it working included a number of factors that necessitated significant effort after the system was basically working. Owing to the economic climate at the time, the project came under pressure to make a profit. Due to this, research funding was used, but this required that new features and additional partners be added to attain the level of innovation stipulated by this funding. This in turn, necessitated additional coordination. And the new features that were added made the system less usable. The pilot took months, during which time no profit was made, and during which a great deal of support was needed for the older people. In the evaluation interviews several months after the pilot had started, the older people who had the system installed were focused on the services and their usability, rather than on the security features that people had initially reported wanting.

After the show home the focus was changed from private homes to assisted-living facilities due to a variety of factors, without reconsidering that the needs of people in these different settings also differ. After the extended pilot, the older people included in the pilot chose not to pay for the system, which seemed expensive to them in comparison to the subsidized costs of the on-site carer. Although the system was installed in another assisted-living facility and still works there, the *HandyHelper* system was withdrawn from the market.

Supplementary studies

The interview study, workshops and interactive poster yielded more than 100 issues. In all, 35 people from eleven different European countries with experience in AAL projects participated in these studies. The participants supported many of the issues identified in the case studies and also helped to identify new ones. In addition, the workshops enabled issues to be categorized and provided some ideas about how some of the issues identified could be addressed.

Five categories were identified into which the issues could be grouped: Financing, Users, Product, Project and Marketing (see Figure 8.1). *Financing* refers to issues relating to getting money from funding programmes. *Users* includes aspects concerning older people, carers and other stakeholders who are in some way affected by the system. *Project* includes aspects about the structure of development teams. *Product* includes various aspects about the systems themselves, including the usability. *Marketing* refers

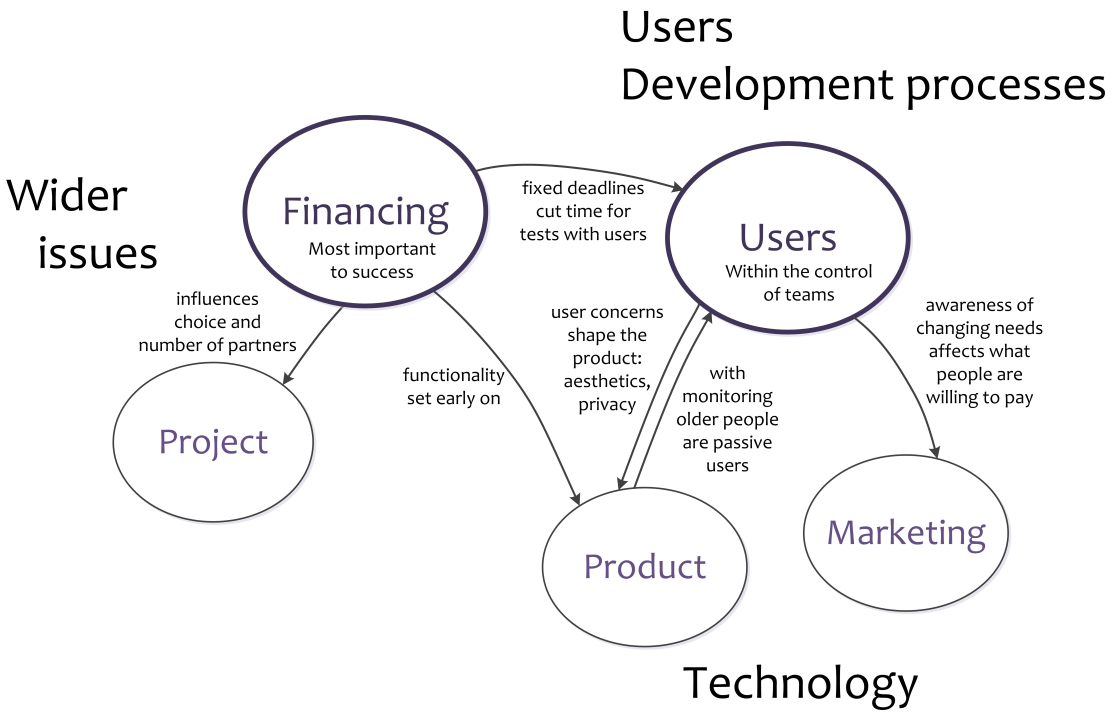


Figure 8.1: Categories for the issues identified, some of the links between them and the overarching concerns from the research questions

to successfully getting a system to market and having a commercially viable product. The categories are not entirely independent, as indicated by the arrows in the figure.

Issues in the categories *financing* and *users* were central: issues in these categories were found in both case studies, the interview study, the workshops and the interactive poster. Hence the categories are shown with thicker lines in the figure. The issues thought to be most important to success were in the category *financing*, but most of these issues were considered to be out of control of the teams. In the other categories, there was a mixture of issues considered to be in and out of the control of teams.

These categories supported connecting the individual issues to form a richer picture, contributing to an understanding of what happens during the development of AAL systems.

8.2 Answering the research questions: Issues when developing AAL

The case studies demonstrated the complex situations these projects faced and provided some rich themes that helped to understand what happened during the development in two specific cases. For the supplementary studies, these themes were reduced to smaller

issues that could contribute to projects not having success, so that the individual issues could be checked by others. In the workshops, groups categorized the issues, thus linking the issues back together and giving them structure. The categories identified through the supplementary studies proved to be a good basis to describe the issues identified, also those from the case studies.

The research was guided by questions concerning the users (RQ 1), the technology (RQ 2) and the development processes (RQ 3), though it was also open to wider issues (RQ 4). The results supported this choice: issues related to all research questions were identified through both case studies; categories and issues about users and the product were identified by all workshops groups.

Regarding RQ 1 about the way in which users and other stakeholders are considered, in both case studies older users were considered first and their needs were considered in detail, including aspects about their activities and physical and cognitive limitations. However, it was often the carers who described the needs - both for themselves and the older people. The results from the supplementary study also indicate that older people may not be included during the needs analysis, and only in tests. Other stakeholders, who do not use the system but are affected by it, such as emergency services and municipalities, are included directly in some projects, for example in the meetings in Case Study 2. Through Case Study 1 it was possible to see how things developed in more detail. The team started out considering the older people as complete people, and not just in terms of the system. However, the aspects about health and frailty were given more weight in the information recorded, and, later in the project, activities that could be sensed were given more focus, perhaps due to the concern of the team members for their relatives or the fact that the goal of the system was to monitor and see if there was a problem. Thus, although the choice of the concern 'users' was supported, the findings show that when people are considered merely as 'users' in the projects developing these types of technology, important nuances get lost.

Regarding RQ 2, monitoring systems integrating sensor technology that were the focus of this research are particularly challenging, as was shown in Case Study 1. With sensor-based systems, the older people are actually *indirect* 'users', people who generate signals that are sensed, and may be forgotten in favor of the carers who actively use the system. This can happen for different reasons, such as the complexity of pattern recognition or because the needs of the carers are closer to those of the developers, who may also have older family members they worry about, as in Case Study 1, or because of difficulties explaining what the system can or will do to get the necessary input, as happened in the show home in Case Study 2 (see also Lindsay et al., 2012). Getting input from the older people who will be sensed is important to ensure reliability. As mentioned above, reliability is important for systems generating alarms automatically based on sensor data; difficulties reaching this can cause delays in projects, reducing the time available for tests with users. Furthermore, sensors raise questions of privacy. As one person in the interview study explained, people of any age would be concerned about privacy; older people may have more concerns, partly because they may not understand what the technology can do, as happened in Case Study 2 where people felt the system

was "watching" them even though cameras were not used for the monitoring. These aspects also affect the *marketing*, another category that was identified.

With regard to RQ 3, in practice the case studies and the interviews showed participants had worked in iterative and user centered ways. With regard to RQ 3.1, different techniques and methods were used to consider and include the various stakeholders in the case studies. These included persona-like descriptions of older people, usage scenarios, early working prototypes to get input from users without user testing, workshops with older people in a show home, interviews with older people, iterative design to integrate feedback, meetings with carers and other stakeholders, extended pilots with older people and evaluation interviews with people involved in the pilot. In the supplementary studies, participants reported using interviews, focus groups, use cases, working prototypes for demonstrating the system to users and long-term tests with users. Using early working prototypes allowed older people to give feedback on the solutions, even if they were not included in other ways during the initial needs analysis. Many of these are accepted UCD methods (e.g. Mao et al., 2005; Bevan et al., 2010).

Regarding RQ 3.2 which deals with design decisions, results of the empirical studies indicate that in many cases the initial project goals and functionality were set before a user analysis was done, so that the projects were driven by the goals of funding programmes, research topics and "tech push". During the development, it was primarily the carers who had a direct influence on decisions regarding functionality. Technical aspects also influenced decisions, as in Case Study 1 where patterns chosen were based less on the actual activities of older people, than what was easiest to recognize. Furthermore, in Case Study 2, even though evaluation interviews were conducted with older people, in some cases, the observations of people involved in the development made during the pilot had a greater influence on the next iteration.

With respect to RQ 4, issues were identified in two further categories: *financing* and the *project structure*. Furthermore, there were also issues in the aforementioned categories *user*, *product* and *marketing* that were not directly related to the specific research questions, such as the diversity of the users. These "wider issues" included a large proportion of those issues rated by experts as being most important to success. Whereas the issues related to financing were perceived to be out of the control of development teams, many of the issues relating to project structure can be influenced through good project management. These issues are described below in more detail.

Together the results give more information about the issues that arise in the development of these types of systems and how they are connected. In the following, some of the issues identified are unpacked and reconstructed to give a richer picture that supports understanding what happens during the development and which aspects could contribute to projects not being entirely successful. Each of the five categories will be discussed based on findings of the empirical studies (Figure 8.1 gives an overview of the categories, including some of the links between them, and also how they relate to the aspects covered by the research questions). The categories relate to the overarching concerns used to define the research questions: the issues relating to both ***users*** and ***development processes*** (RQ 1 and 3) were found to be closely related and were even

included in the same category by some workshop participants, labeled *users* in the figure; the issues concerning the ***technology*** (RQ 2) were split over the categories *product* and *marketing*; the ***wider issues*** related to the exploratory research RQ 4 are primarily in the categories *financing* and *project*. In essence, these descriptions are the key results, as they contribute to understanding what is happening during the development.

All studies contributed in important ways: the case studies allowed the topic to be explored and formed the basis; the interview study, workshops and interactive poster provided additional issues to give a more complete picture; the case studies yielded details to better understand the issues; the rating and categories from the workshops supported seeing how the issues fit together; and finally the the workshops and the interviews from the case studies and interview study provided input regarding how to address some of these issues. Using an analysis method based on thematic analysis helped identify issues in the case studies that were not immediately apparent, and about which the teams were not aware.

8.2.1 Users and the Development processes

In addition to the aspects explored in RQ 1 and RQ 3 described above, also other issues related to the users and the development processes were identified.

Older people, carers and other stakeholders

As mentioned in the case studies, the unqualified use of the word 'users' can hide important aspects that affect the needs and hence also the design of the system (i.e. the category *product*).

This is in part because there are different user groups. For systems with a monitoring component, there are the older people and the people receiving the alarms, e.g. the carers. Furthermore, there may also be emergency services and medical personnel who are contacted if a serious problem arises, and, as with any technical system, there are the people who maintain the system. Even systems incorporating only services might have multiple user groups. For example, with a messaging service, the friends and family members with whom the older people communicate also use the system; telehealth services may involve medical personnel to configure the system or interpret the data, something that was mentioned by one person in the interview study.

There is diversity in each of these user groups. For instance, *carers* can be family members or professional carers - in some cases both, depending on factors, such as the time of day or day of the week. With professional carers, there are different care models, for example, as was illustrated by the two care facilities in Case Study 2: some carers come by daily, while others only come by when there are problems. Differences in the processes used by different carers is also important, as it can affect the design of the system - in Case Study 2 the differences were so great, that the functionality had to be adapted for the second care home, for example, a feature to organize day trips was no longer wanted. Documenting the reasons behind design decisions, like one person in the interview study recommended, can support checking back later, especially if the

context changes, as in Case Study 2 when the focus was changed from addressing people in private homes to ones in assisted-living facilities.

Older people are very diverse, something participants of the supplementary studies identified as an issue for the development. Developers are often younger and may stereotype older people, as happened in Case Study 1. As described in Chapter 2, older people range from 60 to 120, have different experience, and different physical and cognitive limitations, just to name a few of the differences (see e.g. Gregor et al., 2002). Some older people live alone, whereas others live with a partner, a pet or extended family. Several participants in the interview study thought it was valuable to include older people early and to have the developers who are making design decisions see their living environment personally.

The needs of the older people also depend on where they live, whether in private homes or care facilities. If they live in private homes, in many cases these homes are older and hence do not have the latest infrastructure. Some features are valued by people in private homes, but are no longer of interest when people move to an assisted-living facility. For example, the shopping service from Case Study 2 offered relief from a chore to people living in their own homes, but in the assisted-living facility going shopping gave the same people a welcome opportunity to meet people, so that they did not use the service during the pilot. Furthermore, the security features people valued most highly at the show home, were not a reason to keep the system for people living in a care home. This may be because people living at home are under more stress, as they live in bigger homes and have less security, something that was mentioned in the evaluation report of the pilot of Case Study 2. Furthermore, there are different carers involved depending on where people live - with people living in their own homes, family members or municipalities are responsible, whereas in care facilities, health care professionals are involved.

If projects are also aimed at older people in more than one country, for example, due to financing that requires international partners, there is additional diversity that needs to be considered with regard to the system. For example, the language spoken, amount of IT usage common among older people, and also the height of people. As was mentioned by one person in the interview study, the latter can be an issue in fall detection systems. In the interview study, one participant recommended situating the product in one country if telehealth functions are included, due to differences in regulations.

The people who participated in the supplementary studies concluded that development teams do not understand the real needs, which may explain why an evaluation of funded AAL projects concluded that users are not being included enough (Geyer and Good, 2016). People involved in projects report difficulties getting access to older people. Moreover, as described by one person in the interview study, when people have cognitive impairments it is difficult for them to provide much direct input. This may contribute to older people being involved *only* in the testing phases, which was also identified as an issue in the supplementary studies. Instead carers may be used for getting input about the needs of the older people. But as seen in both case studies, the needs of the carers can take over and lead to functions being added that older people do not want, or even ones they have

objections to, e.g. the function for carers to press a button and check if an older person was there that was proposed, though not implemented, in Case Study 2. This issue was supported also by participants of the workshops.

The methods being chosen to work with older people may also be sub-optimal. The supplementary studies identified that prototypes were often too technical for (older) people. In practice, other methods, such as use cases or storyboards could be better suited to explaining a complex system or privacy aspects, as described by a participant in the interview study. Furthermore, asking people in a show home may encourage them to come up with a long wish list of functions, as was demonstrated in Case Study 2. Moreover, the people visiting the show home may not be representative, as they are mobile and may have more interest and experience with technology when compared to the average for that age group, as happened in Case Study 2. But even long-term tests lasting six months have their limits in predicting usage, as needs change over time - people may experience physiological changes and also gain confidence with the technology (see also Spellerberg and Schelisch, 2009; Schorch et al., 2016). At the end of the pilot of Case Study 2, people still wanted features like the shopping service to be available in case they needed them in the future, even though they had not used them during the pilot. This relates to the category *financing*, as the time for piloting the system is often limited by the funding. Furthermore, there may be difficulties finding older people to participate, both during the requirements analysis, as in Case Study 1, and during long term tests, as identified in the supplementary studies.

Among workshop participants, there was a certain sense that educators of software developers are failing. Participants in the interview study indicated that there is a great deal of information about older people available that can be used, but developers do not seem to be aware of the importance of gathering enough information about older people and their needs. But as shown in Case Study 1, even teams who are aware and try to be user-centered, do not always succeed in carrying it through. Aspects that contribute to this happening in monitoring systems are technical problems that arise and take focus away from users and their needs, and also the fact that due to sensors, the older users become less prominent than the carer users who get the alarms.

8.2.2 Technology

In addition to the aspects explored in RQ 2 regarding sensor technologies, there are also other issues when developing AAL systems that are related to the technology.

AAL products

A number of aspects related to the products themselves can be an issue during the development.

The use of the expression 'system' can also be an issue in AAL, as there is a wide variety. Even if the focus is restricted to systems including monitoring, systems differ greatly, as illustrated by the two case studies. Some use simple patterns, like the fixed time schedules implemented in Case Study 1, where others use complex Bayesian statistics

based on past behavior. Also the sensors employed are quite diverse, for example there are microphones, cameras, vibration sensors, sensors placed on doors or cupboards and pressure mats, which can be used separately or combined (see e.g. Wagner et al., 2012); the sensors can also be integrated in different ways, for example, through a tablet, as in Case Study 1, or installed in the home, as in Case Study 2. Furthermore, some systems include only monitoring, while others are combined with interactive services, such as the medication reminder from Case Study 2. The services can also be diverse, such as services to support communication with other people, and telehealth functions, e.g. to measure blood pressure. Depending on the system, there may also be additional differences, for example, with telehealth functions whether the data is intended to be interpreted by the patient or sent to a health care professional.

Another issue identified is the difficulty of achieving reliability, in all situations, something reported also in the literature (e.g. Wagner et al., 2012; Aumayr, 2016). This includes both generating alarms when there is a problem, and *not* generating alarms, when people are actually okay. In practice, the reliability can also be affected by things as simple as people unplugging the system or forgetting to charge the device, as described by participants in the interview study. Some projects also experience difficulties with infrastructure - both in existing homes and in newly built assisted-living facilities, as in Case Study 2. When considering the long-term usage of systems, with systems based on tablet technology there are multiple versions of the operating system and sensors available that can cause problems and affect the reliability of the system, as happened in Case Study 1. In addition, in systems including services, users, either the older people or carers, may want to add or remove services at some point in time. All configurations need to be tested to ensure they are reliable (see also Greenhalgh et al., 2013).

It is also important to design for maintenance, as was described with Case Study 2. In practice, special functions may be necessary to support reliability long-term, for example, a component that allows people to be "checked out" remotely, in case they forget to do so before they leave home overnight, to check why a false alarm was generated or to distribute bug fixes and changes easily. This may also entail having a more centralized system architecture than included in some prototypes. Participants in the interview study indicated having an open system that allows components to be added or changed could support success, for example, in case a certain component does not work as expected or is no longer available - or even if a subcontractor has difficulties completing their component.

In many projects design or appearance also has an impact, something that relates to the category *users*. This includes the aesthetics of whether it fits with the decor and how intrusive it is, e.g. a LED shining when the lights are turned off to watch television as in Case Study 2. The importance of these aspects was underlined by the participants of the interview study. Even small design aspects, like a LED, could also serve to raise concerns about privacy, as happened in Case Study 2. In some cases the appearance can even lead to people removing the system altogether, as an interviewee reported a woman did because she disliked the big black cables.

If systems are unobtrusive, over time people may forget they are there. As a result,

people may be more likely to forget to "check out", or in case of an emergency, may not even be *able* to "check out" before they go to hospital. This can result in false alarms, due to missing "signals". Furthermore, the patterns in people's lives can change, for example a change in the day on which someone goes to dancing class, and then have to be updated in the system if it is based on fixed schedules, like the system developed in Case Study 1. Otherwise, either false alarms or missed alarms could result.

Usability is also important. In Case Study 2, there were many usability problems, which some people interviewed felt contributed to the users not being willing to pay to continue to use the system after the pilot. Given the diversity of the users as a whole, both with different views on the system (older people vs carers) and individual differences within each user group, this can be a challenge in itself. The importance of usability is more obvious in a system with interactive services, but to be accurate, monitoring systems that sense older people may need some sort of configuration, as in Case Study 1. Poorly designed configuration interfaces can reduce the reliability, as people enter incorrect or simplified parameters or rely on others who do not know their patterns in detail, as was demonstrated in Case Study 1, where the project leader did not know whether his father sometimes spent the night at his partner's home.

However, in practice it can be difficult to ensure both usability and reliability in one system, as in Case Study 2. Furthermore, ensuring reliability forces development teams to think about details regarding the system which can take the focus away from the people who will use it and their needs. Methods may be needed to "reintroduce" the different user groups, but especially the older people, so that teams don't lose their human-centered focus, as happened in Case Study 1. For the developers, the reliability is often in the foreground. But even if people purchase the system because of the security features, on an everyday basis they are confronted with the usability of the interactive parts of the system. This was demonstrated during the pilot for Case Study 2, where the large number of functions made the system more difficult to use and an additional button press was required just to turn on the television. Some participants in the interview study felt including a designer might help, and stressed the importance of keeping it simple. A suggestion from the workshops was to have small add-ons to existing products, such as robotic vacuums, rather than dedicated AAL systems with lots of features.

As mentioned when answering the research questions, privacy is also an issue with monitoring systems in particular. The mechanisms used to ensure privacy can also be hard to explain, as one interviewee described in the interview study - linking again to the methods described with the category *users* previously.

Marketing issues

One issue identified in the supplementary studies is that teams are not considering getting to market from the start, but more as an add-on later. However, if systems do not succeed on the market, it is immaterial if they fit the needs and work technically. Even if teams try to consider this, workshop participants in the middle of 2016 described there is generally a lack of information about the AAL systems that are available, the projects that have been developed through the various funding programmes and the other

"players" in the area. This information is essential for companies wanting to develop new products for the market.

In AAL, there are factors related to care structures that affect how much companies can charge, as was demonstrated in Case Study 2. Cost is an important barrier that will not necessarily be overcome when people use the system. The amount people are willing to pay for telecare systems is limited (see e.g. Eisinger and Eisinger, 2011). This complicated is by the fact that the purchase of AAL systems is in some countries not subsidized. This is particularly an issue if carers, who provide a certain alternative to technology, *are* subsidized, as was the case in Case Study 2, as older people also consider non-technological alternatives for support (Peek et al., 2014). Workshop participants indicated this is compounded by the fact that currently there is also a lack of evidence about what works and pays off to help convince customers. It is also important to consider who saves, whether it is the older people and their families who save on a care facility, or the carer organizations who save by having to make fewer visits, and market the system accordingly. In countries with nationalized health care, individuals may not be willing to make concessions to save the state money, something mentioned in one of the workshops.

The changes older people experience and think they are likely to experience in the future also affect the pricing structures, linking back to the category *users*. In Case Study 2, older people described their concerns about changing needs. Large upfront costs may discourage people, as they are not sure how long these systems will suffice for them. On the other hand, large monthly fees can be daunting, where life expectancy is long.

The development costs are also relevant when the initial business plans are made. It can take a long time to identify the right functions. Furthermore, a prototype is a long way from a working system, for example, with regard to reliability, as shown with Case Study 1, and development estimates are generally less accurate with relatively new technologies (International Software Benchmarking Standards Group, 2012, p. 6).

The costs once the system is on the market can cause a long-term burden on companies, as was illustrated in Case Study 2, and have to be considered in the pricing structure. Problems with the infrastructure can also add insecurity with regard to costs, something that happened not only in one of the AAL Programme projects studied, but also in Case Study 2 and a project described in the interview study. These can be difficult to fix, and it can be hard to find competent partners locally, as in Case Study 2. Older people need a lot of support when a system is first installed, something supported by participants in the supplementary studies. In practice, carers and family members do not always provide assistance with this, and so it can take substantial effort. With older people who have some cognitive deficits and those who have less experience with technology, additional training sessions may be necessary, as participants in the interview study described, something also described by others (e.g. Schorch et al., 2016). The logistics of support can be difficult, as systems may be installed over a larger geographic region. In practice, in order to maximize profit, difficulties like these may lead companies to focus their product on assisted-living facilities where there is a larger number of older users in one place, as happened in Case Study 2, however forgetting the differences between the

needs of people living at home and those in assisted-living facilities which were mentioned with the category *users*. Furthermore, with assisted-living facilities, it can be a long time from when a project is first discussed to when it is actually installed and paid for, as in Case Study 2, by which time the hardware initially planned is already outdated or no longer available, an issue also identified by workshop participants.

8.2.3 Wider issues

Since the thesis was exploratory, the wider issues considered by RQ 4 are also important. These were primarily in the categories financing and project.

Financing with grants

Financing can in the end determine whether systems can be completed. Many projects developing AAL technology use grants from funding programmes. At the same time, the framing of these grants can contribute to issues that limit success, as will be explained in the following.

Grants usually require partners to be included. As seen in Case Study 2, adding partners adds complexity to projects, as there are more groups of people who need to discuss and coordinate. When partners are not in the same location, additional effort is required for communication. It also means know-how is split over multiple organizations. Good communication skills are essential to *effectively* transfer information others need access to, for example, if one team does the user research and others are responsible for the design, otherwise, as occurred in Case Study 2, important details about user needs do not always reach those designing the systems. One person in the interview study suggested that regular meetings with all partners can help support success.

People who have worked in projects developing AAL technology report that partners are not always chosen for the right reason. Ideally partners can provide new expertise that is not available within the company, for example in Case Study 2 where a partner provided support with pattern recognition. However, the workshop participants confirmed that in practice partners are chosen to fit other criteria, rather than based on expertise. In some cases this relates to the requirements of funding programmes, for example, that projects need to include partners in certain countries or from certain domains, as mentioned in the interview study.

In practice, the partners may have unrealistic expectations from the funding. Workshop participants described that some partners are just hoping to find a way to push their own systems and are not interested in investing much effort; others may be hoping to get funding to get to market, even though some funding programmes specifically put the focus on *emergence* and end really with just a prototype.

Using grants also introduces additional timing constraints. Due to the fixed deadlines and delays during development, the time teams feel required to prove the results may be longer than the duration of the project, something that was particularly a factor in Case Study 1.

Many funding programmes also highlight the importance of innovation. This increases the likelihood that new technologies that are not yet established are incorporated, such as robotics or the activity monitoring methods applied in Case Study 2. This increases risk (see also Tiwana and Keil, 2004), because there is little experience with developing them and it can also complicate discussing them with future users, as they are unfamiliar with them. In other cases, additional features may be added, as was the case in a later phase of Case Study 2. Adding innovative aspects can make the system more complex to use and also more expensive to develop, even if it just entails adding new features as was the case in Case Study 2. People involved in projects developing AAL technology that participated in the supplementary studies thought that the functionality is in practice often defined by "tech-push", rather than user needs. This is complicated by the fact that if companies are using funding, the basic goals of projects are set in advance before user needs have been analyzed.

Thus this category also also has connections to the categories *project* and *product*.

Project structure in AAL projects

Closely related to the category *financing*, the findings also include issues about projects and project structures that make the development of AAL more complex.

Including team members or partners from different domains provides a good knowledge base and can be a strength (see also Kinney and Panko, 1996), but it can complicate communication between team members, as one person in the interview study described. For example, the terminology used depends on the domain in which people work. In addition, developers and health care professionals also have different ways of working (see also Pagliari, 2007). There is also the issue of what people know and take for granted. Carers may not have the IT expertise to understand technical problems being discussed, while technical partners may not grasp aspects about older people that seem self-explanatory to professional carers.

If partners from different countries are involved, additional issues can occur, as was evident from the interview study. Carers in some countries often do not speak English, so that a technical person has to translate the needs, with the risk that something gets lost. The context also differs, for example, the way the health system is organized and the types of subsidies available. For monitoring systems, even the layout of houses matters, for instance whether there are steps, carpets, narrow hallways, lots of windows - things that may differ by country. Even the fact that it is dark or light all day at certain times of the year in countries far from the equator can affect not only the sensing, but also the functionality, e.g. a function to indicate whether it is nighttime or daytime.

Even with partners from the same domain in the same country, there can be differences between partners that can make projects complicated, for example, whether user research is usually performed by the developers or a separate group, how much lead time there is for ordering hardware, and the flexibility to change things during a project. If one team can make changes to the hardware specifications easily, they may lose patience with delays other partners face. This can simply lead to tension in the team, or even lead to one partner effectively being excluded from a project, something the project

leader of Case Study 1 mentioned in relation to a previous project he had been involved in. Academic partners can provide valuable know-how, but as in Case Study 2 may also contribute to having systems that are less practical, for example, when it comes to long-term maintenance. One participant in the interview study also said that having an academic partner lead a project made it less applied.

8.3 Connecting the results to other research

The following sections reflect on how these findings link to prior research. Despite the complexity of the situation related to the development for these types of systems, in the end, the systems must work, they must fit needs of users and they must make it to market. Like the interconnected issues described above, these also relate to the overarching concerns of ***users***, ***technology***, ***development processes*** and ***wider issues*** used to define the research questions.

8.3.1 Technology: How the market for AAL systems is different

AAL is an area of innovation: it is not yet widespread, and it integrates cutting edge technologies, such as sensors and robotics. Marketing is different with innovative high-tech products. As described in Chapter 3, Moore (2006) says there is a chasm in the adoption cycle for high-tech products - products that are popular with early adopters may not be adopted by the larger majority, and thus not be successful. More recent articles indicate that this is still relevant (Schawbel, 2013) - a newer edition of Moore's book has even been published in the past few years (2014). There are many historic examples. For example, the Xerox Star, the first system with a windowing interface, faded into obscurity. Just a few years later the Apple Macintosh received critical acclaim, however, only Windows managed to reach a wider group of customers, including companies. It is important to remember that the first feedback about whether the product is of interest comes from *early adopters*. But early adopters are different: they are generally more technologically interested and have more experience with IT than many of their peers, as was the case in Case Study 2, both with visitors at the show home and the first person who evaluated the system in a care home. Early adopters are looking for something new and different (Moore, 2006). As such, they are not really good references for the *early majority*, who are less willing to deal with little problems - the early majority is looking for something useful and reliable (Moore, 2006). But these qualities are not easy to achieve in monitoring systems like those studied, because of the technological innovation and complexity of making sense of sensor data.

However, Moore (2006, p. 18) concludes that it is more of a business or marketing problem: finding a compelling argument to help diffuse the technology. There is still work to be done here in AAL. As the experts in the supplementary studies pointed out, it is hard to prove that these systems work, and there is little evidence of the benefits of monitoring systems (Barlow et al., 2007; Wagner et al., 2012), also with regard to improved quality of life (Cartwright et al., 2013). This may help explain why many of the

products are not succeeding on the market. Still, a recent study by the German Federal Ministry of Health (Bundesministerium für Gesundheit, 2013) found there is a potential market, also for sensor-based systems, including fall sensors and systems to automatically turn the stove off. But even recent articles indicate that adoption of telehealth, including these types of telecare monitoring systems, is slow (e.g. Cimperman et al., 2016).

What are the arguments for using these systems - and why are they not more compelling? The monitoring systems being studied in this research can give people a greater sense of confidence (Blythe et al., 2005), however, the real "argument" is being provided by governments and funding programmes: *keeping people in their own homes longer* (AAL Joint Programme, 2017). And the more comprehensive smart home systems, like that in Case Study 2, often emerge from a technological vision (Wilson et al., 2015, p. 473). But the adoption occurs with the users, so it must be useful and satisfactory for them. Here Case Study 2 showed the difficulty of finding features, like the "calling the lift" that was unexpectedly popular, to kick start the engagement of the older users. Furthermore, if the goal of AAL systems is defined as keeping people at home longer, developers are less likely to consider features like "calling the lift".

Looking more closely at the stakeholder perspectives for telecare technologies from Greenhalgh et al. (2012, pp. 5-6), the motivations defined by the funding programmes relate most closely to the technology-centered *modernist* view: solutions to be developed and deployed for people no longer robust enough to live unmonitored at home, and sending results to people who care for them with the goal of helping to compensate for the 'demographic time bomb'. Based on the results of this thesis, it may be more productive if these same funding programmes instead take a *political economy* perspective, for example, with the goal of transferring money from state-run homes to commercial companies, or providing innovative systems to emancipate older people, or even freeing up carers for more valuable tasks. Putting emancipation in the foreground could also raise awareness about the potential for coercion, i.e., the tendency to give carers more control, with telecare systems (see Mort et al., 2013). Alternatively, the funding agencies could focus more on adoption, what Greenhalgh et al. (2012) call the *change management* perspective, based on supporting routines.

The development teams in the case studies tried to take the more user-centered *humanist* view, and not just through a superficial application of methods, they truly tried to understand the needs of older people, rather than focusing on being high-tech. This is particularly evident in Case Study 1, where the specific needs of several individuals were discussed at the start, reciprocity was considered (i.e. the exchange of pictures with family and friends), and a relatively low tech solution was developed. The rich descriptions of the users included most of the aspects recommended with personas (Pruitt and Grudin, 2003). But in the end, the *modernist* perspective won out, owing to a variety of factors, including technical difficulties and timing constraints imposed by the funding.

Greenhalgh et al. (2012, p. 1) say that *"If investments in these [telehealth and telecare] technologies are to bear fruit, more effective inter-stakeholder dialogue must occur to establish an organizing vision that better accommodates competing discourses."* The results support that funding programmes and also development teams could benefit

by keeping all of the discourses alive.

Even if teams succeed in being user centered and keeping all of these perspectives alive, there is a basic problem with the target market. The systems studied tried to satisfy the needs of "older people" with the aim to reach *everyone*, but in the end they were not really optimal for anyone, for example, by adding so many functions that the systems were difficult to use. The detailed principles defining a "market" are relevant here (Moore, 2006, p. 28):

- *"A set of actual or potential customers*
- *for a given set of products or services*
- *who have a common set of needs or wants, and*
- *who reference each other when making a buying decision."*

However, there is a fundamental problem regarding these principles when it comes to designing systems for older people. There is certainly a group of potential *customers*, but two of the four criteria of a *market* are actually missing:

- Due to the diversity of older people discussed earlier, there is not a common set of needs, and
- Since needs change as people age, often quite rapidly and unpredictably, there is not really a given set of products or services.

Furthermore, with regard to the last criteria, there seems to be a tendency for older people to look at others and not those in the "same group" when deciding to buy. Instead, they may defer to younger and/or healthier people like their grandchildren (Luijkx et al., 2015), or the family members or care home personnel they depend on, as described in the interview study.

In AAL, there is a tension between aiming to deploy products for the mass market and tailoring to the specific needs of a narrower group that have more similar needs (see Peek et al., 2016). The evaluation report of the AAL Programme says that currently systems are primarily restricted to niche markets (Busquin et al., 2013). Systems aimed at a narrower group or niche, e.g. those with certain cognitive or physical limitations (e.g. Joshi, 2016; Rasquin et al., 2007), can consider a smaller diversity of needs, but then can also only reach a smaller number of customers. More generally, developing systems for a narrower user group can be a successful strategy for products (McBreen, 2002, pp. 50-51). However, given that the amount that older people can or are willing to pay for AAL systems is quite limited (e.g. Eisinger and Eisinger, 2011) and the costs of developing theses systems are quite high, it may be better to target others when selling them, e.g. social insurances, especially since some of the sensor-based security systems can amortize for these stakeholders in a few months (Bundesministerium für Gesundheit, 2013).

8.3.2 Users: The complex needs with AAL systems

To be successful, systems need to be accepted. However, there are a number of barriers to the adoption of AAL technologies (Peek et al., 2014; Sanders et al., 2012; Yusif et al., 2016). It has been demonstrated that even technical design decisions decide qualities about systems that can be crucial to success (Falessi et al., 2011). The results indicate that many different software quality measures (see ISO, 2001) are relevant, such as usability, reliability, security, maintainability and the functional suitability that makes them useful. As shown, it can be difficult to include all of these in a single system. This is particularly a concern with flexibility, as it can affect the reliability (Greenhalgh et al., 2013).

As the results show, usability is important when older users are involved. Studies show that older people are concerned about the usability of these types of systems (Sanders et al., 2012; Yusif et al., 2016). Older people may also be less confident when using technologies (Cabreira and Hwang, 2016), even though they may be as technologically capable as other age groups (Tonolli et al., 2015). Perhaps due to this lack of confidence, unlike other age groups, the effort to learn a system is key to acceptance with older people (Cimperman et al., 2016; Reid et al., 2016). This is especially important in systems, like that in Case Study 2, that combine sensor-based monitoring with services, but it is also important for monitoring systems (Turner and McGee-Lennon, 2013), like that in Case Study 1. Furthermore, not allowing input can limit acceptance, as older people value freedom of choice (Blythe et al., 2005).

Design aspects are also important, something that falls under usability (ISO, 2001). For one thing, the results support that the system should fit the decor and ambiance of the homes of people - also others have reported on the importance of appearance of technologies for older people (e.g. Fitzpatrick, 2012; Greenhalgh et al., 2013; Sallinen et al., 2015; Dahl et al., 2015). It also should not look like the system is made for old or disabled people, as older people do not want devices that are stigmatizing (Joshi, 2016). However, the solution does need to consider limitations that are common among older people in order to ensure it can be used. Although, physical and cognitive limitations may shift the options, for example, the type of input or number of items displayed, some sort of interaction or user interface is almost always possible (Joshi, 2016; Rasquin et al., 2007). Since designs tailored to people with specific limitations can still be used by people without these limitations, but not necessarily the other way around (Joshi, 2016), the development team should consider a realistic breadth of limitations from the beginning. There are guidelines available that can support development teams with design specifics (e.g. mobi.Senior.A, 2016; W3C, 2010). But even if these are applied, it is still necessary to test that the resulting design of the system is appealing and usable.

Monitoring systems, like those studied here, are particularly challenging. Some of the strongest concerns with respect to AAL technologies relate to these types of systems (Sallinen et al., 2015). However, it can be difficult to explain intangible aspects inherent to sensors and privacy, as mentioned in the interview study, something that has also be reported in the literature (Lindsay et al., 2012). Older people are afraid of surveillance by strangers and many have only *"a hazy understanding of their assistive technologies"*

(Greenhalgh et al., 2013, p. 91). Special care must be taken demonstrating complex interactive technologies in a way that older people understand them (Wallace and Lindley, 2015). At the same time, the area is technologically complex. It is challenging to find patterns that can be sensed reliably, something that developers in Case Study 1 struggled with, when using the sensors available in standard smartphones or tablets. As found elsewhere, during the development user requests may be moderated by the capabilities of the sensors being used (Cucchiara et al., 2004). This can make the older people generating the signals fade into the background, as happened in Case Study 1, and give the concerns of carers priority.

This is important, as this can affect autonomy, a barrier to adoption (Yusif et al., 2016). For example, older people may want to see the status and be able to rescind alarms generated (Dahl et al., 2015). Limiting their control over the system, for example to support usability, could especially limit the acceptance of older people (Sanders et al., 2012), particularly those with computer knowledge. This was a potential problem in Case Study 1, where one older person considered was an IT technician, since the system was designed to be configured by the carers.

Understanding the needs of users is difficult especially with AAL systems. It can be difficult for developers to understand even their own needs (Erickson, 1996) - it can be even more difficult for them to understand the needs of others, especially older people, as they differ from developers in many ways. As suggested by theories of aging, such as Tornstam (2005), older people view the world differently. Developers need to respect the values of older people, and be careful about imposing their values on them, such as the imperative to be active (Tonolli et al., 2015). Even the new meaning of AAL, *Active and Assisted Living* (e.g. AAL Joint Programme, 2017; Aumayr, 2016), implies the technology should support active and healthy lifestyles. When developing AAL, the focus should be on finding technologies that support the needs and preferences of older people, not convincing them that the solutions being developed are appealing (Tonolli et al., 2015). Remembering not just their physical condition, but also the different way in which they view and maintain social interaction can be valuable.

It is important that the systems are *useful*, especially from the point of view of older people (Peek et al., 2014; Mies, 2011; Reid et al., 2016). This is particularly an issue with systems incorporating services in addition to monitoring features. But when *asked* older people do not always think of those functions, like "calling the lift", that they in practice find most useful, and it may be hard for younger developers, especially those not directly in contact with them, to imagine what they need. Although getting information about users indirectly is generally not uncommon in development (Vredenburg et al., 2002), taking the viewpoint of the carer or asking carers may result in functions that are seen as coercive (Mort et al., 2013), and hence not very acceptable to the older users. This is also a risk with monitoring systems, for example, the reminder to go to bed if the sensor data indicated the person was awake that was suggested in Case Study 1. Carers, both formal and informal, give safety the highest priority in monitoring systems, whereas older people may value privacy or freedom of choice more highly (Blythe et al., 2005); for example, older people may want to be able to override alarms, whereas carers

worry that older people may cancel alarms in situations where they actually need help, in order not to be a burden (Dahl et al., 2015). Developers are in a privileged position and can give priorities to those aspects they think are of value, rather than those valued most by older people. If developers base design decisions on personal experiences, these need to be revisited later (Zhang and Wakkary, 2014). This underlines the importance of checking back with the different user groups early, while changes are still possible.

In practice, the technology may actually be used or appropriated in ways development teams did not imagine and do not expect (see e.g. Greenhalgh et al., 2013), something that was described also in the interview study. Here mediation theory, which has been used elsewhere in telehealth (Alberts, 2013), provides an interesting insight. The classical view is that a new tool helps people to do some thing(s). People can use it or not. Mediation theory takes a more dynamic view: that people decide how they use the technology and the technology may change what people do. Even though this theory comes more from the area of user acceptance, rather than the development perspective which this research takes, this could be useful to help remind developers that people may adapt systems in unexpected ways to make them fit their needs, as described by Greenhalgh et al. (2013). As recommended in the interview study, by observing usage, it may be possible to detect when this is happening, so developers can react.

Since the needs of older people are likely to change over time (Spellerberg and Schelisch, 2009), they may not be able to imagine what they really will need. Older people know their needs will change over time, thus they may find it comforting to know there is more assistance they *might* need in the future, even if they clearly do not need these features now, as in Case Study 2. This is also true of monitoring systems, where the patterns and sensors used may change over time, for example, changing from sensors on the front door to sensors in beds. Like some of these previous points, this underlines the importance of ensuring the flexibility of the systems, without adversely affecting the reliability and usability, both of which are important with monitoring systems (Wagner et al., 2012).

The challenges don't stop there for systems aimed at older people. Some people also worry that they will lose their current care structure or lose ground if they have technological support (Sanders et al., 2012). These concerns are not unfounded - monitoring systems can actually undermine the independence of older people (Draper and Sorell, 2013), and independence is something older people value highly (Sallinen et al., 2015). Even in formal care settings, where people have already relinquished some of their independence, there are problems with the acceptance of telecare systems (Sanders et al., 2012).

Because of the complexity of this application area, suboptimal project structures can have a larger impact on success. Companies can differ in their way of working, for example due to size (Gray, 2016). It is important that companies choose compatible partners that add something to the project and not only to the complexity. A person in the interview study thought regular meetings with all team partners supported success. Certainly, insufficient formal project management has been found to be a risk in software development projects more generally (Tiwana and Keil, 2004).

8.3.3 Development processes: Methods to support more successful project outcomes

As Pruitt and Grudin (2003, p. 14) say about the UCD method personas: *"It isn't a science. If not used appropriately, any powerful tool can take one down the wrong path."*

UCD practitioners generally feel the mindset or intention to be user centered is more important than methods (Gray, 2016). In the case studies, the *intention* to be user-centered was not sufficient. In Case Study 2, although the company was focused on the older users, in practice the information from interviews in the show home and the market analysis were of limited value. They are not alone in using these methods: in Austria, interviews is one of the more common methods for gathering information about needs in projects developing AAL technologies (Garschall et al., 2016), and it was also found to be one of the most widely used methods in a study of UCD in small companies (Bednarik and Krohns, 2015). Although interviewing is considered a user-centered method (Sharp et al., 2007), it is worthwhile considering whether other methods might be better, especially since people involved in AAL projects reported that using questionnaires and workshops proved not to be entirely expedient in their projects (Garschall et al., 2016). Furthermore, it has been found that the choice of methods like interviews may not be based on their perceived suitability, but rather due to a lack of knowledge about UCD and the high costs that developers associate with methods such as contextual inquiry (Bednarik and Krohns, 2015). In addition, multidisciplinary teams in the area of telehealth and telecare may employ methods from other domains rather than those from UCD (Pagliari, 2007).

The methods *do* matter. In software development more generally, CMMI® is used to evaluate companies. It puts a focus on the methods applied and how mature these are (CMMI Product Team, 2010). The methods also need to be suited to the skills of the older people, time available and amount of access available (see Bevan, 2009). This emphasizes the importance of having an arsenal of methods. The AAL Programme also recognizes the importance of methods and encourages user involvement in projects. To this end, it published a toolbox of methods for including users (YOUSE, 2015). The costs for doing UCD with older people, who are diverse and may have disabilities, are significantly higher than with user groups without these types of special needs (Thimbleby, 2008). UCD goes beyond just asking people what they think they want, as was done in the market analysis in Case Study 2, but really involves trying to understanding their needs and situation, so that this information can be used as a basis for design decisions, for example, which of the functions to implement. Having users involved in multiple ways supports success in projects (Keil and Carmel, 1995).

Relying on indirect input from other stakeholders, like that from carers or family members, for information about about older people and their needs is a risk more generally: *"Many of the development managers that were interviewed perceived that the problems associated with less successful projects resulted, at least in part, from over reliance on intermediaries or customer surrogates."* (Keil and Carmel, 1995, p. 39) As discussed, this is particularly an issue in AAL telecare systems (see e.g. Mort et al., 2013; Dahl et al., 2015), as people may think they know more than they do, for example, as happened in Case Study 1, thinking of a partner as just a neighbor.

One method that can be useful is observation. People interviewed both in Case Study 2 and the interview study recommended that developers see the environment personally. Certainly, in care homes aspects about the environment that at first do not seem relevant can turn out to be important for the design of systems for older people (Wallace and Lindley, 2015).

It is also valuable to get feedback on designs early on, as recommended in the interview study. There are different methods for this. Using sketches to convey the design saves older people the effort of having to learn to use an interface that is likely to be changed anyway (Thimbleby, 2008), and supports getting input early. User interface prototyping is generally considered to be one of the better methods for developing software systems intended for sale (Keil and Carmel, 1995), but is more relevant to services than to monitoring systems. There also methods specifically aimed at older people, for example, HODI, which was developed to communicate a design and the motivations behind it, so that older people can comment on it (Subasi and Fitzpatrick, 2012).

If access to older people is limited, or if involvement needs to be limited because people are ill or weak (Grönvall and Kyng, 2013; Thimbleby, 2008), methods like personas (Adlin and Pruitt, 2010), scenarios or guidelines (Thimbleby, 2008) can help. Using personas or narratives from real people can help increase developer empathy with users (Grünloh et al., 2015). Since values like privacy and independence play an important role with these technologies, and are generally of central importance to older people (Sallinen et al., 2015), methods like Value-Based Design (Friedman et al., 2006) may also be helpful. It *is* legitimate for developers to draw on their own experiences during the development as happened in Case Study 1 (Zhang and Wakkary, 2014). However, it is important not focus on these or a single persona, as can happen in projects (Friess, 2012), like Case Study 1, and instead to remember the real users in all their diversity. To help ensure that the users and their needs do not get forgotten, there are also techniques that help ensure that all of the personas are kept alive, for example, using the personas to evaluate all functions considered, or regular e-mails with new facts relating to the personas (Pruitt and Grudin, 2003).

The different types of 'user' need to be distinguished. In Case Study 1, some exemplar users were described - but only people from the older user group. Even the AAL toolbox of methods (YOUSE, 2015) utilizes the term 'user', without specifying which type of users are meant or need to be included. This isn't specific to AAL, as other researchers have found that users and customers, i.e. those paying, may not be distinguished, especially in smaller companies (Bednarik and Krohns, 2015).

It is important to consider the views of the different stakeholders early on, as older people and carers may have very different perspectives on what is important (Dahl et al., 2015), as discussed previously. In the end, it must be accepted by both. The different groups need to be given the same capacity to influence decisions. In practice, a recent survey of 27 AAL projects, found that care experts were included more often in generating ideas than the primary users, i.e. the older people, whereas older people were included most often during evaluation (Garschall et al., 2016), when the functionality is more set. Rather than always working with each group separately and prioritizing the needs,

co-discovery may support finding solutions acceptable to all stakeholders (Dahl et al., 2015). Furthermore, a recent survey of requirements practice for intelligent systems, such as the monitoring system studied, underlines the importance of keeping track of which stakeholder group requested each requirement in order to ensure user satisfaction (Bani-Salameh and Al jawabreh, 2015), something that is part of the structured requirements gathering recommended in the interview study. In AAL, with the diversity of the different user groups, the requirements also need to be linked to the specific attributes and situation of the person requesting it to avoid problems like those in Case Study 2 when the target of the system was changed.

8.3.4 Wider issues: Project management supports success

User-centered and PD methods may help teams to understand the needs better, but the results show that just applying them is not sufficient, something also reported by previous research (Friess, 2012). To support success, teams need to carry through until the system is accepted. Project management is important to ensure this happens.

Even if appropriate methods are applied, in telecare systems like those studied here, an effort needs to be made to encourage discussion between stakeholders, and to keep all of the different discourses from Greenhalgh et al. (2012) alive during the project. The technology must work, and it must be reliable (more *modernist*). Keeping the perspective of emancipation or *political economy* alive is also important, and can support ensuring that the systems are not coercive. And obviously, if systems are to be successful, to make a difference, the *change management* perspective, which relates to adoption, is also important. Good project management is necessary to keep these aspects alive when burning technical problems arise. Case Study 1 showed how quickly the *humanist* aspects can get lost and technical concerns take over.

Access to 'users' is important throughout the development. The findings from the workshops indicate that even though older people are being included in projects, teams do not really understand their needs. Reviews of projects developing AAL technology support this, and have concluded that projects are not including users enough, although they do not specify what user group was meant (Geyer and Good, 2016). This may be because, an early focus on users is especially important with older people (Thimbleby, 2008), and as reported in the supplementary studies, older people are included primarily for test. However, Case Study 1 and the supplementary studies showed that it can be difficult to find older people willing to participate during the analysis, as well as later for long-term tests. This is even more of a concern when systems are aimed at specific user groups, such as those with certain disabilities (Joshi, 2016). Project management can support developers by organizing this.

Another issue is that even if the information is being collected by the user researchers, the needed information may not be reaching the developers who are making design decisions (Garschall et al., 2016), as happened with the companies developing the services in Case Study 2. This may be due to the complex structures of teams with multiple partners, as in that case, but can also to way the information about the different user groups is communicated. For example, some developers in companies find personas too

abstract to base the design on, and also find that they can be misleading, and thus prefer access to the raw data about users (Matthews et al., 2012). Thus, consideration must also be given to the methods used to communicate the information about the needs if these are collected by another team.

Although tests are essential to check the usability, functional suitability and reliability, if the effort was underestimated, leading to delays during the development, there may not be enough time for sufficient testing, as in Case Study 1. A large proportion of software development projects *are* underestimated (International Software Benchmarking Standards Group, 2012). If additional effort is required, everything cannot be completed by the deadlines set by the funding, as happened in both case studies. But starting tests earlier, before the system is ready, is not really the answer in AAL: if a system is below expectations, it can be hard to get a realistic feedback on the usefulness and usability of the system (Hattink et al., 2016). This supports the importance of getting some feedback earlier, e.g. using designs or with long-term tests with prototypes with reduced functionality, as recommended in the interview study, but this must be considered in the initial planning.

With AAL systems, significant effort may be required even once the system is working, as in Case Study 2. Additional training sessions may also be necessary (Schorch et al., 2016). Staff in care homes cannot be relied on to do this (Dale et al., 2016), and as seen in Case Study 2, in some cases, neither can family members. Furthermore, assistance may be required for tailoring or adapting systems to the specific needs of individuals, something that is often necessary due to the diverse needs of older people (Home Sweet Home, 2014; Dale et al., 2016). And as Case Study 2 demonstrated, a surprising amount of support may be required. But companies should not save on these points, as the introduction phase is critical for these types of systems (Sallinen et al., 2015). Training sessions and putting a focus on the services requiring active engagement when a system is first introduced may help to increase the positive attitude of older people toward the system (Sallinen et al., 2015). Companies need to ensure that these efforts are considered early on.

Overall, the results show that the situation is quite complex. It is not just an issue of whether developers apply existing methods or not, as it may be hard to find appropriate people to participate, technical problems can detract from the focus on the real needs, and sensors make people into passive signal generators rather than active users. But most importantly, people involved in the development need to remember when using the expression 'user', that there is not one user, and even what look like small differences, such as whether someone lives in their own home or just moved to an assisted-living facility, can make a large difference.

8.4 Contribution

As mentioned in the introduction, the thesis has a number of original empirical contributions. Empirical research is considered to be "the backbone of science" and constitutes a recognized and widespread contribution in the area of HCI (Wobbrock and Kientz,

2016, p. 40). Critical analyses that help find the blind spots provide value to HCI more generally (Bardzell and Bardzell, 2016).

This thesis takes a new perspective on AAL. As described Chapter 3, where other researchers have focused on the technology or the user acceptance and appropriation, this research has studied the development. Case studies of the development of interactive systems have been used in HCI to generate new insights (e.g. Wobbrock and Kientz, 2016; Blomquist and Arvola, 2002; Batenburg and Koopman, 2010; Friess, 2012), but not had not been conducted previously in the area of AAL.

The results provide rich qualitative accounts of two case studies: one an ethnographic account of a project during development and one a retrospective analysis of a larger project developing a system integrating sensor based technology for older people. Since neither project reached their goals of having a successful product on the market, the research provides valuable material to understand the issues that may be faced during development that can affect the success. Because of the public interest in Case Study 2, the research could build on documents, most of which are publicly accessible, though not easy to find; Case Study 1 required a level of access that is rare to receive. As was seen during the supplementary studies, despite reporting requirements of funding programmes, it can be hard to get this level of detail about the development of systems.

The findings also reveal a wide variety of issues that can cause pitfalls for developers and give new insight into the complex situation that development teams face. Many of these issues are new. Even those that have been reported previously are described here in a richer context that shows how they are connected, which supports a better understanding of what is happening during the development, for example, the reasons why the focus on the older users may be lost, as it was in Case Study 1, how changing the target market from private homes to assisted-living facilities can play out, e.g. through Case Study 2, or the different factors that can make it difficult to get people to test the system, such as those described in the interview study. The individual issues and tensions identified included diverse aspects ranging from the diversity of the 'users', how projects can be complicated by funding that is vital to get through until a profit is made, and the difficulties of achieving the necessary reliability without forgetting the people who will use it. Some issues identified could be construed by some as errors on the part of development teams if the context is not considered, such as giving precedence to the requirements from the carers or using a remote control for input, whereas others are inherent to the development of these types of systems, for example the difficulties combining sensors requiring high reliability and services requiring usability. Though understanding the needs is important, the solutions are unfortunately not as simple as merely applying a certain UCD method - a careful choice of methods and care when applying them are necessary. Furthermore, a large amount of effort is required even after a system is basically working until it is accepted on the market and making sufficient profit. Since, with the exception of the category financing, many of these issues identified were thought to be in the control of teams, the results have relevance to the development of these types of system, but also to researchers who may want to find ways to overcome some of them more systematically.

8.5 Limitations

A main limitation is one inherent to the design of the study: it was exploratory. It aimed at identifying the issues developers in these projects face and gaining more understanding of these issues, and thus chose a limited number of projects and participants. As such it is not generalizable. However, as with usability tests (e.g. Rubin and Chisnell, 2008), a careful choice of participants can still identify some important issues. Studying two projects in depth has provided insights not possible just through interviewing a few people; the supplementary studies allowed information to be collected from a wider variety of projects. Measures were taken to support the quality criteria for qualitative research and thematic analysis described by Braun and Clarke (2013, pp. 278-293) and those for qualitative case studies as described by Baskarada (2014), including member checking, triangulation, credibility, transferability, transparency, data quality and ecological validity - see also section 4.5.5 for more details about the measures taken to support the quality of the results.

Inherent to taking a constructivist viewpoint, it can be hard to get a complete view of what is happening. To address this limitation, for the case studies data from the field was collected using a variety of accepted methods: observations, interviews and documents (Wobbrock and Kientz, 2016). Furthermore, people in a variety of roles were included in the interviews to cover different viewpoints, and a longer period of time was covered. In addition, a wider group of people was included in the supplementary studies. Where possible, audio recordings were made, so that the original source could be returned to. Furthermore, accepted analysis methods (Braun and Clarke, 2006) were used to support focusing on the themes suggested by the data in as recommended in Charmaz (2006) for constructivist studies, and not themes set in advance by the researcher.

As an individual researcher, it is easy to get stuck on one interpretation or miss something. In order to minimize this, the analysis was discussed with the thesis adviser. Discussing it with an outside person often made it clearer where information was missing and where additional data collection was required, but also helped to gain new insights. This was important both in Case Study 1, where as a participant observer it was hard to get distance, and in Case Study 2, where the volume and complexity of the data was hard to sift through.

The supplementary studies also have limitations: only a small number of people were involved, these people were not limited to companies and monitoring systems, little contextual information was collected, and most results could not be verified using another source. In all 35 people with experience in the development of AAL technologies participated. This is not a large number in comparison to more general studies collecting issues (e.g. Tiwana and Keil, 2004), but AAL is still a relatively small field. The specific invitations to Workshop 1 ensured that a wide variety of participants and people with experience were included. Still, the participants may not be representative of the community as a whole. Thus, the results only say whether multiple development teams have experienced the same issue, but cannot say how frequent they are, or conclude the other issues have *not* been experienced by others. Some information about the context

that supported understanding was available from the interview study, by listening to recordings of the discussions in the workshops, and by being at hand by the interactive poster.

The studies included people from a limited number of countries. Although the focus was the European context, most of the participants were from Austria, so some of the issues from the workshops and solutions may be specific to this context, e.g. the funding of AAL technology. But this may have less importance than it first seems, as Austria has been one of the top four countries involved in AAL Programme projects (Geyer and Good, 2016) and some participants in the case studies and the supplementary studies had been involved in international projects. The interview study covered projects in four EU countries, including Germany, another country with a high level of involvement in AAL Programme projects (Geyer and Good, 2016). The interactive poster allowed input from a wider group of countries and projects, so that in all eleven European countries and a wide variety of projects developing AAL technology were included. Furthermore, the projects from AAL Programme reviewed as part of the supplementary studies also included partners from a variety of countries.

A further limitation of the research is that the results only represent one time period. The context of AAL is shifting. Through technological developments there will be new possibilities - plus, in the future older people will have more technological experience.

Finally, the thesis is exploratory, and focused aimed at gaining insight into the types of issues development teams are facing. As such, it focused more on issues than solutions and hence did not validate the solutions.

8.6 Recommendations for practitioners

The thesis is grounded in practice. Reading about the complex situation, developers may ask themselves what this means for them, what they can do. Based primarily on the recommendations from people involved in the interview study and workshops, some advice relevant for project leaders and people working in development projects is provided in the following. From a research perspective these may sound simplistic, but they provide a place for development teams to start. Based on the categories identified, these suggestions are grouped into understanding user needs for the products, applying methods in projects and funding and marketing concerns.

8.6.1 Understanding user needs for AAL products

In AAL, teams need to be sensitive about the use of the term 'users', without qualifying which people are meant, e.g. the older people or carers and the characteristics they have. The word 'user' can hide complexity about who is meant. This is particularly an issue in AAL - Case Study 1 showed that when working with a group of people of whom one is not a part, it is easy to stereotype and simplify things, even if one is concerned for the interests of those who will use it.

It is important to understand the older people in their full diversity. People involved in the development of AAL technologies think using existing information about the older population can be a good starting point. Still, it is important not too add too many functions, as this can also complicate usability.

During the development, it is important to be open and to take advantage of opportunities that arise, as it can be difficult to identify what functions will be used, but also what sensors and patterns are most appropriate. Long-term tests starting relatively early in the project support this. People involved in the interview study suggested checking what is used, if the system is used differently than expected, and what is needed - and build on that. Then, test it again. If the observations differ from the expectations, it may be necessary to pivot from the original plan, but avoid adding too many features.

The non-functional aspects are important: reliability for security features, but above all usability for the intended users, whether these are older people or carers. With security functions, privacy is important. To support changing needs and the diversity of the various user groups, flexibility is also important. People involved in the development of AAL technologies recommend documenting design decisions in a way that the reasons for it, or the characteristics of the people who requested each feature, can be traced, e.g. whether they live in their own homes.

With the diversity of older people and their needs, it may be hard to achieve universal design. Thus, it may make sense to have a specialized design for a narrower group or to make the system highly individualizable. Configuration can support usability, and also help ensure that the system is not coercive, for example, forcing people to do certain things in order not to trigger an alarm. The effort for training may be underestimated - as shown with Case Study 2, in practice care home staff and family members may not provide much support with this.

For many of these aspects, people involved in the development of AAL technologies suggested that developers need to be aware of these issues, and that projects leaders can support success by using more formal project management techniques to ensure things proceed as planned.

8.6.2 Applying methods in AAL projects

Developers and project leaders need to be careful when choosing methods to get input from the various stakeholders. Special methods may be necessary to work with older people. Prototypes may in practice be too complex - people with experience developing AAL technologies suggest other methods like storyboards or co-discovery instead; for interactive services, paper prototypes were recommended. Even if people have experience using technology, it can be hard to explain intangible concepts like sensors and the privacy mechanisms associated with them - these methods can support making the solution more tangible.

To support the reliability of monitoring features, it is important to check systems early with people from all user groups, and to have long-term tests to test them under realistic conditions and in all possible configurations. As described by a developer in the interview study, these systems may change people's lives and so they may become dependent on them during long-term tests. Consequently, it is important not to leave them in a helpless situation at the end of the tests.

Project leaders need to find a way to remind the team of the more *humanist* aspects, even when technical difficulties arise, such as the problems recognizing patterns reliably in Case Study 1. Some possibilities include frequent reviews, checking with people from the different user groups, putting personas on the wall, making it a topic in regular meetings, etc.

8.6.3 Financing and marketing concerns with AAL

AAL is a challenging area - there are additional costs associated with the development of AAL systems; e.g., for the long-terms tests to ensure they have the required usability and reliability. The current framing of some funding programmes may actually contribute to the lack of success by fixing goals early and requiring additional partners. Managers in companies developing AAL suggested first checking what systems have been developed and what partners might be a good match. Others stressed it is important to check that the proposed partners have similar goals and are willing to invest effort, as some may primarily be looking for funding to continue the development of existing systems. If multiple partners are included, frequent meetings with all partners were also recommended, rather than meeting with individual partners.

Different aspects must be considered with pricing in AAL. As in Case Study 2, the amount that can be charged may be limited by public subsidies for carers that present an alternative to technology. Furthermore, due to natural aging processes, older people may be uncertain how long the system will be adequate to their needs, which discourages larger investments. Allowing people to pay for and add modules later may both alleviate

some of these concerns, both in terms of costs and ensuring that the system meets their needs longer.

8.7 Looking forward: Future work

To support increased success in the future, there are aspects practitioners and funding programmes need to consider.

8.7.1 Suggestions for funding programmes

Funding programmes may need to consider ways of better supporting AAL systems getting to market.

Having a number of partners can complicate the development process, especially when these come from diverse domains or countries. It can be difficult including organizations with too great a diversity. In attempting to match the criteria for the funding, for example, having X partners from Y different countries, insufficient focus may be put on important aspects, such as whether their goals are compatible and the proposed partners provide needed expertise. Thus, the criteria for partners may need to be relaxed.

While it is necessary to know the project goals in order to grant funding, setting the goals in stone at the outset means there is no flexibility to change things when the needs analysis or first technological prototypes indicate that the proposed goals are not optimal. It was suggested that teams be allowed to request changes to the goals. Alternatively, funding for the further stages could be contingent on results of the initial phases. Since it is not easy to reach the needs of the broader group of older people, it may also make sense to encourage projects to focus on a narrower group of older people; for example, those with arthritis or macular degeneration. In practice, specialized solutions may also work for a broader group (Joshi, 2016).

With these types of system, it can take a surprising amount of time to find the right functions and get the system working with the required usability and reliability. Thus, additional flexibility or support may be necessary at the end of projects to get them beyond the prototype stage, for example allowing some flexibility regarding deadlines for projects, even if no additional funding is given. Additional funding programmes may be needed for the final phases of getting systems ripe enough for the market.

Since these technologies may help people to stay in their homes longer, governments may want to reconsider whether in addition to carers, it also may make sense to support the costs of purchasing technology for individual homes.

8.7.2 Future research

There are a number of ways in which researchers can follow-up on the results presented above.

The AAL community needs to look at ways of supporting teams to gain access to more information about older people. One way would be to consolidate and extend the information that is available about older people (e.g. CURE) and make this more

widely available. Another possibility would be finding better ways of connecting teams with older people, for example, through organizations that cater to older people. One promising approach is *living lab* models, like those at the Fachhochschule St. Gallen (Misosch, 2016), that provide access to a large number of testers from the various user groups.

Methods are also an area with potential. The toolbox of methods for AAL is an important first step (YOUSE, 2015). Further research is needed by people in HCI to see which methods work well in these types of projects, and to give development teams more support in deciding which methods to apply in which circumstances. Some work in this direction has already be started in conjunction with *AAL Austria*. In addition, new methods may be needed, especially ones appropriate for use with people with less technical experience, and ones that are suited to working with sensors and privacy issues that are in practice hard to explain to older people.

Further case studies are recommended to understand what is happening in more detail; for example, looking at the communication between user researchers and developers, or the communication between project partners, especially when diverse partners are included, e.g., from different countries and/or different domains, such as carer organizations. In terms of getting systems to market, more information is needed regarding the factors influencing the decision about whether to purchase a system after long-term tests.

More evidence of the benefits of these systems would help companies convince customers to invest in them. This point was included in one of the "solutions" developed by workshop participants, but is something that is also supported by a report by the German ministry of health (Bundesministerium für Gesundheit, 2013, p. 119). Ideally the evidence would include different aspects, for example, quality of life, length of life, costs to the health system and cost to the individual. Pilot regions, such as WAALter, West-AAL and ZentrAAL in Austria (AAL Austria, 2016), could be used to gain evidence.

As discussed previously, changes to funding structures may be necessary to ensure success. Research is needed to better understand which parameters are most important.

Finally, more information needs to be collected about the "landscape" to support companies when initiating projects, for example, a comprehensive list of products on the market, lists of projects that have been funded by the various funding programmes and a list of companies and organizations that are involved in developing AAL technology. These lists can build on existing sources, like the list of AAL Programme projects (AAL Joint Programme, 2013a) or the list being compiled by AAL Austria. A unified categorization of systems would also support this. Although some have been proposed (Leitner et al., 2015), these are not yet widely used, and may need to be adapted once a more complete list of AAL technologies and projects exists.

There is a need for products to assist people in later life. Particularly sensor-based monitoring systems may be acceptable to people not normally open to care (Draper and Sorell, 2013), and hence are an important alternative to carers. The research identified a rich landscape of issues in the interconnected categories *users, financing, marketing, product* and *project* that could contribute to the success or lack thereof of projects developing AAL technology. Fortunately, many of these are thought to be within the

control of development teams. With more awareness and further research there is hope that the next generation of systems will be more successful.

CHAPTER 9

Conclusion

The aging society will have a significant impact on Europe.

AAL technologies aim to allow older people to reside in their own homes longer, and also to reduce the amount of money and effort required to care for an aging society (AAL Joint Programme, 2017). The sensor-based monitoring systems studied here can give people peace of mind (Turner and McGee-Lennon, 2013, p. 24), and may be combined with services that support people in their everyday lives.

Despite reports supporting the need for these types of systems in the future (European Commission, 2006) and many years of funding (e.g. AAL Joint Programme, 2017), AAL systems are not yet mainstream (AAL Programme, 2015, p. 11), and there are many barriers to their adoption (e.g. Sanders et al., 2012).

To gain insight into why these systems are not more widespread, this research studied the development of AAL technologies, in an attempt to identify the issues and challenges that development teams face that could affect the success of the systems developed, and understand how these fit together. The focus was placed on products being developed by companies, and on monitoring systems based on sensor technology. It investigated aspects related to the users, the technology, the development processes, and other issues that arise during the development.

To this end, a series of qualitative studies was conducted. The core of the research was two case studies, each covering a project with different attributes. One was done as a participant observer, whereby it was possible to follow the discussions in meetings and the way in which decisions were made; the other was a retrospective analysis of a larger project through which it was possible to gather information about other aspects, such as having multiple partners and the introduction of the system to the market. The data for the case studies was collected using a variety of accepted methods (see Wobbrock and Kientz, 2016): observations, interviews and document analysis. The analysis was based on thematic analysis (Braun and Clarke, 2006). Case Study 1 focused more on the user-centered process during the development; Case Study 2 looked at a wider range of aspects affecting the success.

These case studies of companies developing systems with monitoring capabilities contributed not only rich information about projects that are difficult to get, but supported understanding how the issues fit together. The results help explain why more solutions are not getting to market. As such, the research was exploratory.

In order to gather additional data and check whether similar issues had been encountered in other projects, a series of supplementary studies was done. These included an interview study, workshops and an interactive poster. Based on the results of the workshops, the issues identified through the research were grouped into the categories *financing*, *users*, *marketing*, the *product* and the development *project*. People with experience in the development of AAL technologies rated issues in the categories users, funding and projects as being most critical to success.

The findings indicate that when developing these types of technologies there are many issues that can contribute to whether systems are successful, and that these issues are interrelated. The results unpack these and show the way in which the focus may shift away from the older people being monitored onto problems about reliability or the needs of the relatives caring for the older people who receive the alarms. Furthermore, they demonstrate the challenges teams have reaching the high level of reliability required, and the necessary usability for the diverse group of older people. Additionally, the results show the way the word 'users' can mask the needs of different situations; for instance, professional carers versus family members, older people that are living at home versus those living in an assisted-living facility. The challenges of developing systems with a monitoring component for older people may require additional time, and hence also money. In the end, financing issues were some of the most important issues when developing these types of systems. At the same time, using funding programmes to finance projects may add complexity to the project, e.g., by adding additional partners and fixed deadlines.

Some of the problems are inherent to this type of system; for example, the difficulty of achieving the needed reliability with relatively new technology, while at the same time ensuring that the systems are easy to use, having an acceptable physical appearance and including the *right* functions rather than *lots* of them. Many people need to be involved: older people, carers, specialists in design, specialists in sensors, the people who will install the systems, etc. It is a long road from the type of prototype that results from funded projects to a marketable system. And if systems are for new assisted-living facilities, even a long time from signing the contract to the actual installation. This requires funding that supports the development of technology, but also its deployment.

The results of the supplementary studies propose some possible solutions. People involved in development projects underline the importance of focusing on the needs of the various user groups early in projects, and also of testing with older people early enough to be able to reflect on the results and re-test after changes have been made. But it does not suffice being concerned about older people and applying some user-centered methods, as even teams with an interest in helping older people and applying these methods are not successful in developing viable commercial projects. Furthermore, it can be hard to find older people willing to participate in the development.

There are many things that can be done to follow-up on the findings presented. Many of these points related to the 'users' and HCI. As a community, researchers need to discover which methods contribute to success, spread the know-how about existing user-centered methods, gather more data about when which methods should be applied in practice, and find ways to support teams keeping the different user groups in the foreground, even when technical problems arise. The community of people working in the area of AAL also need to collect and spread information available about the issues developers need to be aware of. More needs to be done to communicate the benefits of these technologies to the general public. This may with time also support the development, by making it easier to find older people willing to be involved in user tests.

Some of the aspects, especially those relating to funding, are thought to be out of control of the people developing these technologies. Some of these aspects need to be addressed by funding agencies, for example, by providing more information about projects that have been completed, or allowing more flexibility during projects. People who had worked in projects felt that not fixing the goals at the start of projects, and allowing more flexibility with deadlines to ensure sufficient tests are done could support the success of projects. But projects also need to think about marketing issues earlier.

The studies were exploratory and concentrated on gaining an understanding of the important aspects involved. They have the common limitations inherent to qualitative work, in that they include only a limited number of people, projects and contexts. Thus, more research is needed to gain information from a broader group and also further investigate aspects that were identified as problematic, such as communication between project partners.

This work highlights the importance of approaching the development of AAL systems with a monitoring component in a human-centered way, even though many of the issues were not directly related to HCI. The results support the value of studying not only at the acceptance, but at the development process, where decisions are made about the functionality and design that can affect the acceptance and success on the market. In order to develop more successful systems in the future, it is important to have more understanding of the issues the developers face and their source. As examples from other areas of technology show, such as with the Netscape browser or Apple Macintosh, a single success story can turn the market around (Moore, 2006, p. x).

In the end it isn't "them", the older people, but us, who will be affected by the issues identified here and the systems that result:

- Us, the software developers, who are subject to the same mistakes,
- Us, who are aging ourselves, and may one day use and depend on systems like these,
- And us, and those who follow us, who will pay for the failure to provide satisfying solutions.

Part IV

Appendices

APPENDIX A

Consent Form

The consent forms used were very similar for all studies. This appendix contains the text of the English consent form used for the case studies. The text was modified slightly for other studies, for example, for the workshops the point regarding project documents was removed and the words "development meetings" were replaced with "workshop". There was also a German version of the consent form for the case studies and workshops.

In addition to the contents shown here, the logo of the TU Wien was included at the top. At the bottom, there was a place for both the participant and researcher to sign, as well as, contact information for both the doctoral candidate and her adviser.

Both the participants and the researcher received a copy of the signed form.

Participant Consent Form

Before participating in a research project, it is important to provide you with some information and to get your consent.

- The research is aimed at investigating the development of ambient assisted living (AAL) projects. It is being done as part of the research for doctoral studies at the Institute for Design and Assessment of Technology at Vienna University of Technology.
- The researcher(s) will be doing interviews, taking part in development meetings and analyzing project documents.
- Your participation is voluntary. If you agree to participate, you can withdraw at any time.
- Jean Hallewell Haslwanter is responsible for the realization and scientific evaluation of the results.

- The collected data will be treated confidentially. The data will not be disclosed outside of the research team. It will be used exclusively for the above named purpose.
- The participant gives their consent for recordings (audio/video) to be made and for these to be analyzed for scientific purposes. Transcriptions will be made. The names and locations will be anonymized before publication in scientific conferences or journals.

I have read the provided information, and agree to participate.
☐ YES ☐ NO

I consent to interviews.
☐ YES ☐ NO

I consent that researchers may participate in selected development meetings.
☐ YES ☐ NO

I consent that project documents may be analyzed by the researchers.
☐ YES ☐ NO

I consent to audio recording of interviews and/or meetings.
☐ YES ☐ NO

I consent to photos and videos of interviews and/or meetings
☐ YES ☐ NO

I consent that my data may be published in an anonymized form for scientific purposes.
☐ YES ☐ NO

I would like to be contacted if a picture of me is to be published.
☐ YES ☐ NO

APPENDIX B

Case Study Materials

In the following, an overview of the documents used for Case Study 1 and Case Study 2 is provided, Table B.1 and Table B.2 respectively. In an effort to maintain the anonymity of the projects and companies involved, only a brief description is included. In the following tables, *p.* stands for pages and *min.* for minutes.

In addition, an image of the coding tool used is provided in Figure B.1 to illustrate the way in which the tool made it easier to navigate between codes or themes, the documents, etc.

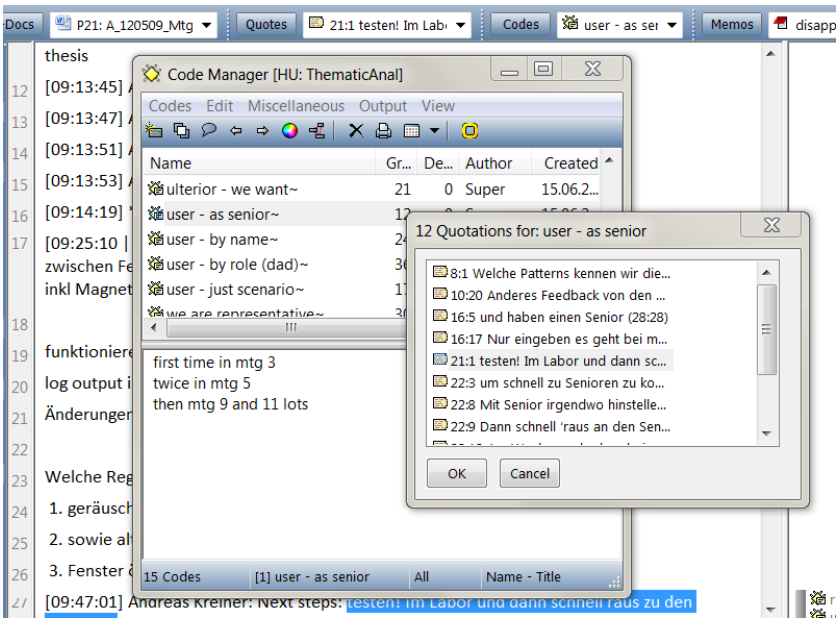


Figure B.1: Navigating codes using the coding tool (example from Case Study 1)

Table B.1: Case Study 1: Sources used

Phase	Type	Description	Length
Pre	Interview	Project leader	103 min.
Analysis	Meeting	1st meeting	97 min.
	Document	Minutes of 1st meeting	6 p.
	Meeting	2nd meeting	81 min.
	Document	Minutes of 2nd meeting	2 p.
Design	Meeting	3rd meeting	75 min.
	Document	Minutes of 3rd meeting	1 p.
	Interview	Older person, possible user / tester	
	Chat	Online exchange - whole team	3 p.
Development	App	Application version (1st)	
	Meeting	4th meeting	66 min.
	Document	Minutes of 4th meeting	1 p.
	Interview	Developer	21 min.
	Chat	Online exchange - whole team	2 p.
	App	New application version (2nd)	
	App	Another application version (3rd)	
	Document	Agenda for next meeting	1 p.
	Document	Presentation of design	11 p.
	Meeting	5th meeting	85 min.
	Document	Minutes of 5th meeting	2 p.
	Document	Updated presentation of design	
	App	New configuration files for application	
	Meeting	6th meeting	79 min.
	Document	Minutes of 6th meeting	2 p.
	Document	Updated presentation of design	+ 2 p.
	Chat	Online exchange with project leader	2 p.
	Document	Minutes of 7th meeting	1 p.
	Chat	Online exchange - whole team	2 p.
	App	New application version (4th)	
	Document	Instructions for testing	2 p.
Evaluation	Meeting	9th meeting	44 min.
	Chat	Online exchange - project leader to team	2 p.
	Meeting	10th meeting	33 min.
	Chat	Online exchange - whole team	1 p.
	App	New application version (5th/last)	
	Meeting	11th meeting	58 min.
	Chat	Online exchange - whole team	3 p.
Post	Interview	Project leader	58 min.
	Interview	Another team member	25 min.
	Interview	Developer	45 min.

Table B.2: Case Study 2: Sources used

Phase	Type	Description	Length
	Promotional	About the company	2 p.
	Promotional	Company time line	3 p.
Initial	Press	New business area opened	
	Press	Financial results: good	
	Scientific	Evaluation from show home	21 p.
	Press	Award for innovative product	
	Television	Report on smart home technology / this product	4 min.
	Press	Results of show home	
	Promotional	Brochure about the product	6 p.
	Promotional	Video: one day with the product	5 min.
	Development	Sensors used (5)	
	Development	Screen shots (20)	
	Promotional	Newsletter for product	5 p.
	Technical	Trade magazine article on product	2 p.
	Television	Report on first person using	3 min.
Intelli	Funding agency	Project accepted / description	1 p.
	Promotional	Project description	1 p.
	Scientific	Presentation at a national AAL funding agency event	11 p.
	Press	Potential savings	
	Scientific	Article about AAL, including product as a model to provide comfort & security	4 p.
	Scientific	Presentation at an international conference about AAL	15 p.
	Promotional	Presentation about latest development and advantages	17 p.
	Press	Financial results: bad	
	Scientific	Article about pattern recognition in product	5 p.
	Press	Pilot / advantages of product with regards to security	3 p.
PAAL	Funding agency	Project accepted / description	1 p.
	Press	Project accepted	
	Promotional	Newsletter for product	8 p.
	Development	Functions and how it works	6 p.
	Development	Meeting minutes - services	1 p.
	Development	Meeting minutes - emergency services providers	2 p.
	Development	Meeting minutes - project members	2 p.
	Press	Minister visits care home where pilot will be done	
	Press	Pilot starts	
	Scientific	Conference presentation with results of market research	16 p.
	Press	Award for innovative product	
	Technical	Presentation about product for building contractors	14 p.
	Press	Financial results: situation improving	

Phase	Type	Description	Length
PAAL	Scientific	Article about experiences during pilot	2 p.
(con't)	Scientific	Article about what product can sense / detect	5 p.
	Scientific	Evaluation of pilot	126 p.
	Press	Award for carers involved in project	
	Scientific	Product presentation at nat'l funding agency event	5 p.
Thornhill	Press	Groundbreaking for care home	
	Promotional	Description of product	2 p.
	Promotional	Services available	1 p.
	Promotional	Safety features available	1 p.
	Promotional	Benefits	1 p.
	Press	Podium discussion - problems with funding models	
	Technical	Trade magazine report including product	4 p.
	Health	Advantages product can provide	3 p.
	Scientific	Review of smart homes including product	92 p.
	Press	Review of pilot in newspaper	3 p.
	Funding agency	Another project accepted (later withdrew)	1 p.
	Scientific	Presentation of pilot results at national funding agency event	5 p.
	Scientific	Technology for people with dementia including product	108 p.
	Health	System soon available in care homes	1 p.
	Press	Care home units with system soon available	
	Development	Screen shots - tablet version (5)	
	Health	Brochure about care home, including product	21 p.
	Health	Tests with product planned at another care facility	
	Scientific	Presentation about experiences with AAL	8 p.
	Health	Presentation of activities, incl. tests in other facility	
	Press	Ministers visit *Thornhill*	
Post	Interview	Carer from *PAAL*	59 min.
	Interview	Service provider (from other company)	148 min.
	Interview	Technical project leader	91 min.
	Talk	Evaluator of show home	20 min.
	Interview	Project manager *GellIT*	69 min.

APPENDIX C

Interview Study

This appendix includes the questions used for the interview study, an overview of the interviews held, and a summary of all interviews.

C.1 Interview questions

The questions were not necessarily asked in exactly this order or with exactly this wording.

Introduction There have been a lot of projects to develop technology to support older adult who want to live independently, however there do not seem to be many systems on the market. My research aims to look at the development process (rather than user acceptance) in an effort to understand the complexities and problems developers face, particularly those relating to users and their needs. I have studied two projects closely – one during the development and one after the completion. I am now interviewing people involved in other projects to extend the scope and to see what problems other projects have faced, as well as, to see if the aspects identified so far have also been an issue in other projects. Aspects related to the process and reflections about problems encountered are particularly valuable.

Background Info

- Describe the/a project briefly.
- What was your role?
- What led to the project being started? What were the initial goals?
- How long was development? What was done first? (When?) How many versions were done?

- How was it funded? Did you receive any grants for development? For what?
- Were other people involved, either partners in the development or user groups, or ...

Users

- How would you characterize users? Are there different groups? Who gets alarms / handles them in your system?
- If focus not older: is there a reason for this, how many of users are older?
- Team make-up: was there someone focused on usability?
- Were any users included in the development? Which users? How? Why / what was the goal?
- What methods used to work with older? What experiences (positive/negative)?
- How did you balance the different user groups in development: (older) people / (carers) those answering alarms?
- System requires reliability/privacy/usability: What was given priority in this project?

Result

- What did you end up developing? Was it the same as what was initially planned / envisioned?
- What problems were experienced during development? (e.g. technical or relating to methods)
- What diversity is there, e.g. between homes?
- Were changes necessary to support maintenance?
- What do you think leads people to buying it? (e.g. is it the children / carers / older who decide)
- Most popular features? Features that did not work out? Any surprises with respect to this?

Table C.1: Interview Study: Overview

		Type of organization	Region	Length	Location held
1	Bernhard	small company	central Europe	25 minutes	at the company
2	Salvator	large company	southwestern Europe	70 minutes.	Skype™
3	Per Ove	research organization	northern Europe	65 minutes	Skype™
4	Julien	research organization	western Europe	70 minutes	at a conference

Reflection / Recommendations

- Overall how well would you say the project went/is going?
- Looking back, would you do something differently? What? Why?
- How did the funding work out? Gain or disadvantage? Do you plan to apply for additional funding in the future?
- Is there anything you would recommend to others developing a similar type of project?
- Any support you feel research could give you? If nothing: add e.g. methods... *(don't close with this question)*

Wrapping up

- Open – anything you would like to add, other thoughts, ...

C.2 Information about the interviews

Table C.1 contains an overview of the interviews, including the pseudonym used, type of organization, region where the organization is located, length of the interview and location the interview was held.

Afterward of summary of each interview is presented, formatted as follows:

- Description of system / project,
- Methods applied,
- Problems encountered, and
- Recommendations for others.

In Figure C.1, an image of the transcription tool used is shown.

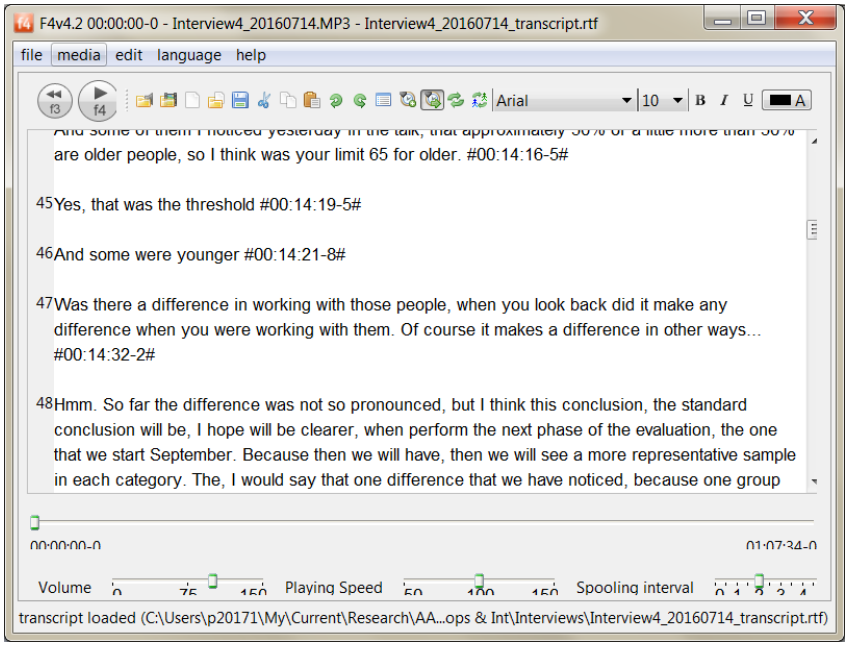


Figure C.1: Transcribing the interviews (example from Interview 4)

C.3 Interview 1 - Bernhard

Bernhard is the founder and head of a small start-up building smart home systems in a central European country. He is an electrical engineer. The company has a working smart home system and is just starting in the area of AAL. They have recently received funding for a project in the area of AAL. The interview was held at the company's offices - unfortunately on a day with unexpected problems.

C.3.1 Description

The system is a smart home system designed to be installed in new homes. It includes functions such as:

- Actuators combined with buttons to turn lights on and off or open and close shades,
- Contact sensors to detect if windows have been left open,
- Configuration on tablet in order to open and close shades at a certain time, and
- Special sensor to determine whether someone is in the room, in order to turn the lights on or off accordingly.

The product idea was initially personally motivated. In 2007, the founder of the company wanted to install smart home features in his new house and realized there was nothing

"finished" on the market, but entailed getting individual components and integrating these. His goal was to reduce the complexity and develop an affordable system for private homes. For this, he first found a developer to work with him. By 2016, the company had sold approximately 20 systems and has 9 and a half people working for them. The company still depended on venture capital at that time.

Looking back, Bernhard says that compared to the proof of concept they completed and installed in his house in 2007: "that wasn't even 2% of what we have now." One advantage of their system, is that with a button press they can send updates to all installed systems.

They were aware of the potential of the AAL market and have long planned to expand into this area. With their special sensor, they feel they are in a good position to monitor older people, for example, to check if a grandmother has gotten up by 8:00, opened the shades and made her coffee, and otherwise notify someone. They are now embarking on their first project in collaboration with a university, a user group, installers of infrastructure and a specialist in communications technologies. This will be a three-year project funded by national funding aimed more generally at innovation.

C.3.2 Methods applied

The input for the project initially came from the developers themselves. Once there was a version available the suggestions came from users. The users include both people who have it installed in their homes, as well as the people configuring and installing it. They work iteratively, adding new features when they are ready.

When evaluating new functions they consider the whole process chain based on a use case.

For the next phase with older people, they are aware that they need to get more information. This includes information about what functions are needed and which parameters need to be recorded. They want to keep it simple and affordable, and not use devices like mats to detect falls. At the same time, they are aware additional functions may be needed for the carers, such as recording the times at which carers are with the older person to support billing. They are also plan a second version of the configuration interface for the older users - a simpler one.

C.3.3 Problems encountered

Generally Bernhard feels that the development has run fairly smoothly. He identifies the main difficulty as being the difference between "theory and practice" - in practice it is always different than you imagined it. Up to now they have been able to fix any hardware problems with the software. At the same time, on the day of the interview, the interview had to be cut short, because a problem with the special sensor was causing the lights to go on and off unexpectedly at their most important customer.

It has been difficult getting funding, however, they have been fortunate as they got venture capital. This has limited their freedom to some degree and added costs for reporting, but has worked out well for them.

Working with subcontractors has been another source of difficulties. In retrospect, there were things they should have probably outsourced. On the other hand, in one case where they depended on people to do something, the part has not been finished to this day.

C.3.4 Recommendations for others

No recommendations were mentioned explicitly.

C.4 Interview 2 - Salvator

Salvator works on the software development of the back-end part of a system. He has a technical background and works in southwestern Europe. He has worked in software development for many years and started his first AAL project approximately three years ago. The company is now trying to go to market with their product.

The interview was held by Skype™ video conference.

C.4.1 Description

Based on the number of employees, the company classifies as a large international company. It is well established and known for producing reliable software systems. It has recently moved into the area of AAL, and created a new subsidiary for this. Prior to Salvator joining the company, the company had developed some individual AAL components.

This project aimed to integrate a series of existing components from different companies into a single AAL system, including both functions to determine if something has happened, and assistance features:

- Monitoring if an older person is okay, e.g. fall sensor, pill box
- Generate alarms and notifying carers if there is a problem
- Opening a channel of communication between an older person and a carer at a remote location.

For this a common back-end or platform had to be developed to support the different parts. They tried to make this very open, so that components could be exchanged or additional components could be added later.

The system includes several different user interfaces. There is the interface that the older users sees, the smartphone app used to inform carers in case of a problem, and a web-based configuration interface intended for carers.

Overall, the project went well. Experiences using funding from the AAL Programme were positive, once the grant was accepted. Generally, he finds there is not much discussion beforehand. During the project they were able to stick to the budget. And if certain tasks were done by another partner than initially planned, there was no problem

transferring money between partners. They did need to apply for an extension in order to test for the amount of time initially planned, which was granted.

For going to market, they plan to improve the appearance of the user interface, use smaller computers in the older users' homes, and find a way to make the overall system more affordable.

C.4.2 Methods applied

For this project, they wanted to adapt the technology to the users, and not the other way around. For this the process was user-centered and iterative.

However, at the beginning of the project, they first did a technical analysis to see what changes were needed to have a single platform to combine the different services. This was due to the fact in this case the individual components already existed, and just needed to be integrated.

After this, the needs were collected from both carers and older people. In order to understand the work processes of the care givers, first meetings were held to understand how they worked and what they wanted from the system. After this the specifications were developed and implemented.

Older people were included in the functional specifications and again in tests. It was generally the carers who talked to the older people and relayed the information back to the development team. He stressed how important it is to go to the users frequently and test. He felt this was more important for older people, because they are less willing to adjust to technology. He also mentioned that since they had working components, from the start they could go with a working version and not just designs, which he also thought made it easier.

C.4.3 Problems encountered

Generally, the project was described as going very smoothly.

Having different European countries involved in the project increased the diversity the system had to support. For example, there were large height difference between people in the northern and southern European countries. For this additional parameters had to be added. Furthermore, the processes of the care givers differed greatly between countries, so that the system had to be configurable.

Another problem he reported was that older people did not want to be a bother to others and worried about generating false alarms. One cause of these false alarms was that older people forgot to charge some of the components. For this they added a feature that could notify the carer if the device needed to be charged. This could also be configured, as the number of days between visits varies. These worries were balanced by the fact that the older people were happy that they can continue to live in their own homes longer due to the technology. Privacy did not seem to be an issue, but was a consideration throughout the design - the physical design / appearance was more of an issue.

The diversity of older people was also an issue. For their system, an important aspect was how fast people moved. They had 70 year old marathon runners, and then some people who had difficulty moving and were very slow.

From their experience in the project, they have found that not all markets are as ready as others. For example, the layout of houses is not suited in some countries due to steps and the width of hallways. Also in terms of how invasive people find this type of technology, independent of the usability. In these respects, they think the US is more prepared than Europe.

C.4.4 Recommendations for others

Salvator's main recommendation is to be user-centered and highly iterative. And to remember that little things can make a big difference with this type of end users. They also found out it really helps to involve family members.

He also thinks one of their success factors was having a technical architecture that is flexible, so they can easily change components, both for monitoring and notifying carers. This also supports adapting the system to different user requirements in the future.

C.5 Interview 3 - Per Ove

Per Ove is a specialist in software development for e-health applications who works at a research organization in northern Europe. He worked in three different projects in the area AAL over a period of approximately eight years, including one project funded by the AAL Programme, before switching back to e-health. He has also done projects with Austrian partners in the past. Even though he was working at a research organization, some of these systems were intended for the market. The meeting took place by Skype™ video conference, with Per Ove sitting in his office. Even though the projects took place several years ago, he remembered many details, only occasionally looking something up on his computer. When the agreed hour was up, he was happy to continue talking to me.

C.5.1 Description

He worked both on the development of the back-end or platform to support services, and also on services for this, e.g.:

- Calendar service to remind people of appointments
- Communication with others, e.g. family, carers
- Connection to sensors, e.g. windows sensors
- Small PC with large touchscreen for the interface

Cameras, even infrared cameras, were not considered, because they read up in advance and knew they could be an issue with acceptance and also privacy.

He remembers how in practice the system changed the lives of individuals. An older person with mild dementia kept forgetting appointments, which was difficult for her, but also her family and doctors. Just having reminders made her more independent, and also made it easier for the family, since she no longer called to check when they were coming.

In all, the testing phase of this project lasted almost one year. At the time, the technical know-how of the older people was very low. He thinks later more advanced features could have been included. Looking back he remembers that in one of the systems there were just the reminders and the messages to switch between. In practice, people got very few messages and mainly used the reminders. Some people always left it switched to the messaging function and used messages to record reminders, so they didn't need to switch between screens. He thinks they may have done this because they did not want to miss any messages and were always checking those, even though they got so few.

For the platform itself, interoperability was very important, so it could work for different sensors, Bluetooth devices and services. For this, standardization was a big issue. Reliability and robustness were also important.

But even when they were developing the platform, it was important to them to have a system that worked from the user interface down, and not just a perfect technical solution. For this reason, they wanted to provide the users with solutions that could be tested.

Overall, the functionality of the system, what it did, was what he expected. On a quality level, he was not entirely satisfied - but it was a prototype. He thinks they did a good job - they got solutions to the users early so they could test for almost a year, unlike many projects.

The plan was to go to market, but this did not work out, in part because they could not get funding. At the time they were aiming more at private homes. He thinks the situation has changed, and that now he would aim more at care homes, in part because there are lots of messaging and calendar systems available now. He also thinks that for care homes the sensor support would be more important.

Comparing projects, he found it interesting how some were focused on getting something to the users and others were more focused on technical sophistication and being state-of-the-art. The latter project received more funding, but in his opinion achieved less. The danger in that type of project is that they may not include a user group. In practice, they spent a lot of time discussing things a user could have answered quite easily. If you have a user, even if they are not always there, you think of them and so are doing what is actually needed.

C.5.2 Methods applied

Per Ove reports that what he calls user-oriented design being used in the projects.

For needs requirements they used an existing method. They hold workshops with different stakeholder groups, for example, one with carers and one with families. They also held interviews with families and relatives. In this case, the older people had mild dementia, so it was difficult to include them. These workshops and interviews supported understanding the tasks. The information from the analysis was then recorded in use

cases. These often included a scenario that described the way the situation was now - and how it would change if the working system was in place. From this they tried to derive the features. Per Ove mentioned how important it is to ask the older people themselves. The carers and family members wanted security systems, such as stove alarms, fall monitors, but the older people wanted other types of services, such as calendars, chatting services, sharing photos, etc. It is important to focus on the right services, something he thinks they were successful with.

After this, the team developed the information model, class models and database models. At this point they stopped involving carers and specialists in dementia. In practice, they would often refer back to specific use cases or scenarios - e.g. *scenario 6 in use case 7*. When asked, he does think this detaches you from the user a little, especially if you weren't in the meetings with them. He remembers that it was a real eye-opener for some of the developers when they went to install the system and saw these people in wheelchairs and experienced the smell - some developers found it kind of frightening. He thinks it's good to see the real world and not just sit in an office full of computers. He has found this also with his other e-health projects.

For the design they used mock-ups and screenshots to communicate what they wanted to the developers, who were located elsewhere. To review the designs, they had a specialist in dementia who would explain the functionality to the older users to get feedback. But first they usually tried to explain what they wanted to do to the carers and get feedback from them. For the older users, they generally needed something more tangible, some sort of electronic prototype.

Then later they also tested with the end users, in this case both older people and their families. They had nurses do some training sessions initially. Any changes were made quickly and rolled out to the users as soon as possible. These changes were often based on notes that carers made about problems that had occurred. Then a specialist in dementia would then explain why the problems were happening. But in practice, the interface was designed in a very simple way, and he doesn't remember any usability issues.

Although he generally thinks the methods worked well, there are a few things he might change if he had to do over. For example, it might make sense to check if they actually captured the feedback correctly. And also to have some sort of diagrams showing the interaction patterns with the system.

C.5.3 Problems encountered

Funding was the main problem. Due to lack of funding, they could not continue the project after the funding ran out. They did not want to leave the people who had the system installed and had come to rely on it in a mess, so found a way these people could continue to use it through the municipality. This is tricky, because an older person in this situation cannot wait for six months to find a solution and municipalities have a lot of bureaucracy to go through before they can buy something new. In the end, they had to look for alternatives that were commercially available. Many of these were too complex for the users in practice.

Costs were an issue also in other ways. Some of the equipment they felt they needed was very expensive at the time. Also the standard infrastructure that was available was not sufficient, so they had to use internet cards, which then were not reliable in some areas.

In terms of selling systems, he mentioned how difficult it was for them as a research organization to get into the national health care system, and thinks commercial companies have better chances. He also mentioned there are differences between systems aimed at private homes, where nursing organizations are involved, and those aimed at care homes, where municipalities are responsible.

If you want to scale up, you need more advanced services, a higher quality, a real installation, ... and a lot more money. For this, it may also make sense to include professional designers and not just programmers.

Working on an international team had some challenges. Because the development team is not all in one location, the information has to be passed on. Even though most developers spoke English, language was still a problem, because the nurses took notes in their native tongue. Also with the large differences in latitude of the different partners, it was for example difficult to explain to people in southern Europe why an indication that it was daytime was so important, at least until they showed them how dark it was in the early afternoon in a video conference. Also the differences in weather were sometimes relevant. There are also different privacy regulations which need to be upheld.

There were also problems with delays. The software developers were very optimistic in their estimates, that as a project leader you had to multiply them by ten. But he thinks this is known - and is not a problem with AAL specifically.

Another problem they did not foresee was the difficulty finding people to test, especially since they had a partner that specializes in aging. The main problem, was that they needed the permission of the relatives, and they were often hesitant. And once they got approval, they had to train people. In all, recruiting and training took almost a year.

Some people involved also had an issue with the system, due to the ugly black cords. One woman unplugged it and put it in the closet. He thinks this is less of a problem now, as there are now other options.

C.5.4 Recommendations for others

When asked about recommendations, he says that it has been said so often before, it shouldn't be necessary to say people should involve end users in an early phase. He also recommends reading scientific papers - there has been a lot published about design in HCI conferences and journals. He also recommended including a good user-interface designer or interaction designer as part of the team, as they know some useful techniques, and are better with colors and shapes. And allowing a lot of time for the testing phase.

At the end, he reiterated his recommendations, having end users, involving them and meeting in their environment. Families are less important, really only necessary for the consent.

Finally, he recommended not making the system too complicated by adding lots of functions. Especially health care professionals do not have a lot of time to play around with the system. They just need a system that works and they can use effectively.

C.6 Interview 4 - Julien

Julien works in the development of e-health projects at a research organization in western Europe. He has been involved in two projects related to AAL. The interview took place over lunch at a conference. Also here once the conversation got going, he was happy to go over the agreed hour.

C.6.1 Description

One project was an AAL monitoring system with contact-less sensors. It also included a number of services, such as a list of contacts and a calendar. The system consisted of a fixed touchscreen terminal. The system was aimed at both private homes and nursing homes. In practice, it was not the older people who really asked for the system.

The other project was a system helping people to transition from being in hospital to going back home. This aims at people who take multiple different medications, so they are not necessarily ill, but generally frail and includes people of all age groups. So far they have not noticed a difference between the age groups, but he thinks that may change during the trials. This system usually has a touchscreen terminal for patients and a laptop for health care professionals, but the choice was based on the health card needed for e-health in that country.

For both systems, the primary user was the patient or older person. At one point, he mentioned that the users who were most motivated, were those who had a serious problem and had had surgery, and now wanted to do everything to maintain their health. They were the ones who were interested in patient involvement.

Patients in both systems had concerns about privacy. But in the end, despite their efforts, he did not think people really understood the encryption mechanisms, but just felt assured by having to enter a PIN code (Personal Identification Number). There was also an issue about who received the alerts and which health care professionals had access to the data. But he thought this may relate to their health system, where only people directly involved in care have a right to access data and they can ask that certain people do not have access. But it goes both ways - doctors can also say which data people have access to, and often worry about being blamed for not recognizing something early enough.

He felt at the point of a proof of concept, having funding is essential. The actual efforts were in the end quite close to what they estimated. As a research organization the full costs are not covered, so it is important that they can valorize the remaining costs of the project later. For this reason they include representatives of companies that are interested from the beginning. This way they can ensure the system will fit the needs of these companies during the requirements phase and give them the right of first refusal

afterwards. Some companies even built an interface based on feedback from the tests, even though they were not funded. In the end it is a good deal for both sides. But the partners are also important, because having company partners support adding additional modules later.

The funding did, however, have an impact on the partners chosen, because there are often criteria, for example, you need one university, etc. It makes a real difference if the grant requires that it be led by a university, because it affects the objectives and tends to be less applied.

C.6.2 Methods applied

Julien stressed that it is essential to start with a literature search and to look at other projects. And then to discuss in the consortium to gain an understanding about what is needed and what is possible. In the first stage this type of project is more driven by the medical people, and then by the technical.

Later discussion groups were held with users, both medical professionals and patients. In the first project, the monitoring one, this was more individual contacts - and started later, often only after first designs were available. In the second project, they held focus groups to collect requirements, but also interviews with individual patients. For these they had list of points to cover. The focus groups were separated - patients and health care professionals. They even separated the different health care areas, because the practice differed, for example, in a private practice or in a hospital. If there were meetings that people had to attend anyway, for example, staff meetings in the hospital, in some cases they would use those to get feedback. For convenience, meetings with patients were often held at the hospital.

In the second project, things were done quite formally. They were very structured collecting the requirements of the people and also tracking these. This enabled them to trace the history and dependencies between the requirements. They also showed the medical partners screen templates and checked if those were okay. Even more important was the rating they used: very important, not so important, this is a reason for refusal, etc. Although he cannot remember it happening, patient requirements would be given more priority in case of a conflict, because it was after all for them.

Overall the development was highly iterative. The experimental phase was done in the homes. They did not have a strong idea of what they wanted when they started, as so were quite willing to review their plans after evaluation. In the first project there were only five to ten installations during the pilot, which wasn't sufficient.

C.6.3 Problems encountered

Right at the start his first thoughts are about technical problems and difficulties recruiting users.

Based on his experience in multidisciplinary projects, he thinks that having a common understanding is important. This includes the vocabulary and acronyms, but also a more

general understanding of the different fields: technical, sociologists, lawyers, physicians. It is a difficult process, but all views are necessary if you want a valid system.

For the monitoring project, it was difficult to recruit people for test. This was in part due to privacy issues with the video cameras. Some advisers were surprised, because they thought people are more rational than that, that it would suffice if you explain that the videos are processed locally and that there are mechanisms to make the images fuzzy. He thinks this may have been due to a lack of understanding of the technology, but was also related to privacy concerns people of any age would have. They found, however, people were more confident and willing to consent if a health care professional recommended it. But families were also important.

Another important aspect were aesthetic concerns. Some people did not take part in the pilot for that reason. The camera initially had a kind of tripod that was not well integrated, and was, well, ugly.

The two factors also influenced each other. Due to the aesthetic aspects, visitors were more likely to see the camera. From this a new need emerged, that they needed to be able to deactivate it, because the visitor might not agree being filmed. But this came up relatively early in the design.

Security features were discussed at more length. People need these because they have early dementia or risk of falling. He thinks that people find it difficult to admit that they need it, that these types of changes are happening. Because of this, older people are not so ready to accept they need the system, even if they are already living in a care facility.

With regard to the services, they found that the first version was too complex. He thinks this is generally a risk as a researcher or technical person, that we tend to see things too complex, distinguish too many things.

C.6.4 Recommendations for others

A key success factor they learned after their first project, was to recruit an institution or non-profit organization to support finding people to test, so that you don't have to rely on your mother and her friends. Because it is important to have enough people, maybe 20. These people can also take over the initial explanations about the benefits and also the training.

Another key factor is if the partners are willing to go beyond their competencies, and not just stick exactly to what was agreed. If you stick to your own part, you don't really understand what the others need.

Looking back, Julien thinks having the structured approach to gathering requirements is better.

He also thinks having regular face-to-face meetings with all partners is important, approximately every four to six weeks. This especially important in the beginning, as otherwise people don't make progress or go in different directions from each other. And it helps if stakeholders take time to understand each other at the beginning, to ensure that you have a common understanding and direction.

APPENDIX D

Workshops and Interactive Poster

This appendix includes additional information about the workshops and posters, including information about the participants and lists of the items presented to participants to check if they had also experienced similar issues. In addition, includes some photos of results from the workshops and the interactive poster. At the end, the solutions developed in the workshops are presented.

D.1 Information about the workshops

D.1.1 Participants

A list of participants is included in Table D.1, including the type of organization and discipline in which the person works. Under "WS", "1" indicates workshop 1, which was held on the same day as an AAL Austria meeting, and "2" indicates workshop 2, which was held at ICCHP 2016, an international conference on assistive technology. Under type of funding, it includes either product or the type of funding, i.e., AAL Programme, *benefit* - the national AAL funding programme of Austria, or Interreg - the EU funding programme to support cooperation between regions.

D.1.2 Issues provided to workshop participants

The list of issues from the case studies provided to workshop participants in step 2 of the workshops is shown in Table D.2. The markings are as follows:

- A ✓ under "CS1", indicates issues that came from Case Study 1, the smaller system studied during development,
- a ✓ under "CS2, indicates issues that came from Case Study 2, the larger smart home system studied retrospectively,

Table D.1: Workshops: Information about participants

WS	Type of organization	Focus or discipline	Type of funding
1	large company	electrical engineering, management	product
1	research organization	computer science, HCI	AAL Programme
1	university	HCI, sociology	AAL Programme
1	university	electrical engineering, assistive technology	AAL Programme, *benefit*
1	start-up company	economics, strategy	product
2	university	computer science, HCI	AAL Programme
2	university	embedded systems, assistive technology	
2	Fachhochschule	sociology, families	AAL Programme, Interreg
2	Fachhochschule	computer science, health care	
2	Fachhochschule	computer science, HCI, health care	*benefit*
2	companies (various)	computer science, pervasive systems	product, AAL Programme, *benefit*
2	Fachhochschule	sociology, telehealth, older people	Interreg, *benefit*
2	research organization	computer science, older people	AAL Programme
2	Fachhochschule	human service management, older people	product, *benefit*

- a ✓ under "Supported", indicates that one person added it to their list, meaning that they had also experienced it.

Table D.2: Workshops: List of issues provided to participants

Issue	CS1	CS2	Supported
Shouldn't be too obvious, e.g. LED light		✓	✓
Reliability - in all situations, over time	✓		✓
Problems with needed technical infrastructure		✓	
Adding partners adds complexity		✓	✓
Diversity of user group	✓	✓	✓
Developers not older – fall back on stereotypes	✓		
Reliability takes over – but usability important to acceptance	✓	✓	✓
What people say (e.g. show home), isn't necessarily what they do		✓	
Special needs for maintenance (esp. with private homes)		✓	✓
Finding people for long-term tests	✓		✓
Changing needs of older people		✓	✓
Needs of carers take precedence	✓	✓	✓
Lots of support needed at start		✓	✓
Change in care makes difference to functions needed		✓	
Technologies not financially supported – carers are		✓	✓

Table D.3: Interactive Poster: Countries represented by participants

Country
Austria
Belgium
Germany
Ireland
Italy
Luxembourg
Romania
Switzerland
United Kingdom

D.2 Information about the interactive poster

D.2.1 Participants

The countries from which it was possible to confirm that people participated are listed in Table D.3 (in alphabetical order).

D.2.2 Issues use to pre-populate the poster

Table D.4 shows the issues used to pre-populate the poster. The markings are as follows:

- A ✓ under "CS", indicates issues that originally came from the list provided to case study participants,
- a (✓) under "CS" indicates that although it was suggested at the workshops, was also experienced in one of the case studies,
- a ✓ under "WS", indicates the issue was suggested at a workshop,
- a ✓ under "Supported" indicates that it received at least one red dot to indicate that someone else had experienced it.

D.3 Some images from the workshops and interactive poster

To give an impression of these studies, and also to provide evidence of the research having been done, some pictures are provided below in Figures D.1 and D.2.

Table D.4: Interactive Poster: Issues used to pre-populate the poster, ordered by importance

Issue	CS	WS	Supported
Communication between stakeholders	(✓)	✓	✓
Partners chosen to get funding not expertise		✓	✓
Project goals set in stone if funded		✓	✓
Don't really understand needs of the user group	(✓)	✓	✓
Project ends with a prototype	(✓)	✓	✓
Very diverse user group	✓		✓
Privacy concerns	(✓)	✓	✓
Needs of the users take precedence	✓		✓
People not willing to pay / technology not funded	✓		✓
Benefits hard to prove		✓	✓
Initial support needs high	✓		
Hard to find people for long-term tests	✓		✓
Development lifecycles differ: computer vs. buildings		✓	
Technical partners want easy funding		✓	✓

Figure D.1: Workshops: Categorization of issues from group B in Workshop 2

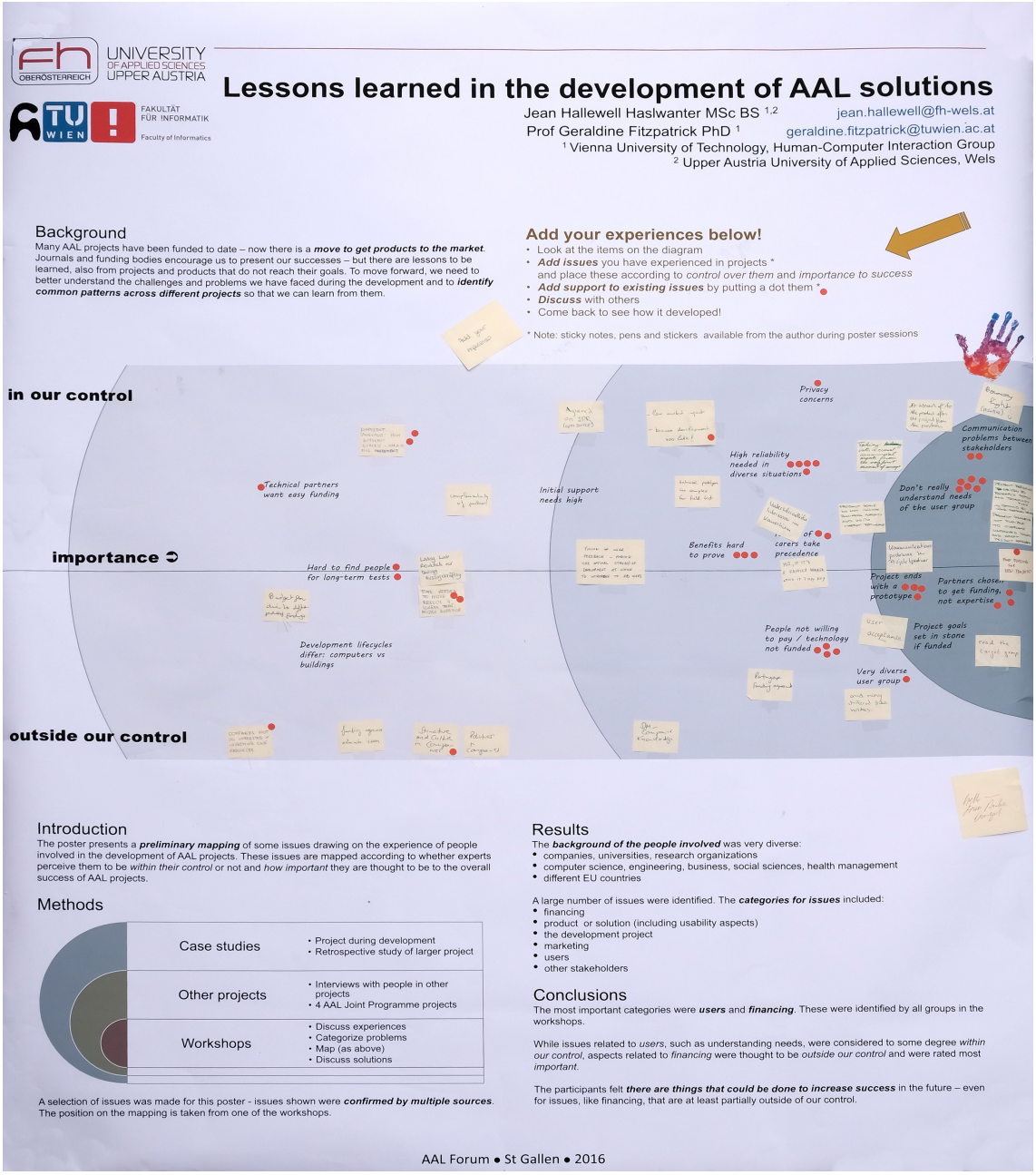


Figure D.2: Interactive Poster: Image

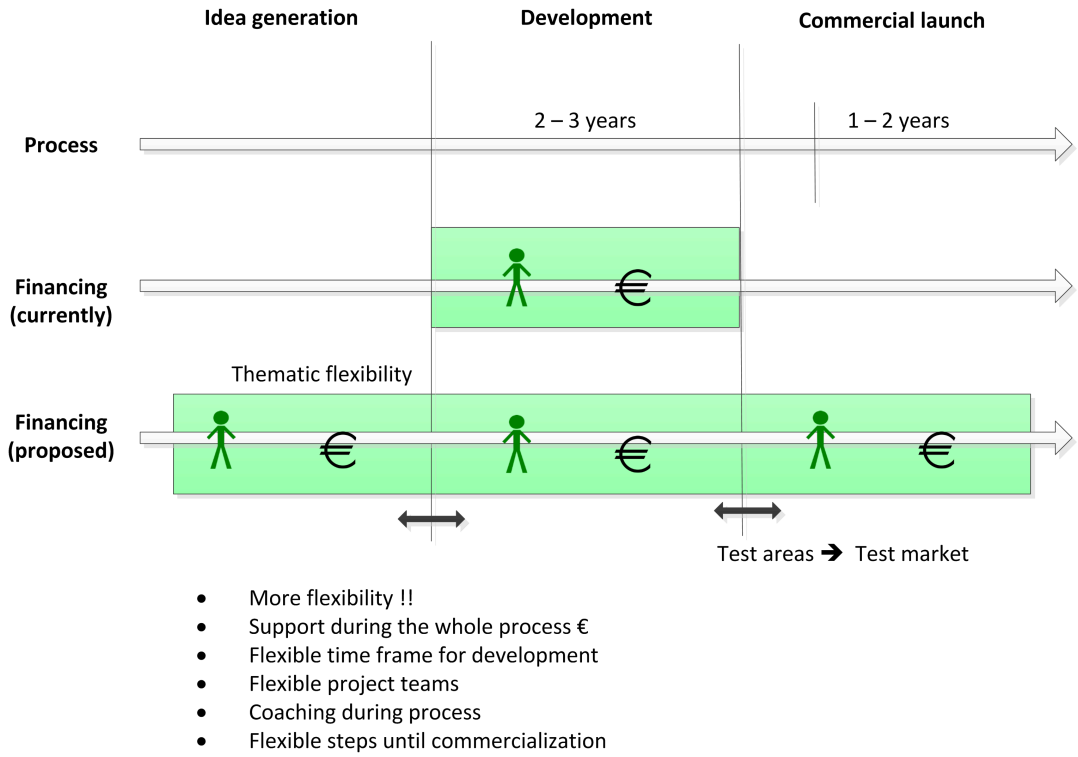


Figure D.3: Solution for *Financing* issues from Workshop 1

D.4 Solutions developed in the workshops

In the following, figures the solutions drawn by the participants have been recreated [1]. These are described textually with the results of the supplementary studies in Chapter 7.

[1]Figure D.4 has been published previously in Hallewell Haslwanter and Fitzpatrick (2017a)

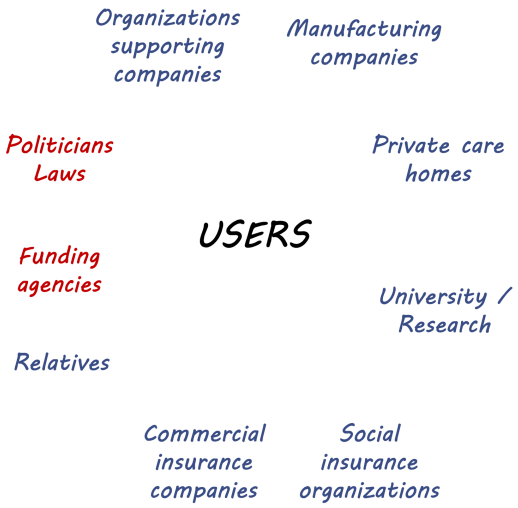


Figure D.4: Solution for *Marketing* issues from Workshop 1 (previously published)

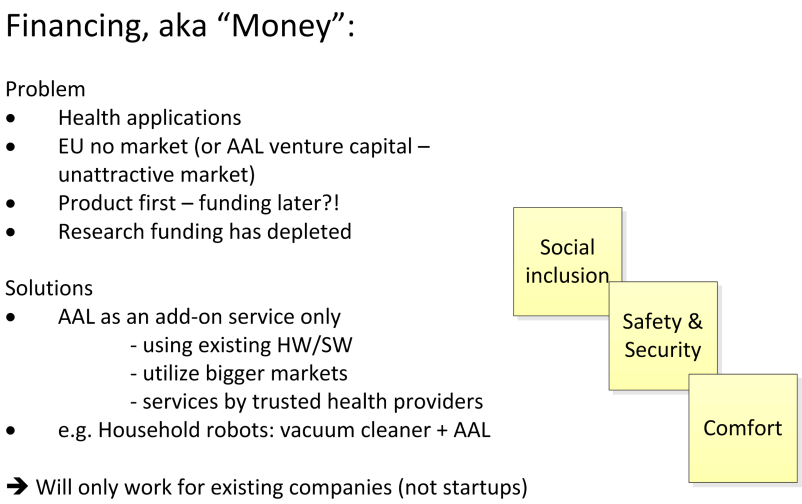


Figure D.5: Solution for *Financing* issues from Workshop 2

BENEFIT

Problems:

- Benefit of AAL doesn't exist
- Visible due to lack of knowledge of "real" needs of the elderly
- Benefits are difficult to prove
- Lack of research on the benefits of AAL

Comment from group:
➔ relates to financing "product first"

Solutions:

- Requirements analysis (gathering data on needs)
- Tailor-made AAL products (according to needs and not technology)
- Developing appropriate instruments to measure the benefit (outcome, effects, etc.)
- Research on the benefit of AAL (longer term study panels, etc.) – funding!

developers

Comment from group:
➔Market problem (user acceptance)

Figure D.6: Solution for *Product* issues from Workshop 2

Developers are young. They do not understand the individual needs of elderly people

- Managers of research projects are not young.
- Young developers can ask their grandmothers / grandfathers
- User research available about needs of elderly people in social sciences
- Interdisciplinary research is necessary
- Developers must talk with the elderly end users

Comments from group:
➔ We've failed (Software Engineering)
➔ "Forcing" developers to talk with older users might work – but risky unless it's a big company

Figure D.7: Solution for *User* issues from Workshop 2

APPENDIX E

Review of similar AAL Programme Projects

This appendix provides additional details about the AAL Programme projects studied as part of the supplementary studies, especially in relation to Case Study 2, the *HandyHelper*. It starts with an overview of the sources used and then gives a brief description of each project.

E.1 Sources used

A list of the sources used is given in Table E.1.

E.2 Description of project 1

This project differed in that it is more medical also increasing needs for privacy, and that the sensors only work when activated by a person, e.g. scale, blood sugar measurement.

For project 1, information was only available about the requirements phase.

The user needs analysis applied primarily quantitative interviews with a small number of people. The process was:

- Literature review,
- Interviews with nurses, doctors and psychologists,
- Interviews with patients and care givers,
- Interviews with professionals and
- Elaborate scenarios as use cases

Table E.1: Review of AAL Programme projects: Sources used

Project	Description	Main Source	Length
Project 1	Project overview		1 p.
	Requirements document	✓	138 p.
Project 2	Project description		8 p.
	Web site description		14 p.
	Dissemination plan		27 p.
	Requirements document	✓	95 p.
	Design for GUI		27 p.
	Dissemination plan (updated)		11 p.
	Web site description (updated)		19 p.
	Evaluation results	✓	62 p.
	Evaluation report	✓	62 p.
	Project overview		1 p.
	Web site	✓	5 p.
Project 3	Project overview		1 p.
	Web site description		10 p.
	Business plan		5 p.
	Dissemination plan - health professionals		4 p.
	Dissemination plan - public		4 p.
	Conference presentation	✓	17 p.

There was a diverse user group, because one target group suffered from mild cognitive impairments, while the other had cardiovascular or diabetes problems. In practice, for the group with cardiovascular or diabetes problems, five qualitative semi-structured interviews were done with experts. In the cognitive group, quantitative interviews were done based on questionnaire developed by health care professionals. The participants included, fifteen patients and fifteen family caregivers and ten professional carers. The questionnaire for patients and caregivers focused on rating whether or not they thought older people would use various services, such as medication reminder, calendar, photo books, cognitive training, chatting, etc.

After gathering the information, the information about the user needs was summarized using use cases. Use cases were written about the health problems, as well as three use cases for general home care. The services suggested to support the latter were:

- Medication reminder
- Information about weather, films, etc.
- Alarm system activated by a button

The technology is quite similar to the initial *HandyHelper* version. The technology chosen included Bluetooth medical devices and a set-up box. The user interface consisted of a

TV screen with a TV remote control and/or speech.

E.3 Description of project 2

This project was a smart home based almost exclusively on sensors, without actuators to control things, which also included a reminder function. It primarily addressed people with Alzheimer's disease.

For this project, detailed information was available about the requirements and evaluation phase.

The user needs analysis surveyed a large number of people using questionnaires. The questionnaire focused on functions. The 300 participants included patients, family members, carers and doctors. In addition, patients were evaluated cognitively. Answers from 225 patients were evaluated using statistical methods. Based on these results a functional analysis was done, considering both customer and technical requirements.

The system was highly configurable in order to meet the needs of each individual end user and his or her home. It consisted of various sensors. The user interface for older people generally consisted of voice messages. The system seems to have been intended for later commercial sale, as a business plan is included.

For the evaluation, a pilot was done with a few users for an extended period of time. The pilot was done in three phases. The *first* phase was checking that it worked technically, followed by a *second* phase where carers were informed of problems for a subset of issues and *thirdly* the fully functional pilot. In total, the pilot ran eight months. The technical part of the pilot was done in two installations. After the initial pilot, the participants were asked to complete a questionnaire regarding the functionality of the system. The final configuration was done after this. The fully functional pilot ran for four months and included five additional installations. During this phase, a technical operator asked about problems every two weeks. At the end of the pilot, a questionnaire was distributed with goal of measuring cognitive improvement.

The documents also describe some technical problems encountered. Some things mentioned include problems with components, interference with speaker systems, the range of the wireless components, the need for a redundant internet connection, battery life of the wireless components and problems with the power supply being interrupted. In retrospect, they think doing tests in a living lab first would have been useful.

E.4 Description of project 3

This system is quite similar in terms of functionality to the *HandyHelper*, but differs in that it was targeted at people with dementia.

For this project, the information available was less detailed.

The development was done in two phases. The first phase was first workshops with patients and informal carers, followed by workshops with experts. After the system was designed, further workshops with patients and informal carers were done in a show

home. This was supplemented by an evaluation by experts. The report emphasizes the importance of including people with dementia in the development.

The final system was similar to the final version of the *HandyHelper*. It included sensors for security, as well as, some services. The user interface consisted of a touch screen for using the services. The system lists specific partners for distribution. At least one of the partners now offers a solution for sale in one country, however they have also been involved in other projects, so this may not be the direct result of this project.

The evaluation was done with twenty systems. These pilots lasted from one-half month to eight months. Both pretest and post-test interviews were done with the people. In addition, focus groups and questionnaires were done with carers. Home visits were planned to provide support. Apparently technical problems did arise, but most could be resolved during the pilot. No specifics were provided. A larger and longer trial was suggested, but only related to outcomes related to dementia.

In terms of features, it mentions that the agenda and fall detection were popular, while the photo book was not. People felt it increased the feeling of security and delayed admission to an institution.

APPENDIX F

Student Study

This appendix describes the study conducted with students to "replicate" the development of Case Study 1 to gain further understanding. This was done because the findings seemed surprising, specifically that the focus would move away from the older people and that no interface was developed for them. Since companies were not involved, it was not an integral part of the thesis.

F.1 Research methods

A group of master's students were asked to replicate the development. This meant developing a system that could check if an older person was still okay and to inform relatives if there were problems.

This was done in the context of a combined project students were required to do for classes on software project management and software architecture, thus combining both technical and project leading. The topic varies from year to year. For this project, the students were given sample personas (renamed) from the Case Study 1 on which to base their results (permission was received for this). For the course itself, a running system needed to be produced and the project had to be documented. For the study, the students additionally filled out a short questionnaire at the beginning and end of the project and were asked to audio recorded all project meetings. The students were given a recorder for the purpose of the research, either a memory stick capable of recording or a dictation device. The questionnaires did not ask the name of the person, but only the group. The risk of acquiescence bias was reduced somewhat, due the fact that they had to do the project anyway and did not know what the study was looking for, but were informed it was part of the doctoral research of the lecturer.

There are similarities, but also differences to the case study. The effort and time available was similar to Case Study 1. Like the developer in Case Study 1, the students were master's students with programming experience. For the project, however, they

worked in groups of three to four students, one of whom acted as project leader, so more than the team from Case Study 1. They did not have office space, but met at university four days a week. Furthermore, they were doing this for a grade rather than as part of their work, each person worked only part-time on this project and had competing claims on their time.

The participants / developers were quite similar to the developer from Case Study 1. All were doing a Masters degree in automation engineering and so had a relatively homogeneous background. They ranged in age from 20 to 28. All students had previously had courses in software engineering and HCI, and so were familiar with methods such as iterative development, use cases, user-centered design and personas. As automation engineers, all had previously programmed and have learned about working with sensors. All students had previously done at least a three-month work study in a company, and one person in each group had worked in software development full-time prior to starting their masters. Others indicate that the difference between this type of student and people in industry is minimal Tichy (2000). In this case, the similarities are greater, as the developer in Case Study 1 was also doing his Master's and did not have much work experience.

For the analysis, the recordings were analyzed and the results were examined to see if similar problems were encountered. Issues of particular interest were losing the focus on the users, the problems with reliability and the a user-interface for the older users.

Regarding ethical issues, signed consent forms were obtained from all students (see Appendix A). The students were not asked to do anything beyond the normal coursework. An assignment that was normally was done was adapted to meet the requirements of the study. The students were given a choice between doing the research project or another project. It was explained that should they they would be asked to record their meetings and complete two questionnaires. Some of the students expressed great interest in doing the research project and convinced the others, so that there was some pressure from the group. Students were reminded they could withdraw and were given the recording devices to operate themselves, but no one did and all students submitted the final questionnaire. Some students asked afterwards about the results and even suggested their results be given to the company from Case Study 1, something that was not done, as the students did not initially give their consent for that.

F.2 Results from student group A

In the questionnaire prior to the project there was an indication that the students stereotyped the older users, for example being "frail". Furthermore, they indicated that they felt that working with sensors made it more complicated and specifically mentioned the difficulties of transferring images. They saw the goal as providing more security for the older people.

In the first meeting, the students discussed one of the scenarios provided. The group also mentioned using the scenarios for test later. After this they spent some time discussing how to organize the team. By the end of the meeting, they agreed to use

images to decide whether someone is moving close to the tablet. In the following meetings a number of technical concerns are discussed, including reliability.

The solution that was developed used cameras to detect movement in the room. The logic was that in a room in a private home, if the image changed, someone must be moving and hence could be considered to be okay. The time span of inactivity and contact person could be configured. The prototype of the application basically worked. The prototype of the part to be installed inside the home of the older person showed the video that was recorded. The video data was not passed outside the home. The configuration was relatively complex, and would require a certain level of computer experience.

In the final presentation, the students said that the system could also be used with children, to see if they had woken up from their naps. They also mentioned that in the final version, they would hide the video images and perhaps replace this with a slide show. They also mention the possibility that this could be extended not only to provide help, but used in both directions so older people could also receive help doing something if they wanted it.

The questionnaire at the end of the project indicates the interest in working with older people and sensors had increased since the beginning of the project. They reported having experienced difficulties processing the images. With regard to the question about who they saw as the users, they answered the older people, but also added a comment that this user group was less present due to the sensors.

F.3 Results from student group B

In the questionnaire prior to the project, one person mentioned that they were very interested in the project, because it was very realistic. No mention was made about sensors. However, two people specifically mention older people and describe three different scenarios, including two regarding people without computer experience and one with. In informal discussions with the students later, two students mentioned having grandparents from whom they think such a system could be interesting.

During the meetings the students spent little time looking at the materials provided about the users, but mentioned the needs of both the older people and the relatives. The group specifically mentioned that the goal was to provide peace of mind for the older people. A decision was made not to include sensors in the prototype very quickly. This decision was based on practical reasons, i.e. complexity.

The final version consisted of an interactive interface on which the older person must press once a day. Since the person might forget, a text was displayed on the screen and the button changed color, if this had not been done for a longer time. For example, it turned yellow after 12 hours, and red after 24 hours when the message went out. In this way it was also possible for the older person to see if the message had been sent. Little configuration was required - it was only necessary to enter a list of contact numbers. The system was called TechNanny.

In the questionnaire at the end of project the students reported that they wouldn't like to have the system themselves. They reported that they did not use the scenarios

provided, but some of their own, based on their own family members. Even though no cameras were installed, the team expressed concerns about privacy.

In an interview after the course / project, the project leader for this group indicated that the interactive solution was based not so much on the needs of his own grandmother, as on the technical challenges of using sensors. They wanted to be sure to have something working. For the next version, they would add some type of sensors, but also leave an interactive part.

F.4 Comments

Group A has quite a few similarities to Case Study 1. The team started by considering the user, and soon became wrapped up in issues related to the implementation. In the end, the prototype did not have an interface for the user. Interestingly, as a next step, they thought of adding reciprocity in the future. Where Case Study 1 aimed to exchange photos, here the reciprocity was the more immediate need to get assistance with a task, something that was also mentioned during the case study.

Although at first it could be easy to conclude that the people in Group B who mention specific scenarios related to their grandmothers developed a interface for the older people, the interview afterwards indicates that the decision was instead based on technical concerns related to developing a solution that was sufficiently reliable in the short time available.

The results demonstrated that also other teams that start out by considering the needs of older people lost focus on these people as the technical issues, again related to reliability, took over. Furthermore, one group also developed a solution without an user interface for the older users.

Since these are masters students not working to truly get a system to market, the results provide only an indication. However, since both group included people with experience working in software development in a company, and the developer in Case Study 1 was a Master's student himself it has a high level of similarity to the situation in some real projects in companies.

Glossary

AAL Ambient (or Active and) Assisted Living: technologies that enable older people to live at home longer independently. May also be referred to as technology for aging in place.

ADL Activities of Daily Living: for example eating, bathing, housework, reading the newspaper.

ageism bias based on age, especially against older people.

Android an open source operating system used in smartphones and tablets.

app a small program, often for smartphones and tablets.

Bluetooth a standard for transferring data wirelessly, e.g. for sensors.

carer someone who takes care of another person, here either a professional or family member helping an older person. May also be called a caregiver.

CMMI Capability Maturity Model Integration, model used to appraise software processes.

Fachhochschule University of Applied Sciences - cannot grant doctorates.

iteration in software development, a repetition of analysis, design, development and test.

LCD Liquid Crystal Display: a relatively modern flat display, e.g. for computers or televisions.

LED Light Emitting Diode: type of low-energy light, used for example to show when a device is turned on.

monitoring system used here to designate a type of telecare system that automatically monitors people, e.g. for fall detection or sensing activity.

persona a description of a fictitious person, protraying their attributes, abilities and preferences, that is used to keep the focus on the user throughout the (user-centered) software development process.

presbyopia age-related vision problem that makes it hard to focus on objects that are close by, so that many older people need reading glasses or multi-focal lenses.

prototype an incomplete system version, used for demonstration or evaluation. Usually has fewer functions or details than the final version, so that it takes less effort to produce and change.

rollator a device people with balance or strength problems can use for additional support while walking. Also called a frame or walker.

Skype a program that provides video calls and messages.

smart home refers to home automation, for example shutting the shades when the sun shines on them in hot weather. Can be used to increase living quality, energy efficiency and/or security.

smartphone refers to a mobile telephone with a touch screen on which "apps" (interactive applications) can be installed. Can use different operating systems, e.g. iOS (Apple), Android or Microsoft Windows 10.

tablet refers to a touch screen device, often cheaper and smaller than most laptops. Operation similar to a smartphone.

telecare systems that support caring for a person from a distance, e.g. fall sensors, emergency assistance button.

telehealth systems that support health care from a distance, e.g. for blood pressure monitoring.

thick description in ethnographic research, a detailed description of the actions and context. It allows people not directly involved to understand and evaluate the data.

UML Unified Modeling Language: a graphical notation used by software developers to record information about the system, including the structure and behavior.

User-eXperience or UX, the overall experience of the user with a system, including both behavior and emotions, before, during and after the use.

XML eXtensible Markup Language: document format with structuring tags directly in the text, so it is readable by machines, but also humans.

Acronyms

AAL Programme Active and Assisted Living Programme of EU (funding), formerly Ambient Assisted Living Joint Programme.

AT Assistive Technologies.

COPD Chronic Obstructive Pulmonary Disease (a type of lung disease).

CSCW Computer-Supported Cooperative Work.

EU European Union.

HCI Human-Computer Interaction.

ICT Information and Communications Technology.

IEC International Electrotechnical Commission.

ISO International Organization for Standardization.

IT Information Technology.

PC Personal Computer.

PD Participatory Design.

RQ Research Question.

SME small or medium size enterprise.

SMS text message on a phone - Short Messaging Service.

TV television.

UCD User-Centered Design.

UK United Kingdom.

UN United Nations.

WCAG Web Content Accessibility Guidelines of the W3C.

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Work Experience

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1987 - 1989	**IBM Federal Systems Division**, Boulder, USA Software Engineer: Satellite simulation.
1989	**Tessella Support Services**, Oxford, United Kingdom Software Consultant: Scientific visualizations, e.g. for Joint European Torus.
1989 - 1993	**ABB Netzleittechnik**, Gebenstorf, Switzerland Software Engineer: User interface for electricity control system.
1993 - 1994	**Department of Information Technology, University of Technology, Sydney**, Australia. Research and lectures on Human-Computer Interaction.
1995 - 1996	**Independent Consultant**, Tübingen, Germany Courses in Windows, Word and Excel for companies.
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