NTNU
Norwegian University of
Science and Technology

A Study of ICT Acceptance Among Seniors with Fall Risk Assessment Technologies as a Case

Lars Tore Vassli

Master of Science in Informatics
Submission date: June 2016
Supervisor: Monica Divitini, IDI
Co-supervisor: Babak A. Farshchian, IDI

Norwegian University of Science and Technology
Department of Computer and Information Science

Abstract

The proportional number of elderly citizens is increasing in many parts of the world, and the need for healthcare ICT solutions that allow them to live independently in the community is equally increasing. It is important to tailor these solutions to this age group, in order to achieve a high degree of acceptance among the end users. To do this, we need to have a thorough understanding of *how* and *why* seniors use (or do not use) these technologies.

This master's thesis aimed to gather knowledge about how best to assess acceptance of an ICT system for community-dwelling seniors, and to evaluate this assessment method in a case involving a fall risk assessment system.

The first phase of the project consisted of a systematic literature review, aiming to find and present the findings from previous research relating to acceptance of health-related ICT among community-dwelling seniors. This involved analysing 11 review articles and 31 qualitative, primary research articles. The UTAUT2 acceptance model was used to structure the findings. The review found that some of the important factors for ICT acceptance among elderly include *independence, safety and security, socialization, self-management of their health, getting help using the service,* and *tailored training.* Some of the reported barriers to acceptance are *lack of privacy, poor interaction design, obtrusiveness,* and *social stigma.* These findings were then mapped to the constructs and moderating conditions in the UTAUT2 model, and a methodological tool for conducting theoretical evaluations of the acceptance of an ICT solution for elderly was created based on this mapping. The study also found that more research is needed in order to develop a specialized and operationalized acceptance model for ICT use among seniors. The mapping of the findings to UTAUT2 is a step in this direction, and suggests some improvements to this model.

Next, a set of concepts and a prototype of a front-end web solution was developed. This work was tied to a research project titled Adapt, regarding fall risk assessment for seniors. The acceptance of each of the concepts and the prototype were then theoretically evaluated using the evaluation tool created from the literature review. This demonstrated how the evaluation tool can be used in a real-world ICT project in order to assess which solution has the highest predicted acceptance. This could be a useful tool for healthcare service providers and others interested in finding the solution with highest acceptance when seniors should use a health-related ICT system.

Keywords: *Acceptance; older adults; health ICT; community-dwelling; UTAUT2; assessment; Adapt; fall risk assessment; fall prevention*

Sammendrag

Antallet eldre innbyggere øker i forhold til andre aldersgrupper i store deler av verden, og behovet for løsninger innen helse-IKT som gjør dem i stand til å bo selvstendig i samfunnet øker i tilsvarende grad. Det er viktig å tilpasse disse løsningene til denne aldersgruppen for å oppnå en høy grad av aksept hos sluttbrukerene. For å oppnå dette kreves det en grundig forståelse av *hvordan* og *hvorfor* seniorer bruker (eller ikke bruker) slike teknologier.

Denne masteroppgaven hadde som mål å innhente kunnskap om hvordan man på best mulig måte vurderer graden av aksept til et IKT-system for eldre personer som bor ”*in the community*” (ikke på institusjon/sykehus), og å evaluere denne vurderingsmetoden gjennom et prosjekt som involverer et IKT-system for vurdering av fallrisiko.

Den første fasen av prosjektet består av en systematisk litteraturanalyse av helse-relatert IKT blant seniorer ”*in the community*”. Dette involverte analyse av 11 gjennomgangsartikler og 31 kvalitative, primærforskingsartikler. Aksept-modellen UTAUT2 ble brukt til å strukturere funnene. I gjennomgangen ble det oppdaget at viktige faktorer for IKT-aksept blant eldre inkluderer blant annet *selvstendighet, sikkerhet, sosialisering, selvforvaltning av egen helse, hjelp til å bruke tjenesten,* og *tilpasset opplæring.* Noen av de rapporterte barriærene til aksept er mangel på *personvern*, dårlig *interaksjonsdesign*, at løsningen føles *påtrengende*, og *sosial stigma.* Funnene ble deretter tilordnet konstruksjonene og de modererende faktorene i UTAUT2-modellen, og på bakgrunn av dette ble det laget et metodisk verktøy for å foreta teoretisk vurdering av aksepten til en IKT-løsning for eldre. Studien fant også at det gjenstår mer forskning før det kan utvikles en spesialisert og operasjonalisert akseptmodell for IKT blant eldre. Tilordningen av funnene til UTAUT2 er et steg i denne retningen, og foreslår forbedringer til denne modellen.

Deretter ble det laget et sett med konsepter og en prototype av en front-end web-løsning. Dette arbeidet var knyttet til et forskningsprosjekt kalt Adapt, som fokuserer på vurdering av fallrisiko blant eldre. Aksepten av hvert av konseptene og prototypen ble deretter teoretisk vurdert ved hjelp av vurderingsverktøyet som ble laget ut ifra literaturanalysen. Dette demonstrer hvordan verktøyet kan brukes på et ekte IKT-prosjekt for å evaluere hvilken løsning som er estimert til å gi høyest grad av aksept. Dette vil kunne være et nyttig verktøy for tilbydere av helsetjenester og andre som ønsker å finne den best aksepterte løsningen når eldre skal bruke et helse-relatert IKT-system.

Nøkkelord: *aksept; eldre mennesker; helse-IKT; hjemmeværende; UTAUT2; vurdering; Adapt; vurdere fallrisiko; forebygge fall*

Preface

This report presents the work done as part of my Master's study in Informatics at the Norwegian University og Science and Technology during the autumn and spring semesters of 2015/2016.

I would like to thank my subject supervisor, professor Babak A. Farshchian for valuable feedback and guidance throughout the project. I would also like to thank Thomas Vilarinho and Yngve Dahl, both research scientists at SINTEF ICT, for additional help and support.

Trondheim, 2016-05-27

Lars Tore Vassli

Contents

List of Figures

List of Tables

Part I

Introduction and methodology

1 | Introduction

1.1 Motivation

Due to radical demographic changes in the Western world, the proportional number of elderly citizens is increasing. This is primarily a result of increased life expectancy and reduced birth rates. By 2050, the number of people aged 60 or above is expected to more than double, and the number of people over 80 is expected to triple, compared to 2015 [1]. As a result of this, the number of older adults in need of healthcare services is predicted to greatly outnumber the available healthcare providers. This puts pressure on societies to come up with new ideas and solutions to improve the health and well-being of the seniors.

Studies have shown that most elderly want to live in their own home or residence of choice for as long as possible, thus maintaining their independence [2]. By enabling the elderly to stay safely in the community for a longer period of time, the society as a whole also benefits economically, as there is less need to increase capacity and workers in nursing homes and institutions. One way to accomplish this is to utilize new ICT solutions.

After a brief overview of the literature on this topic, it was found that there exist a large number of different technological aids whose purpose is to facilitate elderly people staying in the community for as long as possible, while providing safety and increased quality of life. Some ways to achieve this involves using sensor monitoring (including the use of ambient, wearable, and/or embedded sensors), smartphones, computers, or other electronic devices.

However, most of these systems require some degree of user interaction in order to serve its purpose. Depending on the system, this might include pressing buttons, touching screens, using voice commands, being in a specific location (on/in range of a sensor), or, in the case of wearable sensors, simply putting the device on every day. This might present usability challenges, seeing as the elderly population is prone to many cognitive and physical challenges that might make it difficult to use the system as it was intended. Users could also perceive the system as not being useful, and can thus end up not using it at all. There may also be numerous other reasons why such a system is not used in practice, like privacy issues, stigma, and feeling that they lack the skills or knowledge to use the system.

An example of a technological aid that many seniors would benefit from, is an ICT system for assessing the user's risk of falling, and can thus help in preventing future fall-related injuries. Fall injuries among the elderly population is a serious problem in societies all around the world [3, 4]. Studies have shown that among seniors over the age of 65 living in the community, approximately one-third of them fall every year [4, 5].

1.2 Research aim

The overall aim of the study is to gather knowledge about how best to assess acceptance of health-related ICT among seniors. In doing this, researchers, practitioners, and other stakeholders involved in the design and development of ICT solutions aimed at elderly users will be provided with information and tools that will enable them to increase the probability of creating a system with a high level of acceptance among the end users.

As shown in fig. 1.1, the research is split into three main parts: *gathering of empirical evidence*, *design*, and *evaluation*. These are described in the following subsections. Note that fig. 1.1 shows the overall idea behind the thesis, while the research method used in each part of the study is described in detail in chapter 2.

1.2.1 Empirical evidence phase

The goal for the first phase was to conduct a systematic literature review to gather existing empirical evidence relating to elderly people living in the community and their acceptance of health-related ICT.

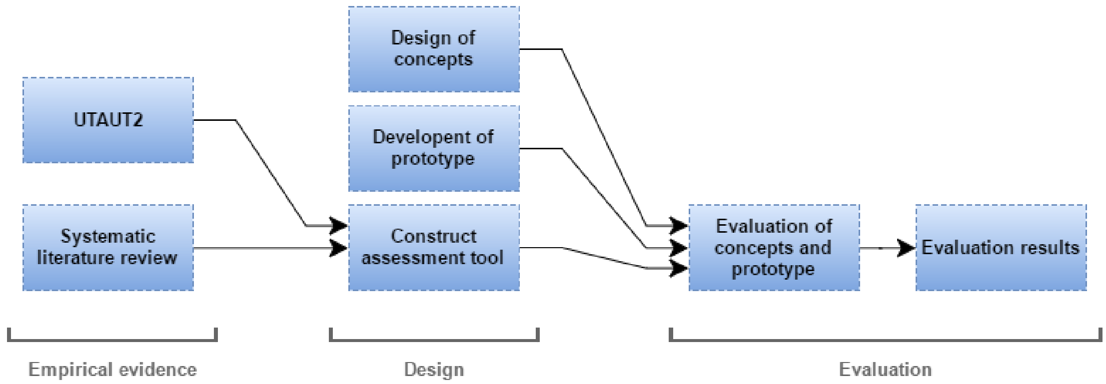

Figure 1.1: The phases and steps in the research process.

The findings from this review were then mapped to the UTAUT2 model[6], which is a technology acceptance model aiming to explain user intentions to use an information system and subsequent usage behaviour in a consumer context.

1.2.2 Design phase

Based on this mapping of the literature review findings from the previous phase, an evaluation tool was developed. This is a tool in the form of a checklist that can be used to calculate an acceptance level for an assistive technology, and allow its user to reflect on how the technology will be used by senior users.

The phase also involved the design of a set of *concepts* based on the literature, and the development of a *prototype* front-end interface of an ICT system, both of which are connected to a research project (Adapt, described in section 1.5 below).

1.2.3 Evaluation phase

Here, the evaluation tool (described above) was used on the concepts and the prototype from the design phase.

This is useful, as it tests the evaluation tool on a relevant, real-life health ICT project, and illustrates how it is used.

1.3 Research questions

The main research question for the study is as follows:

RQ1: *How can we best assess the acceptance of an ICT system concerning community-dwelling seniors?*

This research question is split into two sub-questions, used in the *empirical evidence* phase and the *design/evaluation* phases respectively:

RQ1.1: *What empirical evidence from qualitative research do we have regarding the acceptance of health-related ICT among elderly people living in the community?*

RQ1.2: *How should an ICT system for monitoring and assessing fall risk be designed to achieve the highest possible acceptance among community-dwelling seniors?*

Fall risk assessment technology is used here as a case in order to allow the demonstration of the results in a practical case. However, most of the results from this thesis can be equally applied to other cases of assistive technologies for seniors.

1.4 Report outline

The report is organized in the following parts and chapters:

Part I: Introduction and methodology

Chapter 1 is this chapter. It presents the motivations, research aim, and the research questions for the study.

Chapter 2 presents the research methodology used in the different phases of the project.

Part II: Related research in acceptance of ICT among elderly

Chapter 3 describes how the systematic literature review was conducted.

Chapter 4 lists the findings from the systematic literature review.

Chapter 5 looks at the findings from the systematic literature review and maps them to the UTAUT2 model.

Part III: Design and evaluation

Chapter 6 presents the various concepts for the Adapt service that was created.

Chapter 7 describes the prototype implementation of the Adapt front-end web app.

Chapter 8 presents a theoretical evaluation of the concepts and the prototype presented in the previous chapters, based on the findings from the systematic literature review.

Part IV: Conclusion

Chapter 9 contains the discussion of the work that has been done, limitations, suggestions for further work, and a conclusion.

1.5 The Adapt project

Adapt[7] is the name of a research project funded by the Norwegian Research Council. It is led by the Department of Movement Science[1] at Norwegian University of Science and Technology (NTNU), and Stiftelsen for industriell og teknisk forskning (SINTEF) is one of the partners in this project. Its main goal is to

[1] `http://www.ntnu.edu/inm/movement-sciences`

develop and evaluate technology that can be used to assess the fall risk among seniors. By using sensor monitoring (typically wearable sensors on the user's body), movement data from the user is recorded for analysis, which can be used to calculate the user's mobility index. This index reveals how prone the user is to falling, and a low mobility index means that the user has a high risk of having a fall-related injury. If this is the case, the user should be encouraged to perform physical exercises that will increase his/her mobility index. This feedback should be sent to the user with a wording or illustration that is perceived as motivating and positive.

2 | Research Methodology

This chapter describes the research methodology that was used in the various phases of the project.

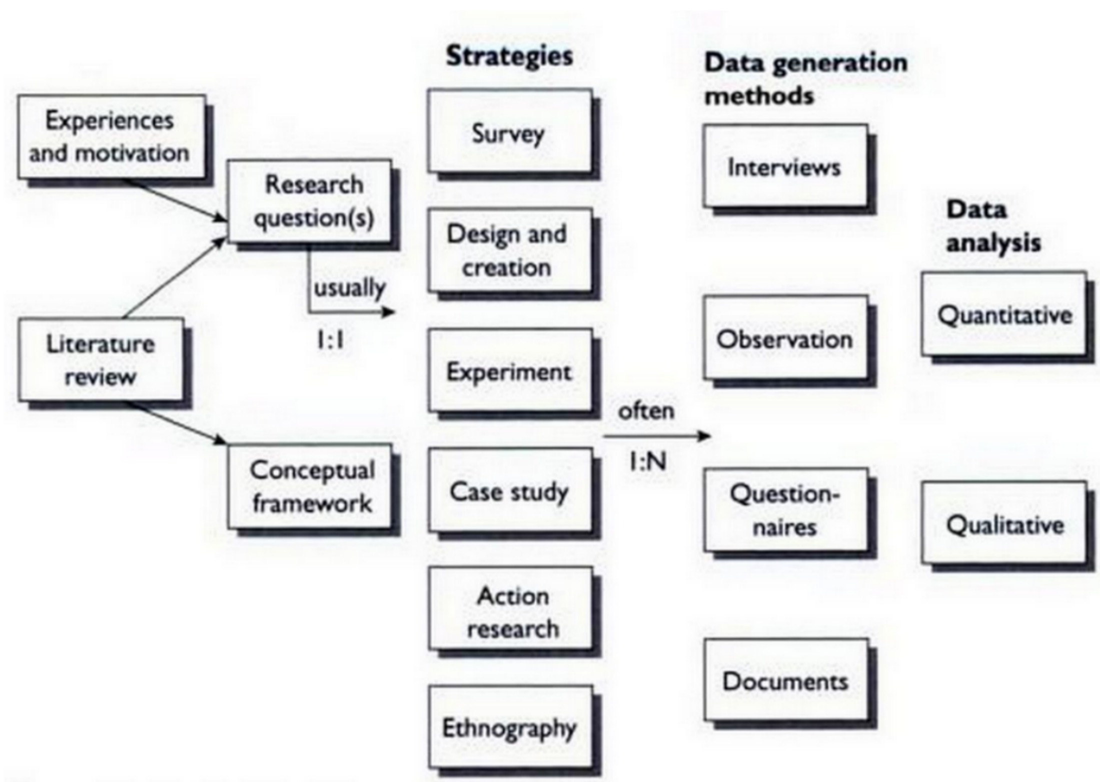

Figure 2.1: Model of the research process [8]

The project follows the research process defined by Briony J. Oates [8], shown in fig. 2.1. Below is a brief overview of the different components of the model:

- **Experiences and motivation:** Personal experiences and motivations that lay the foundation for wanting to conduct the research.
- **Literature review:** A review of the existing research can be conducted before defining research questions, to better understand what has already been done in the given field.
- **Research question(s):** A question or set of question stating what the research aims to answer, typically summarizing what new knowledge it will provide.
- **Conceptual framework:** An analytical tool created based on findings from a literature review.
- **Strategies:** The overall approach for answering the research question(s).
- **Data generation methods:** How empirical data for the research is generated.
- **Data analysis:** The generated data is either analysed using *quantitative* or *qualitative* data analysis.

As explained in the previous chapter, the project is split into three phases: a systematic literature review, followed by a *design* phase tied to the Adapt project, and an evaluation phase.

The following sections describes the research process for the literature review, and the design/evaluation phases respectively.

2.1 Systematic literature review

The review method used in the systematic literature review is described in detail in *Appendix A*, and also (slightly summarized) in *section 3.2* in *chapter 3*. This section will provide a brief summary of the review method used during the review process.

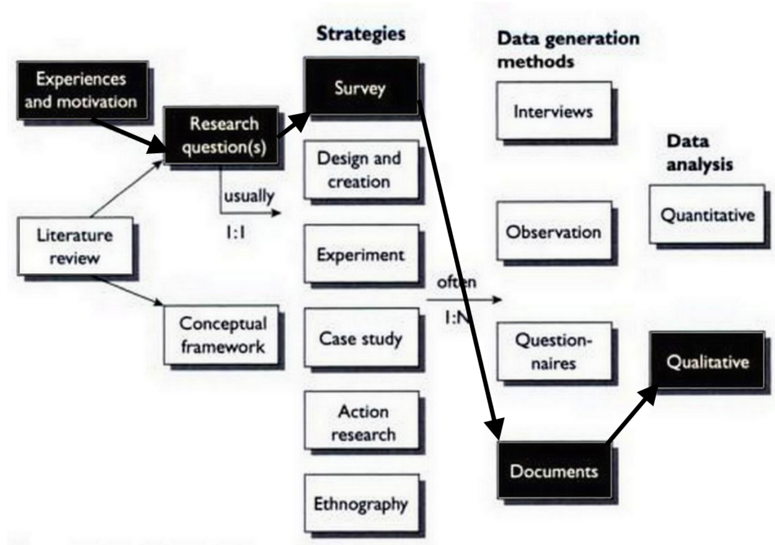

Figure 2.2: Iteration 1: the literature review

Figure 2.2 presents the first iteration of the research process - the systematic literature review - illustrated using the model by Oates [8]. The black boxes indicate which components of the model were used, and the thick arrows show the path between them.

The review is seen as a *survey* of the existing research, and the data is gathered from *documents*. The findings are analysed qualitatively, since only qualitative research is included (reasoning for this is presented in *subsection 3.1.3: The need for this review*).

To find relevant articles for the review, the Scopus [9] and PubMed [10] databases were searched using a search query presented in table 3.1.

The review started by looking at secondary sources - previous literature reviews - by limiting the search result to this type of publication. The articles from the different databases were merged and duplicates were removed. The articles were then screened based on the inclusion and exclusion criteria, shown in table 3.2. This left n=11 review articles that were analysed, coded, and compared to this review.

As for the primary sources, the process was more or less the same. The first phase was merging and duplicate removal, followed by the screening phase. Here, both authors did a screening process by comparing the abstracts of the articles with the research question and inclusion/exclusion criteria, without communicating with each other. When both were done, the results were compared, and for those of the articles that the authors had reached different decisions about, the review was repeated, until a decision was made.

It was decided during the screening phase to only include journal articles, and the decision to include only qualitative research was made during the coding process. Qualitative research tends to focus on answering questions about *why* and *how* certain solutions works or not, compared to quantitative research, which primarily aims to answer *what* works. This review wanted to answer the deeper questions, which can be found in qualitative research.

For analysing the results, a mixed method approach was chosen. Firstly, an *a priori* coding scheme was used, where predefined categories are used when starting to analyse the content in a top-down coding process. The methodology of the research was one of the factors being coded here.

Next, *bottom-up* coding was used, which is based on the grounded theory approach [11]. The themes revealed in the bottom-up coding make up the main categories presented in *section 4.2: Findings from primary sources*, and the findings were qualitatively analysed and presented here.

2.2 Design and evaluation

The *design* phase was focused around the Adapt project (described in *section 1.5: The Adapt project*). This thesis contributed by aiming to find out how the system should be developed to achieve the highest possible level of acceptance from the end users.

A prototype version of the user interface for the elderly users of Adapt was created, both as a mockup sketch and a full HTML implementation. Also, various potential concepts for how the system could be implemented (both the Graphical user interface (GUI) and sensor monitoring aspects) were formulated.

The systematic literature review laid the foundation for the rest of the project, by providing relevant empirical evidence. This is illustrated by fig. 2.3 and fig. 2.4, which illustrates the two research iterations done in the design and evaluation

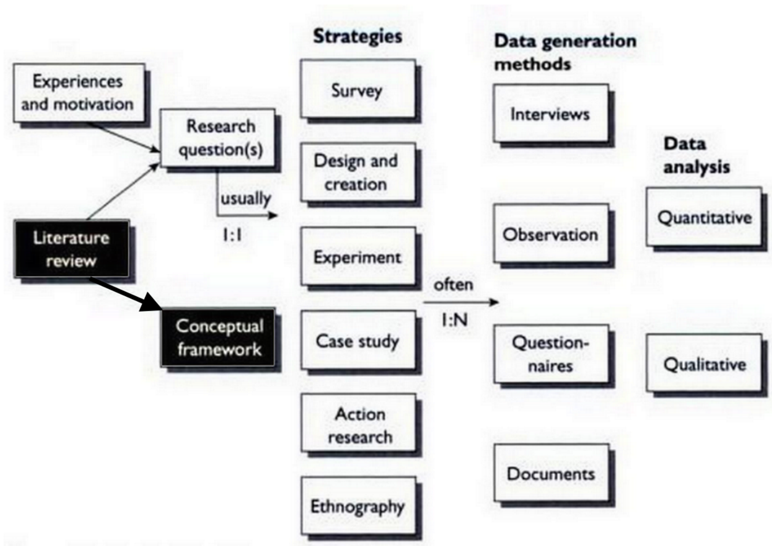

Figure 2.3: Iteration 2: creation of the evaluation tool

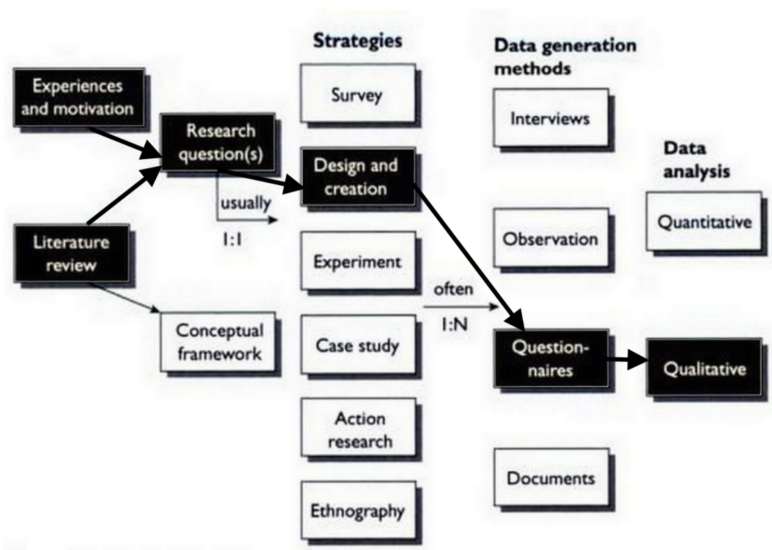

Figure 2.4: Iteration 3: creation and evaluation of concepts+prototype

phases of the project.

Figure 2.3 illustrates the generation of a tool for performing theoretical evaluations of ICT concepts. During this iteration, the empirical data from the literature study was structured using the UTAUT2 model into a conceptual model of ICT acceptance among seniors.

Figure 2.4 shows the steps in the iteration concerning the generation and evaluation of various concepts and a prototype for the Adapt system. Here, the *design and creation* strategy is used. Data is generated by analysing each concept using the evaluation tool from the last iteration. This evaluation tool consists of a questionnaire-based checklist that is filled out for each concept, thus making the data generation method a *questionnaire*. Lastly, the data is analysed *qualitatively*.

Part II

Related research in acceptance of ICT among elderly

3 Conducting the systematic literature review

This chapter describes the systematic literature review that was conducted. In fig. 1.1, this phase is marked as ”Systematic literature review”, showing how it corresponds with the other phases that make up this thesis.

It will present a summary of *why* and *how* it was conducted, the findings from the study, and an analysis and conclusion of these findings.

The article was co-written with Babak A. Farshchian, who was the subject supervisor for this thesis. The article was submitted for review by the International Journal of Human-Computer Interaction on the First of May, 2016.

For the full review article, see *Appendix A*, which presents the version that was submitted to the journal.

3.1 Background

3.1.1 Motivation

The main motivations for this thesis are discussed in *section 1.1: Motivation*.

It was decided to conduct a systematic literature review because this would provide an in-depth understanding of the existing research on this topic. This knowledge could then be used in the design phase of the project.

Also, if the article were to be published, it would help other academics and practitioners by providing an overview of the most recent research in this field, and to summarize some guidelines for achieving acceptance among older adults.

To do this, the review will focus on answering the questions of *how* and *why* ICT is accepted, not just *what*.

3.1.2 Research question

The research question for the literature review is as follows:

What empirical evidence from qualitative research do we have regarding the acceptance of health-related ICT among elderly people living in the community?

3.1.3 The need for this review

There is constant development and advancements in the field of ICT, including technologies designed specifically for older adults. However, doing research to get feedback about these technologies from the elderly is financially costly and requires extensive planning and effort. It is therefore of great value to be able to reuse the research results that has already been found in this field, and can also apply to newer technologies.

There are already a substantial number of literature reviews published regarding older adults and acceptance of ICT. It was therefore decided to start by doing a review of existing literature reviews, and see what they have found and, equally important: what they did not focus on and/or what weaknesses they have in the way they were conducted. These existing reviews will hereinafter be referred to as *secondary sources*, as opposed to *primary sources*. While the latter collects first-hand knowledge from *'the field'*, e.g. through interviews or questionnaires, a secondary source presents the findings from multiple primary sources on a specific topic, and looks for patterns and other interesting connections between these sources.

After the initial review of secondary sources, it was revealed that most of these existing literature reviews were impact-oriented, meaning that they focus on what works and what does not work in a given scenario. Few have a more qualitative approach by looking at *why* and *how* certain solutions work or not. This is one thing this review will try to find answers to.

Another element that is lacking in previous reviews, is the attempt to build *theory*. Theories can be a valuable tool for practitioners for design and evaluation purposes. In this review, the aim is to map the findings to the existing UTAUT2 model[6], which is an extension of the UTAUT model developed by Viswanath Venkatesh and others [12]. The original UTAUT model focuses on acceptance and use of technology in an organizational context, while UTAUT2 extends this model to make it fit a consumer context. However, neither UTAUT2 nor other generic acceptance models provide guidelines for specific aspects of ICT acceptance among elderly. The goal is therefore to try to validate the UTAUT2 model in the field of ICT acceptance among elderly living independently in the community.

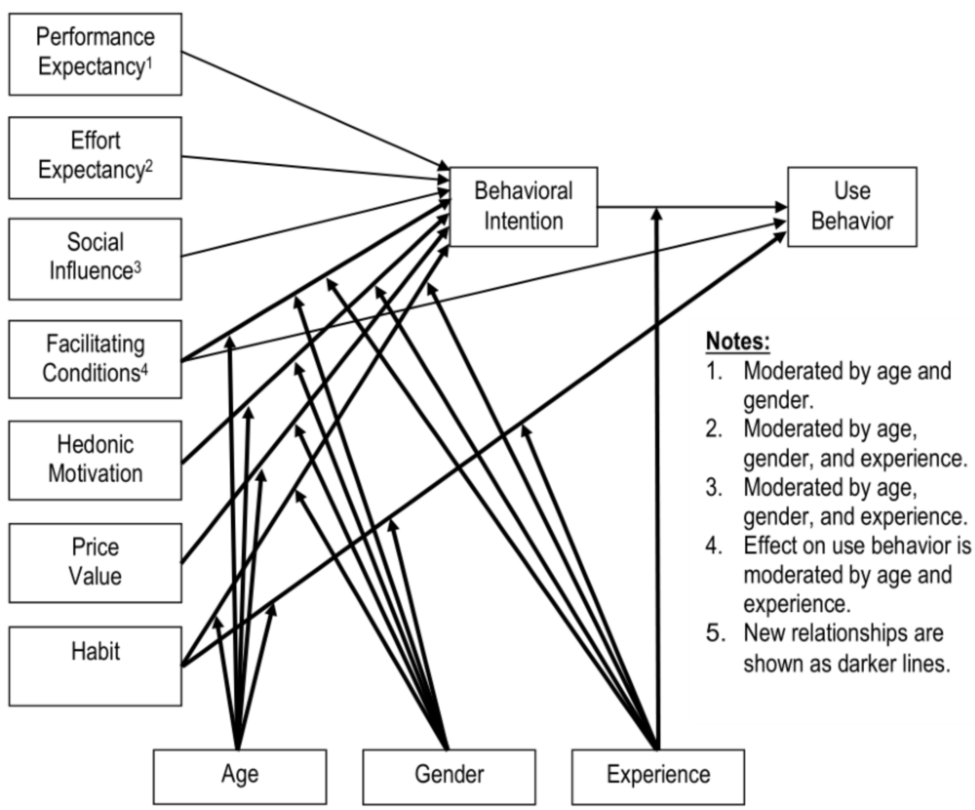

Figure 3.1: The UTAUT2 model

3.2 Review method

3.2.1 Data sources and search strategy

3.2.1.1 Search query

The first thing that was done after defining the research question, was to determine the search query to use when searching the databases. The query was build using the AND and OR logical operators, dividing the query into multiple concepts separated by the AND operator, while the OR operator separated each alternate or similar search term within these concept categories. In addition, the NOT operator was used on the *excluded* category, which lists terms that matches the exclusion criteria.

A thesaurus [13] was used to help find synonyms to the various search terms. Different combinations of search terms were tried during multiple iterations, before the final search query was chosen. A log of these different search queries can be seen in the background material for the review that is provided online [14]. The final search query is presented in table 3.1.

AND

OR

INTERVENTION	**PURPOSE**	**USER**	**TECHNOLOGY**	**EXCLUSION**
Acceptance	Healthcare	Elderly	ICT	Hospital
Willingness	Health care	Seniors	Information technology	Nursing home
Usability	Health-related	Senior citizens	Smartphone	Institution
Perception	Well-being	Aged population	Wearable	
Perceptive behaviour	Independence	Aging population	Mobile	
Attitude	Autonomy	Old people	Phone	
Ease of use	Comfort	Old adults	Sensor	
Easy to use	Happiness	Older adults	Telemedicine	
Approval	Welfare	Old age	Pervasive	
Concern	Aging in place	Elders	Ubiquitous	
Satisfaction	Geriatrics		Wireless sensor network	
Human-computer interaction	Gerontology		WSN	
HCI			Smartwatch	
Acceptability			Activity tracker	
User experience			Fitness wristband	
User-experience			Activity monitoring device	
Perceived value			Health information technology	
Human factors			Health IT	
Barriers			Ambient Assisted Living	
			Smart home	
			E-health	

Table 3.1: Search query

3.2.1.2 Sources

Two databases were chosen to conduct the search on: Scopus [9] and PubMed [10].

Scopus was a natural choice for conducting the search, since it is "*the largest* *abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings.*" [15]. This is a very large database (over 60 million records in total [16]), and includes most of the major journals in the field of information systems and computer science, making it the perfect place to start the search process.

"*PubMed comprises more than 26 million citations for biomedical literature from MEDLINE, life science journals, and online books*" [10]. Contrary to Scopus, PubMed is specialising in medical and healthcare publications, and might include articles from these fields that is not covered in Scopus.

The Scopus search provided n=745 articles, while PubMed gave n=107. This includes both primary and secondary sources. Figure 3.2 illustrates the following process of removing duplicates, screening, and coding for the primary and secondary sources respectively. This is described in further detail in the coming sections.

3.2.2 Secondary sources

3.2.2.1 Screening and inclusion/exclusion criteria

After limiting the Scopus and PubMed search results to show only literature reviews, using the filter feature of both search engines, there were n=77 articles from Scopus and n=23 from PubMed. After merging the results and removing duplicates using the EndNote software [17], there were a total of n=87 literature reviews. These can be found in the Research Information Systems (RIS) file made available among other background material for the review [14].

Next, the reviews were screened based on the inclusion and exclusion criteria defined for the secondary sources, shown in table 3.2. This reduced the number of relevant review articles to 11. These are listed in table 3.3.

3.2.2.2 Coding

The differences between this review and the previous literature reviews are presented in table 3.4. It presents multiple conditions (in each column) and whether the review article (in a row) matches this condition (green), does not (red), or

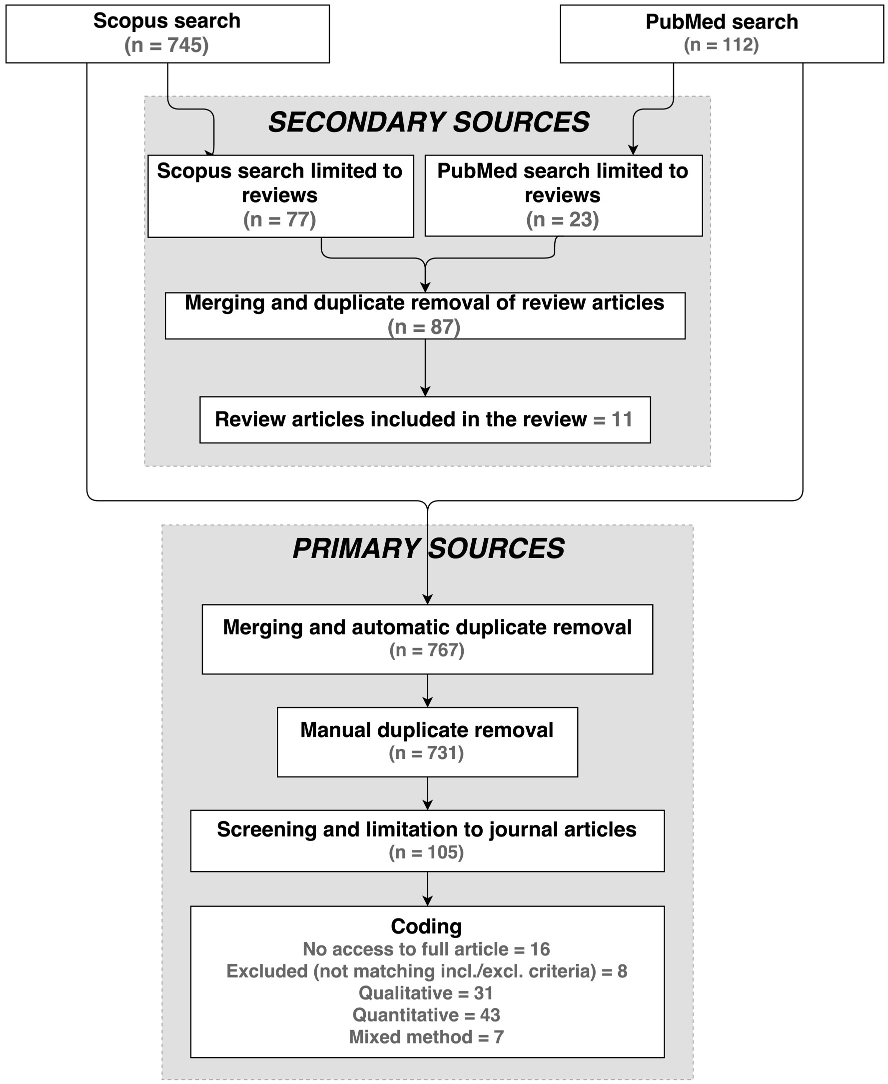

Figure 3.2: Flow chart of the search strategy

does to some degree (yellow). The conditions used in the table are described below:

- **Focus on elderly:** whether or not the review focuses on the elderly population.
- **Focus on ICT:** whether or not the review focuses on an ICT-related inter-

INCLUSION CRITERIA	EXCLUSION CRITERIA
It is a literature review, presenting the findings from multiple primary sources.	The review is addressing elderly people not living in the community (e.g. nursing home, institution, hospital).
The review investigates the acceptance of health and well-being ICT.	It reviewed sources that are not research papers (e.g. commentary, editorial, workshop summary, expert opinion, conference proceeding).
The review focuses on elderly people.	Duplicate (not detected by bibliography software).
The review is published in English.	Unable to gain access to free version of full article.
The findings in the review must be based on empirical evidence.	

Table 3.2: Inclusion/exclusion criteria for the secondary sources.

vention.

- **Focus on acceptance of ICT:** whether or not the review focuses on the user acceptance of a specific ICT intervention.
- **Reviews data collected from elderly people:** whether or not the papers reviewed collected data from elderly people. A ”no” here could for instance mean that the review only looked at papers about the technological aspects of an ICT intervention, without collecting data from the potential end users, or that the paper looked at the opinion of professional caregivers.
- **Looks at the general use of ICT in healthcare:** whether or not the review investigates the use of ICT in healthcare in general, not a specific intervention. For instance, a review about ICT interventions specifically related to fall detection has a too narrow scope.
- **Looks at ICT in general:** whether or not the review investigates all kinds of ICTs, not a specific type of ICT. For instance, a review limited to monitoring technology has a too narrow scope.
- **Systematic literature review:** whether or not the literature review was done systematically. A ”no” here could still mean that it is a thorough literature review, but it might for instance not include a well-documented search process.

Title	Ref.	Authors	Year
A Review of Monitoring Technology for Use With Older Adults	[18]	Wagner et al.	2012
Acceptance and use of health information technology by community-dwelling elders	[19]	Fischer et al.	2014
Ambient Assisted Living healthcare frameworks, platforms, standards, and quality attributes	[20]	Memon et al.	2014
Approaches to understanding the impact of technologies for aging in place: A mini-review	[21]	Connelly et al.	2014
Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved	[22]	Jimison et al.	2008
Does smart home technology prevent falls in community-dwelling older adults: a literature review	[23]	Pietrzak et al.	2014
eHealth literacy and older adults: A review of literature	[24]	Rios	2013
Enabling patient-centered care through health information technology	[25]	Finkelstein et al.	2012
Fall detection devices and their use with older adults: A systematic review	[26]	Chaudhuri et al.	2014
Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review	[27]	Hawley-Hague et al.	2014
Review of ICT-based services for identified unmet needs in people with dementia	[28]	Lauriks et al.	2007

Table 3.3: List of included secondary sources

The findings in table 3.4 shows that our review has a broader scope than the previous reviews, in addition to presenting more recent research. The review by Jimison et al.[22] is closest to ours, but it differs in that it investigates interactive consumer health IT, while this review encompasses all types of health-related ICT. This shows the need to conduct the review of the primary sources.

In addition to the coding presented in table 3.4, additional coding was done, which can be seen in the background material [14]. This includes:

- General notes
- Databases searched
- Search strings

- Inclusion criteria
- Exclusion criteria
- Time period covered
- Number of papers before screening
- Number of papers after screening
- Research question(s)
- Summary of findings
- Recommendations for further research / Future work
- Themes / topics covered

Title	**Focus on elderly**	**Focus on ICT**	**Focus on acceptance of ICT**	**Reviews data collected from elderly people**	**Looks at the general use of ICT in healthcare (Not at a specific intervention)**	**Looks at ICT in general (Not a specific type of ICT)**	**Systematic literature review**
A Review of Monitoring Technology for Use With Older Adults	**Yes**	**Yes**	**Partially**	**No**	**No** (fall detection and health monitoring)	**No** (monitoring tech)	**No**
Acceptance and use of health information technology by community-dwelling elders	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**
Ambient Assisted Living healthcare frameworks, platforms, standards, and quality attributes	**Yes**	**Yes**	**Partially**	**Yes**	**Yes**	**No** (AAL)	**No**
Approaches to understanding the impact of technologies for aging in place: A mini-review	**Yes**	**Yes**	**Yes**	**No**	**Yes**	**Yes**	**No**
Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Somewhat** (interactive consumer health IT)	**Yes**
Does smart home technology prevent falls in community-dwelling older adults: a literature review	**Yes**	**Yes**	**Partially**	**Yes**	**No** (fall detection and prevention)	**No** (smart home and monitoring tech	**No**
eHealth literacy and older adults: A review of literature	**Yes**	**Yes**	**Partially**	**Yes**	**No** (eHealth literacy)	**Yes**	**No**
Enabling patient-centered care through health information technology	**Yes**	**Yes**	**Partially**	**Yes**	**Somewhat** (patient-centered care)	**Yes**	**Yes**
Fall detection devices and their use with older adults: A systematic review	**Yes**	**Yes**	**Yes**	**Yes**	**No** (fall detection)	**No** (fall detection devices)	**Yes**
Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review	**Yes**	**Yes**	**Yes**	**Yes**	**No** (falls prevention, detection and monitoring)	**Yes**	**Yes**
Review of ICT-based services for identified unmet needs in people with dementia	**Yes**	**Yes**	**Yes**	**Yes**	**No** (dementia)	**Yes**	**No**

Table 3.4: Overview of relevance of included secondary sources

3.2.3 Primary sources

3.2.3.1 Merging and duplicate removal

EndNote [17] was used to merge the results from Scopus and PubMed, and automatically remove duplicates. This left n=767 papers. Next, a manual duplicate removal process was done, to find duplicate entries not detected by the software. This reduced the number to n=731. This selection of papers can be seen in the RIS file for the primary sources [14].

3.2.3.2 Screening

The screening process was done in parallel by both authors (this author and the subject supervisor). Both screened the papers without communicating with each other, and the results were compared and discussed when both were done.

The screening process consisted of reading the abstracts, and comparing this to the research question and the inclusion/exclusion criteria (see table 3.5). The article was then marked as either relevant or irrelevant to our review.

INCLUSION CRITERIA	**EXCLUSION CRITERIA**
It is a research paper, reporting on a specific study of using ICT.	The research is addressing elderly people not living in the community (e.g. nursing home, institution, hospital).
The research investigates the acceptance of health and well-being ICT.	It is not a research paper (e.g. commentary, editorial, workshop summary, expert opinion, conference proceeding).
The research focuses on elderly people and data relevant for acceptance is collected from elderly people.	The research is on acceptance but is not based on empirical data collected from elderly.
The research is published in English.	Duplicate (not detected by bibliography software).
The findings in the research must be based on empirical evidence.	Unable to gain access to free version of full article.
The research is qualitative.	
The research is published as a journal article.	

Table 3.5: Inclusion/exclusion criteria for the primary sources.

Papers that both authors had marked as relevant were immediately accepted into the coding phase, and those that both agreed were irrelevant were discarded. When a paper was marked as relevant by one author and irrelevant by another, the review was repeated until both authors agreed on whether or not to include it.

During this phase of the study, it was decided to limit the scope of the study to include only journal articles, and exclude all other types of publications (conference proceedings, serials, books). This was done because journal articles typically have high credibility (more so than e.g. conference proceedings), and this helped reduce the number of articles to a feasible level.

After the screening phase, the number of papers were reduced to n=105.

3.2.3.3 Coding

The coding phase consisted of reading the whole articles, analysing the content and code the article in a number of categories.

First of all, the full version of the articles needed to be fetched, not just the abstracts. Most were available online by accessing the journal's website while using either the NTNU or SINTEF network. However, n=16 of the articles were not available for free access online, even through the NTNU/SINTEF network. If the article was found on ResearchGate [29], the authors were contacted through the website and asked for access to the full article, but none responded.

Upon reading the articles, n=8 papers were excluded, as they did not match the inclusion/exclusion criteria. These were articles where the abstract was not specific enough to tell if it was relevant to the review, and were thus not excluded in the screening phase.

The articles were top-down coded for the categories listed below. A spreadsheet presenting this coding is available in the background material [14].

- **Methodology:** Whether the article uses qualitative, quantitative or mixed method data analysis.
- **Type of ICT:** What type of ICT the study investigates (e.g. telehealth, sensor monitoring, or Internet use).

- **Usage setting:** The setting for the usage that is being studied, e.g. the user's home.
- **Condition:** Whether the participants or user group being studied are healthy, or suffers from an illness. May contain multiple values.
- **Number of participants:** The total number of people participating in the study.
- **Lowest age of participants:** The age of the youngest participant in the study. If this is not specified in the article, this value presents the minimum age limit for entering the study.
- **Highest age of participants:** The age of the oldest participant in the study. If this is not specified in the article, this value presents the maximum age limit for entering the study.
- **Mean age of participants:** The mean (or average) age of the participants in the study.
- **Standard deviation of participant age:** The standard deviation of the age of the participants, which represents the dispersion of the age values.
- **Main focus of article:** What the main theme of the study is, e.g. technology adoption, usability, or privacy. May contain multiple values.
- **Theoretical framework used:** What (if any) theoretical framework was used when conducting the study.
- **Research strategy:** What research strategy was used to conduct the study.
- **Data generation methods:** What data generation method was used to collect data for the study. May contain multiple values.
- **Geographic area:** In which geographical area of the world the research was carried out.
- **Notes:** General remarks about the study.

The coding revealed that n=31 articles were using qualitative data analysis, n=43 used quantitative, and n=7 used a mixed method, combining qualitative and quantitative. Only the qualitative studies were analysed further, as per the inclusion criteria. The other methodologies were not excluded in the initial screening, and were coded for all categories in the top-down coding, even though this was not part of the literature review. However, it is interesting to see how the different methodologies compare to each other, and this might be used in future work.

For the remaining n=31 articles (listed in table 3.6), a bottom-up coding process was conducted, following the grounded theory methodology. The articles were analysed qualitatively for emerging categories using an inductive approach. These categories were then split into two main groups: barriers and facilitating factors for ICT acceptance. These categories are presented in *section 4.2: Findings from primary sources*. The spreadsheet that was used during this bottom-up coding is not available online, but was attached as part of a zip file attachment upon submission of this master's thesis.

Title	**Ref.**	**Authors**	**Year**
Acceptance of Swedish e-health services	[30]	Jung et al.	2011
Advocacy of home telehealth care among consumers with chronic conditions	[31]	Lu et al.	2014
An ethnographical study of the accessibility barriers in the everyday interactions of older people with the web	[32]	Sayago et al.	2011
An extended view on benefits and barriers of ambient assisted living solutions	[33]	Jaschinski et al.	2015
Assessing older adults' perceptions of sensor data and designing visual displays for ambient environments	[34]	Reeder et al.	2014
Attitudes Toward Information and Communication Technology (ICT) in Residential Aged Care in Western Australia	[35]	Loh et al.	2009
Bridging the digital divide in older adults: A study from an initiative to inform older adults about new technologies	[36]	Wu et al.	2015
Defining the user requirements for wearable and optical fall prediction and fall detection devices for home use	[37]	Govercin et al.	2010
Diabetes management assisted by telemedicine: Patient perspectives	[38]	Trief et al.	2008
Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare	[39]	Steele et al.	2009

Title	**Ref.**	**Authors**	**Year**
Exploring an informed decision-making framework using in-home sensors: Older adults' perceptions	[40]	Chung et al.	2014
Exploring barriers to participation and adoption of telehealth and telecare within the Whole System Demonstrator trial: A qualitative study	[41]	Sanders et al.	2012
Findings from a participatory evaluation of a smart home application for older adults	[42]	Demiris et al.	2008
Impact of monitoring technology in assisted living: Outcome pilot	[43]	Alwan et al.	2006
Implementing technology-based embedded assessment in the home and community life of individuals aging with disabilities: A participatory research and development study	[44]	Chen et al.	2014
Indoor and outdoor social alarms: understanding users' perspectives	[45]	Sjolinder et al.	2014
Keeping silver surfers on the crest of a wave - Older people's ICT learning and support needs	[46]	Damodaran et al.	2013
Making sense of mobile- and web-based wellness information technology: cross-generational study	[47]	Kutz et al.	2013
Meeting seniors' information needs: Using computer technology	[48]	Campbell	2008
Older adults are mobile too! Identifying the barriers and facilitators to older adults' use of mHealth for pain management	[49]	Parker et al.	2013
Older adults' acceptance of a community-based telehealth wellness system	[50]	Demiris et al.	2013
Older adults' attitudes towards and perceptions of ”smart home” technologies: a pilot study	[51]	Demiris et al.	2004
Older adults' perceptions of usefulness of personal health records	[52]	Price et al.	2013
Older adults' privacy considerations for vision based recognition methods of eldercare applications	[53]	Demiris et al.	2009
Passive sensor technology interface to assess elder activity in independent living	[54]	Alexander et al.	2011
Privacy and senior willingness to adopt smart home information technology in residential care facilities	[55]	Courtney	2008
Senior residents' perceived need of and preferences for ”smart home” sensor technologies	[56]	Demiris et al.	2008

Title	Ref.	Authors	Year
Use of information and communication technology to provide health information: What do older migrants know, and what do they need to know?	[57]	Goodall et al.	2010
What matters to older people with assisted living needs? A phenomenological analysis of the use and non-use of telehealth and telecare	[58]	Greenhalgh et al.	2013
Willing but Unwilling: Attitudinal barriers to adoption of home-based health information technology among older adults	[59]	Young et al.	2014
You get reminded you're a sick person: Personal data tracking and patients with multiple chronic conditions	[60]	Ancker et al.	2015

Table 3.6: List of included primary sources

3.3 Publishing

On 1 May 2016, the article was submitted to the International Journal of Human-Computer Interaction (IJHCI), for a special issue on Mobile Human-Computer Interaction (HCI) [61]. This journal was chosen mainly because the article fits into the topics specified for this special issue.

The IJHCI Editorial Office informed in an e-mail that the review process will take 12-16 weeks. The decision about whether or not the article is accepted for publication, in addition to comments and recommendations, will be sent shortly thereafter. The targeted publication date for the special issue is January 2017.

A set of background material used during the review process, including the log of search queries, coding spreadsheets, and RIS files, was also made available online [14].

4 Findings from the literature review

This chapter presents the findings from the reviewed articles. This is a direct copy from the review article (see *Appendix A: Systematic literature review*). This part of the article was written primarily by the master's student, with a few alterations from the subject supervisor.

In the next chapter, Discussion of findings from the literature review, the findings listed here are discussed and an evaluation tool is presented.

4.1 Findings from secondary sources

The review studies have identified and discussed several barriers for technology acceptance among community-dwelling elderly, including issues with privacy [19, 20, 23], usability/ease of use ([18, 20, 22, 23, 25, 27], reliability [20, 27], data presentation accuracy [20], cost of technology ownership [20, 25], security [20], obtrusiveness [18, 26], social stigma [18], familiarity with technology [19], willingness to ask for help [19], trust in the technology [19], technology design challenges [19], access [25], lack of training [25], and low computer literacy [24, 25].

Important motivating factors for the use of technology include increased independence [27], safety [27], control [27], satisfaction [25], usefulness [25], efficiency [25], and convenience [22].

The importance of technical support and supervision is emphasized by [20, 23]. At least one review suggests that the user interface needs to be tailored to and tested by the elderly users [23]. Informational websites need to be better attuned to users with dementia, and should offer personalized information [28].

Systems that are considered intrusive or causing infringement on privacy might still be accepted by older adults if their health needs are great enough, according to [23].

Many older adults consider monitoring technology suitable for ”others” or ”someone else who may need it”, indicating that they have a different perception of their own health needs compared to their caregivers and family members [18].

Low computer literacy is common among older adults and a major barrier to technology acceptance. Having access to health information and skills to effectively find and use information to solve health problems have been found to be very important in increasing eHealth literacy [24].

In the case of fall detection, the elderly want devices that can accurately detect falls, while at the same time be as unobtrusive as possible [26].

When evaluating the acceptance of technology in an aging-in-place context, it is often not sufficient to use a single evaluation method. A wide range of evaluation techniques should be considered in order to provide the richest insights for a particular project: “*In addition to the normal measures for health outcomes, there is a need to be able to measure the users' experiences with technology: when, how and why will older adults and their caregivers use technology? Such questions require a multimodal approach to evaluation to gain deeper insights into how we may design technologies that are acceptable to people*” [21].

4.2 Findings from primary sources

In multiple studies, the elderly have expressed that they generally have a positive attitude towards ICT [31, 36, 40, 42, 43, 44, 51, 56]. However, there are many factors affecting acceptance, both in positive and negative ways. This section will take an in-depth look into the different categories that affect acceptance of health ICT the most, summarising the findings from the primary sources. We first review factors that seem to increase acceptance, and the present barriers to acceptance.

4.2.1 Factors increasing acceptance

4.2.1.1 Support for independence

In many of the studies, participants emphasized the importance of being able to live independently in their own homes for as long as possible [33, 35, 37, 41, 46, 50]. In one study, the participants got a feeling of accomplishment when they managed to carry out an activity on their own, and they all aspired to use the Internet without relying on anyone [32]. In another, the elderly envisioned a telehealth kiosk as a tool that can enhance their independence and control over their health status [50].

However, some issues regarding technologically aided independence were also reported. In one study, the authors write: "*Most respondents indicated that they associated the use of telehealth and telecare with a high degree of dependency and ill health. In the majority of cases, respondents seemed to want to distance themselves from negative connotations of old age, sickness and dependence, and instead depicted themselves as having a strong sense of personal responsibility for maintaining health, self-care and independence that could be threatened by the interventions. (...) Responses commonly indicated a strong sense of personal responsibility for health, illness and self care; and the interventions threatened to undermine such a sense of 'control' and current approaches to managing health problems*" [41]. Similarly, participants in another study reported that they did not use assistive technologies because they viewed them as something that belonged in a hospital, and felt that it brought them one step closer to institutional care or death [58].

4.2.1.2 Support for socialization

Elderly users wish to use ICT to socialize and play a more active role in society [32, 33, 36, 50]. "*A key and common motivation for all the participants to use the web was to socialize. They did not want to do activities that could isolate them*" [32]. Elderly users value the ability to communicate with family and friends through ICT [36, 46] and are positive toward using ICTs to prevent social isolation [32, 33]. Most want to learn more about ICT in order to maintain an active engagement in life and society [36]. By getting the elderly out of the house and be more socially active, they can get back a sense of life, as well as stimulate their activity level

[33].

In one study [39], participants did not perceive any ICT system to impose any changes on their social lives, and stated that their social trends would not be affected by such a system. They strongly opposed to the idea of notifying family members about lack of social activities, and similar functionality.

4.2.1.3 Increased safety and security

Studies reported a feeling of safety and security as a result of using ICTs, and/or a desire to use ICTs to prevent or detect accidents and medical emergencies [31, 33, 36, 37, 39, 45, 49, 51, 54, 56].

In two of the studies, the participants emphasized the importance of facilitating communication between the patient and healthcare providers or emergency services when they needed help [45, 49]. "*The lack of feedback reduced the feeling of safety and increased the uncertainty regarding whether someone would help.*" [45]

There was also a wish for social alarms to work outside the home, which would let the elderly go out without feeling unsafe [45, 51]. Another study found that the elderly wanted devices or sensors that can detect a range of different emergencies [51].

However, safety and security seem to exist in a context that includes more than just being monitored by the healthcare provider. Sharing health-related information with family members and healthcare providers was a requested feature [47, 52]. In cases where assistive technologies have a limited uptake and use, one explanation could be that the solution focuses purely on providing safety to the user, but does not improve the lived experience of impairment: "*Many of the assistive technologies in this study (e.g. blood pressure monitoring, falls detectors, alarms) had been supplied after an acute event (e.g. stroke, fall). They served, at best, to provide objective information (biometric data, emergency alerts) to health and/or social care providers. But they did not improve the lived experience of impairment. Indeed, they were not designed to do so - but therein may lie one explanation for their limited uptake and use.*" [58].

4.2.1.4 Managing own health

Elderly users are positive towards using ICT to help manage their own health, by getting information about their current health status [31, 38, 40, 50, 52]. The perceived benefit is that this will make them less dependent on their physician, and make them more aware of their own health problems and underlying causes. One study [52] lists the following desired functionality for a "magic box" tool for managing their health information:

"*Participants expressed a need for a tool that will store all their health information in one place and allow them to share this information with healthcare providers and family members. The e-health tool should be interactive, and help users manage appointments, medications, bills, and statements. It should provide reminders for various health tasks, and provide a diagnosis or answer questions about a concern based on the personal health information stored within the tool. They want a tool that would track their health status over time, and give general health advice based on their personal health information. Older adults indicated that they would prefer to have the responsibility of entering information into the "magic box", rather than giving this responsibility to their doctor. It should provide easy accessibility to their records for healthcare providers*".

4.2.1.5 Access to online information

In two of the studies, participants valued the ability to use the Internet for information searching [46, 48]. In [48], the participants stated that they felt the Internet was "*good for finding information that the physicians don't tell you about or forget.*" However, in another study, some participants considered it a social injustice that people have no choice but to use new technologies to get access to information and services [36].

4.2.1.6 Support for daily activities

In three of the studies, participants stated that they used ICTs to aid them in their daily activities, and appreciated this ability. Activities that the technology assists the elders with includes chores and reminders (e.g. medicine and important appointments) [33], online banking, shopping online, writing letters and financial budgeting [46], and enhancing their lives and increasing their productivity in general [48].

4.2.1.7 Perceived usefulness

The elderly population generally find the functionality offered by health ICT systems useful [30, 31, 38, 39, 50, 54, 56]. This might be linked with their desire for increased independence and/or quality of life: "*Determination in sustaining one's independence can affect a WSN [Wireless Sensor Network] system's PU [perceived usefulness] and any indication on WSN's ability to improve an elderly individual's quality of life would appear to have a positive impact on the system's PU.*" [39].

However, one study found that the elderly "*did not uniformly accept the smart home IT shown and most indicated a preference for being able to select only the technologies they perceived they needed*" [55]. As an example of what can be perceived as useful, the following factors were identified as affecting usefulness of sensor data [34]:

- Participants' desires to understand personal activity patterns
- Changes in health status
- Living situation
- The availability of contextual information about sensor data
- Age
- Time when health monitoring begins
- Perceived interest level of others in accessing data
- Accessibility of data to others

4.2.1.8 Availability of proper training

Generally, the elderly find it important to get sufficient training and coaching in the usage of the ICT system [32, 39, 40, 46, 49, 51]. Tailored training was considered as the best way to bridge the gap of the digital divide [36]. However, the quality of these training sessions can vary. In one of the studies, the majority of the participants stated that they still did not know how to use the system after the training session [31]. In this specific case, the reasons were too little training, and lack of access to any kind of help on how to use the device afterwards.

Some users' perception is that the system is more complicated to operate than it actually is [41]. This might cause users to give up on even trying participating in training sessions. Some users state that they have no interest in learning how to use computers [57].

The number of ICT training courses exclusively available for older adults is limited, and information about ICT training opportunities is generally poorly publicized [46]. Some people get training from their family and friends [36]. However, one study found that the children of the elderly are generally not the most appropriate teachers, as they tend to be impatient and speak computer jargon without explaining the meaning of technical terms [32].

When learning how to use an ICT system, an expert should sit down with the user and guide him/her systematically through the operating process [31]. Repetition is also crucial, since the elderly are more prone to cognitive conditions and thus have a harder time remembering how to perform certain tasks [31] (See also *subsubsection 4.2.2.3: Memory and cognitive abilities*).

A trainer should be patient, have perseverance, and use understandable language [32]. The training itself should be accessible, timely, affordable, tailored, local, and in a welcoming and safe environment [46]. The elderly also want an instruction manual that they can consult when they are unsure how to perform a certain task [39, 51]. This manual should be designed specifically for senior citizens, written in an understandable language [51].

4.2.1.9 Support / help

Several studies found a distinct correlation between the support available to the user, and the users' acceptance and attitudes towards the ICT system [39, 46, 58]. In one of the studies, the authors write: "*The availability of help and support has emerged as a key factor of paramount importance to sustaining connection. (...) Human support and encouragement was reported by a significant number (25.2 per cent) of survey respondents to be the most important thing to help them use technology successfully. Most of this help and support was gained informally from family and friends.*" [46]. Another study states: "*Most participants pointed out that the availability and quality of user support is crucial in determining whether users can interact successfully with the technology.*" [39].

4.2.2 Factors preventing acceptance

4.2.2.1 Violation of privacy

Many studies found that some or all participants have concerns about privacy [33, 36, 37, 39, 49, 51, 52, 53, 55, 56, 58, 59]. "*Privacy was the bigger barrier to adoption, more so than usability*" [52]. One of the most cited reasons is that the technology makes the elderly feel observed [33, 39, 51, 53, 56], e.g. by the use of optical sensors and video surveillance [51, 53, 56, 37]. "*All participants felt that the use of cameras within their homes for the purpose of identifying falls or other accidents was 'obtrusive' and would be violating the resident's privacy.*" [51].

The elderly want to be able to control the frequency and location of monitoring [2]. Some would like to be able to turn the system off [33, 53], and some would even like the option to "*get rid of it*" when desired [39]. However, some think such a surveillance system would only work to its full potential when it cannot be switched off [33]. One study reported cameras that only detected shadows or silhouettes and movements, and thus hid identifiable features. The elderly perceive this as less obtrusive compared to a conventional video surveillance system [51, 53].

Elderly users want to control what data to share and with whom [33]. Most would grant access rights to their healthcare providers and others who need to process the information for the purposes of monitoring [53, 56]. Some expressed that they wanted to grant access to their family members [53, 56], while others expressed privacy issues with family members having access rights [53]. Some users want to have the ability to access their own data collected from sensors [53, 56]. In one study, the participants thought their physicians ought to be able to see how much activity they were engaged in, while they did not think their caregivers, spouses or children would be interested in that level of detail [44].

The elderly population lacks knowledge about computer security [46]. They are worried that their information is not stored securely [52, 59], and fear that it can be hacked [59]. Some accepted that they had to trade privacy and security for perceived utility [59].

Despite there being many barriers relating to privacy, several studies found that the participants did not have any issues with privacy [30, 40, 42, 44, 49, 50]. They expressed that they had no concerns about the use of cameras [53], GPS tracking

[45], or wireless transmission of health data [39]. Reasons for this include that they trust the service provider [30], that the monitoring provides peace of mind [42], and that they value security over privacy [39, 55]. Therefore, there needs to be a balance between the benefits of monitoring and the perceived invasion of privacy [42, 56].

4.2.2.2 Interaction design

Some elderly users have both physical and cognitive impairments, and are not good at learning to use new technology. It is important that the system is user friendly and requires minimal to no user action [51]. Several factors relating to ease of use and HCI were found, that have a negative impact on acceptance when such impairments are present (see also the following two sections). For instance, visual communication in a GUI can be challenging. Icons are confusing, and some users prefer text terms [32]. Buttons can be too small [44, 57]. Users have low confidence and are afraid of doing something wrong, and do things slowly to minimize chance [32]. Cognitive overload can be a larger problem for elderly users than younger users, e.g. too many system functions can lead to confusion [57]. There is also a tendency to automate some tasks so users won't need to be involved in the interaction: "*An elderly person's preference on the system design, personal preferences and several external factors it appears can affect a user's PEOU [perceived ease of use] of the system. An embedded solution with an easy to understand and good usability is the most accepted implementation among the participants, suggesting that interaction with the system may be 'an automatic thing' or 'as simple as 'push the button''.*" [39].

4.2.2.3 Memory and cognitive abilities

Several studies found that elderly people often forget how to use the technology, or forget to use it at all, due to age-related cognitive decay. This includes keeping track of devices [49], putting on wearable sensors [39], charge battery-driven devices [44], and remembering passwords and steps in a process [46].

ICT can be used to compensate for these cognitive difficulties [36, 50]. However, this kind of functionality can also have negative effects: "*For some, reminders about appointments or to take medicine were seen as unnecessary or even insulting, an indication that one could not manage health affairs without assistance.*" [59].

4.2.2.4 Physical abilities and ergonomics

A recurring theme in several studies was that interfaces, including computer mice and small buttons, were not tailored to the elderly population with functional limitations [32, 46, 49, 50, 51, 54, 57]. "*The majority of interfaces [of new technological devices] are not designed to take into consideration the functional limitations that come with age. As a result, some tasks requiring the use of technological devices become even more difficult for the older adult.*" [51]

One study found that the elderly preferred using the keyboard instead of the mouse, due to normal age-related changes in precision and manual dexterity [32]. They did not want to use alternative input devices in order to avoid stigmatization, and they had issues with using accessibility tools for making text and elements larger, since this increased cognitive demands by moving or removing elements.

4.2.2.5 Comprehension and awareness

Several of the studies found that participants had problems with understanding the technology and/or the terminology [39, 46, 54, 57, 58]. They often have trouble understanding how to use the technology, and/or its purpose.

- "*Responses suggested that participants did not understand the technology.*" [57]
- "*Many had a hazy understanding of their assistive technologies, and we found one fully installed and functioning alarm system (with pendant) of which the intended user claimed to be unaware.*" [58]
- "*Many participants reported that they had difficulties understanding technical 'jargon'.*" [46]
- "*It is evident that the functionalities and benefits of WSN systems is a concept some elderly persons find hard to grasp. (...) They [participants] expressed their frustration in not being able to understand what happened when error occurs and hence expressed a desire for the system to have 'common sense' and give out meaningful and easy to understand error messages.*" [39]

4.2.2.6 Obtrusiveness / intrusiveness

It is important to the elderly that system components should be unobtrusive [37, 39, 40, 51, 56]. Generally, smaller devices are perceived as less intrusive, and technological devices installed in the home should be hidden or hard to see for visitors [56]. The use of cameras for video surveillance is considered ”too intrusive” [39, 51]. In the case of wearable devices, the elderly prefer to wear them on their wrist, and women want sensors that can be worn as jewellery [37].

In several studies, the participants answered that they were not bothered by the technology, and/or that it did not interfere with their daily activities, which would indicate that the developers succeeded in creating an unobtrusive system [40, 42, 44, 56]. In one study, participants pointed out that some people are ’techno-phobes’, and refuse to utilize new technologies [51]. See also *subsection 4.2.3: Other findings*.

4.2.2.7 Fear, anxiety, and discomfort with use

Many elderly people might experience discomfort, anxiety or even fear while using ICT [32, 36, 39, 43, 46, 58, 59]. In one study, participants stated that they are ”terrified of a computer” [39]. Possible causes for these feelings include a low level of comfort with and control of technology, age-related cognitive difficulties, or a lack of familiarity [36, 39, 59]. Elders are afraid of not getting help quickly if they were to fall while using a fall detection service [43]. At the same time, they might be uncomfortable using such a service because of many different reasons:

“*Others viewed the pendant alarm as potentially exposing them to sinister intrusion or surveillance by unwanted strangers, or as threatening to precipitate dramatic scenarios that were embarrassing (e.g. ambulance arriving when they were not dressed), socially disruptive (e.g. disturbing their children at work) or personally threatening (e.g. leading to unwanted hospital admission). When such perceptions were held, the device was rarely, if ever, activated*” [58].

One study found that connectivity could increase older adults’ comfort with technology in general [49].

4.2.2.8 Low technological self-efficacy

Elderly users often doubt their own abilities to understand and properly use ICT solutions [30, 39, 41]. One possible reason for this could be that many have had negative experiences with technology in the past, where they were unable to interact with the technology properly [39]. However, one study found that even those with the least Internet experience and lowest self-efficacy in the study, reported being confident in their ability to use the services once they had tried them [30].

4.2.2.9 Digital divide and generational differences

Elderly people are concerned about using technologies that can make them look different and frail, and they want to be able to use the same technology as their children and grandchildren are using, both to feel closer to them, and to dispel stereotypes they could have about them [32]. However, most elderly people are unable to follow the technological trends, which might make some feel labelled as old fashioned and obsolete, which in turn can make them feel inferior or powerless [36].

"*They [participants] frequently reported social pressure that pushes them to use technologies in order to fit in with the society. Otherwise, they would be excluded from it.*" [36]

One study found an exception to the theory that the digital divide is a significant barrier to the adoption of e-health tools:

"*Older adults in this study were more likely to adopt some form of technology than younger adults (e.g., create a medication list within a word document). Older adults' willingness to adopt some form of technology may reflect the perceived usefulness and importance of the task of remembering medications, as well as the usefulness of being able to easily edit and print the same information to a multitude of healthcare providers.*" [52]

4.2.2.10 Stigmatization and pride

The installation of heathcare ICT solutions may cause some elders to feel stigmatized or ashamed [33, 39, 51, 56].

"*While assistance with chores was well perceived by a few older adults, others felt no need for assistance and almost felt insulted by the idea (...). We observed that some older adults were very proud of their independence and therefore, rejected anything which would imply otherwise.*" [33]

They do not want to be seen wearing a health monitoring device, as they were afraid it would stigmatize them as frail or needing special assistance [39, 51].

4.2.2.11 Financial cost

Generally, elderly people see the cost of a health-related ICT solution as an important concern when deciding if they want to buy it [31, 33, 39, 46, 49, 51, 57, 59]. "*Cost was the most significant concern to the elderly participants.*" [39]. ICT systems need to be affordable for elderly people living on a pension if it is to get a large user base. However, in one of the studies, cost savings for the user was mentioned as a benefit, as it is cheaper (or even free) to use the ICT solution once it is installed, rather than get an appointment with a doctor [30].

4.2.2.12 Lack of human interaction

An ICT system should not replace human contact. The elderly emphasized the importance of having human care and human interaction, and the thought of replacing this with a computer caused concern [33, 35, 36].

"*The need for human contact and a warm relationship appeared paramount to the residents. This was simply and forcefully expressed by a resident who said simply: 'We are not robots here.' More importantly the residents were 'one voice' and in consensus about human contact.*" [35]

4.2.2.13 Reliability and trust

Elders often have some degree of mistrust or concern about the reliability of an ICT system [31, 33, 39, 49, 51, 56, 59]. These concerns involve the accuracy of devices (including false alarms) [31, 33, 39, 56], uncertainty about whether a device is malfunctioning or not [31, 39], depleted batteries [39], delivering information to providers in a timely manner [49], and trusting that the computer would do its job [59].

4.2.2.14 Readiness to adopt technology

Many of the elderly are reluctant or not at all interested in using the ICT solution after getting a presentation, demonstration or having tried it themselves [33, 36, 39, 56, 57, 59]. They find they have no need for it in their current situation [33, 36, 59], and think of it as something more appropriate for people who are older, frailer, less independent, less active, less healthy and/or more isolated than themselves [33, 36, 41, 53, 56, 59]. Some acknowledge that they soon will be in need of such technology [36], while others find this hard to imagine [33]. Some perceive computers as something only young people use [57].

4.2.2.15 Other barriers

Some elderly people are worried that a wearable sensor system can have negative effects on their health, like getting cancer from radio waves used for wireless communication, getting allergic reactions, or the pain caused by having a sensor underneath their skin [39]. One study investigating self-tracking of data [60] found that elders who tracked their health data themselves recognized this as work, and judged themselves as ”good” or ”bad” for their data and their diligence in collecting it, and noted that data should be considered within the patient's personal context. Medical data often reminded patients of the negative aspects of their illness, which made many give up self-tracking.

4.2.3 Other findings

Elderly people are generally positive towards sensor monitoring in their home [51]. The process of adoption and acceptance of sensor technologies included three phases: familiarization, adjustment and curiosity, and full integration [42]. Sensor technologies can be divided into three main categories: wearable sensors (sensors worn on the body, e.g. pendant alarms, smartwatches, or sensors embedded into clothing), ambient sensors (stationary sensors installed in the home, e.g. cameras), and embedded sensors (placing sensors under the skin of the user). The elderly report positive attitudes towards wearable sensors
citeGovercin10,Steele09. They do not mind the concept of wearing sensors on their body [39], and prefer wearable sensors over an optical system (ambient monitoring) [37]. A wristband sensor is well accepted [37], and having sensors embedded into clothing accessories such as rings or watches was also requested [39]. Women want to be able to wear sensors as jewellery [37]. Some problems identified with wearable sensors include that users might refuse to wear them at all times, and might end up not wearing it in an emergency, and they have limited mobility as the sensor functions only within a certain area [51]. In the case of ambient monitoring, the elderly are uncertain whether a pure ambient implementation is adequate to ensure that an elderly person is monitored at all times. Some suggest a hybrid solution consisting of both ambient and embedded sensors may be better for solving perceived problems [39]. The elderly are reported in one study to be positive towards the idea of having embedded sensors placed under their skin, as long as the pain is not significant, and the chip did not need to be taken out regularly e.g. for battery replacement [39].

5 Discussion of findings from the literature review

This chapter describes how the findings from the systematic literature review relates to the UTAUT2 model. The product of this mapping is an evaluation tool for assessing the acceptance of health-related ICT among seniors. In addition, the result of the mapping (and the overview of the findings that does not map to UTAUT2) presents some suggestions to a possible altered version of the UTAUT2 model adapted for older adults.

5.1 Mapping to UTAUT2

This section will present how the findings in the systematic literature review are mapped to the UTAUT2 model and its constructs [6].

Table 5.1 presents the seven constructs in the UTAUT2 model, along with a quote from Venkatesh et al.[6] explaining each construct, while fig. 5.1 (created by subject supervisor and co-author Babak Farshchian) illustrates how the findings map to the UTAUT2 model.

5.1.1 Performance expectancy

Performance expectancy is an important aspect for seniors living in the community - they will not use technologies that they cannot perceive any benefit from using.

Construct	**Explanation** [6]
Performance expectancy	"*The degree to which using a technology will provide benefits to consumers in performing certain activities*"
Effort expectancy	"*The degree of ease associated with consumers' use of technology*"
Social influence	"*The extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology*"
Facilitating conditions	"*Consumers' perceptions of the resources and support available to perform a behavior*"
Price value	"*Consumers' cognitive tradeoff between the perceived benefits of the applications and the monetary cost for using them*"
Hedonic motivation	"*The fun or pleasure derived from using a technology*"
Habit	"*The extent to which people tend to perform behaviors automatically because of learning*"

Table 5.1: The constructs of the UTAUT2 model and their explanations

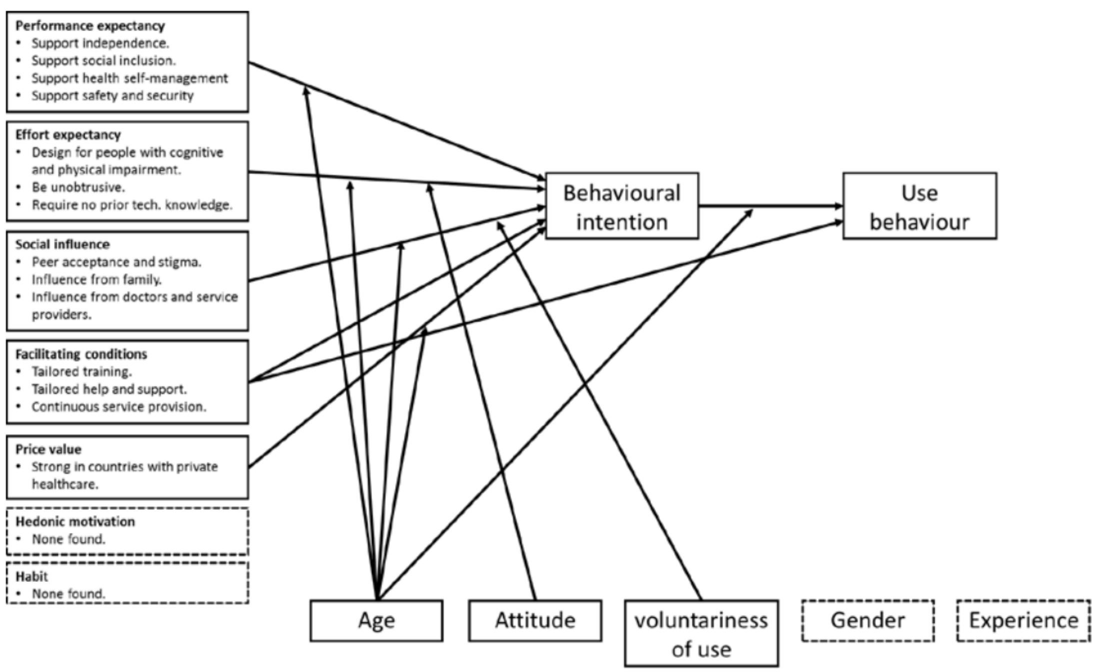

Figure 5.1: Mapping of the findings to UTAUT2

The findings suggest that the most important benefit that the elderly users seek in ICTs, is to keep their independence. Many older adults do not want to become dependent on others, and are willing to use assistive technologies as tools to prevent this. This way they can still be an active member of society.

Social inclusion is another important benefit. The study found that seniors value technology that enables them to socialize.

It is also important that users feel safe while using the technology, whether it is a health monitoring system, or another health-related ICT solution. Being able to better manage their own health through the use of ICT , is another factor increasing the acceptance.

5.1.2 Effort expectancy

Both perceived and real ease of use has been shown to be a major factor in influencing acceptance. The elderly are generally prone to physical and/or cognitive impairment, making it harder for them to effectively use ICTs, especially if these are not tailored to this user group. System designers have a challenge in finding a balance between tailoring the system to elderly users (e.g. using large icons/symbols/fonts etc. and limiting the functionality and complexity), and designing the system as if it would be used by younger users to prevent stigmatization.

The effort expectancy is also affected by the obtrusiveness of the system. Ideally, older adults want ICT systems to function and provide the expected benefit while requiring minimal to no user intervention.

Having low technological self-efficacy is another common factor among seniors that negatively affects the effort expectancy. If the user lacks basic technical knowledge, even the most basic ICT systems might prove to be highly difficult to understand and use.

5.1.3 Social influence

Older adults using health ICT might feel stigmatized or that their personal pride is in jeopardy, as a result of others in their peer network discovering that they use such technological aids. This will in turn result in low acceptance.

Seniors generally want to use the same technologies as younger generations do, but are often unable to follow technological trends since these rapidly change and requires a certain level of technological knowledge and self-efficacy to adopt, which seniors often lack. This might make some feel old fashioned and obsolete.

Non-peers like healthcare providers or family members have been found to potentially affect their opinion and use of health ICTs to some degree.

5.1.4 Facilitating conditions

Seniors generally require more training and support than younger users in order to effectively use an ICT service, as it is more difficult to learn new skills at an older age due to cognitive impairment. It is important to deliver tailored courses and training in order to teach the elderly how to use the service, and also to provide support to the users while they are using the service.

Another facilitating condition that seniors often lack, is trust in the technology. They are often somewhat mistrusting about the reliability of ICT. When using a system involving some form of monitoring of the user, it is important that the user is assured that the system is working and ready to react to changes in measured values, e.g. if the system should detect an emergency.

5.1.5 Price value

The practice of reimbursing healthcare systems differs from country to country - some countries offer assistive technology free of charge, covered by tax money, while in other countries the users will need to pay for these services out of their own pocket.

In the cases were the user needed to cover part of or the whole cost of the service, this was seen as a major barrier to acceptance.

5.1.6 Hedonic motivation

The findings show no indication that hedonic aspects affect acceptance. Health ICT is typically designed to serve a specific purpose involving the betterment of the user's health, and does not involve a "fun factor". It is, however, predicted that gamification will be incorporated into health ICT to a greater extent in the future, thus making hedonic motivation a relevant aspect.

5.1.7 Habit

Like hedonic motivation, habit was found to not be a relevant factor. It might be that many of the barriers that are identified — e.g. fear of technology, low self-efficacy — are actually symptoms of a habit of not using technology. It might also be that the studied seniors have rarely used assistive technologies enough in order to allow for habit creation.

5.1.8 Moderating conditions

Age, gender and experience are the three moderating conditions defined in the UTAUT2 model.

Age is obviously a hugely important factor in the findings of this review, as it is limited to older adults. Thus, all the findings aim to illustrate how age affects acceptance.

Surprisingly, *gender* is not discussed as a moderating factor in any of the included studies.

It is not possible to draw a conclusion about the *experience* moderator either, as it is not a topic that is discussed in the studies, and all the research is focused around users with limited or no experience at all with (certain types of) ICT. Data about prior experience among the participants is rarely collected, possibly because the authors assume a lack of experience.

Also, many assistive technologies share few similarities with domestic ICT that users might have experience using, and leans more towards medical devices. Thus, prior experience might be irrelevant.

5.2 Findings that are not mapped to UTAUT2

Among the major findings that are not directly mapped to the UTAUT2 model are *privacy*, *information security*, and *perceived usefulness*. The studies show that older adults have mixed attitudes toward the use of the ICT service, be it the sharing of health data or the usefulness of different functionality. These variations are hard to express with the UTAUT2 model, and thus, a moderating condition called "*attitude*" is suggested. This was considered as a parameter in the original UTAUT model[12], but was eliminated in favour of performance expectancy.

It is also suggested that a moderating condition named "*voluntariness of use*" is re-introduced. This was part of the original UTAUT model, but was removed in UTAUT2 because the authors saw it as irrelevant in a consumer ICT setting. But assistive technologies are not necessarily defined as consumer ICT - it is somewhere between consumer ICT and "institutional" ICT - and while consumer ICT is always bought intentionally, an older adult might be pushed towards using assistive technologies by an authoritative person like a doctor. In this case, the level of voluntariness greatly affects the acceptance of assistive technologies, and should be measured.

5.3 Evaluation tool

In order to make it easy for practitioners to apply the findings from the literature review, the extension of the UTAUT2 model has been mapped to a questionnaire-based checklist, presented in table 5.2. This can be used as an evaluation tool for acceptance of health-related ICT among seniors.

- The left column lists the different mechanisms that was found in the literature review, organized based on which construct they are mapped to.
- In the centre column, the evaluator can write about how well the concept complies with the given mechanism, and other relevant remarks.
- In the right column, a 'score' is set for the given mechanism. In this initial version, it is sufficient to write whether the mechanism is supported or not, or partially/indirectly so. However, this should be extended to specify a

numerical value (e.g. from 1 to 5), and a final score should be calculated based on these (see *section 9.3: Further work*).

In chapter 8, this tool is applied to the design concepts (described in chapter 6) and the prototype (described in chapter 7).

Mechanism	Connection	Supported
Performance expectancy		
Support independence		
Support social inclusion		
Support health self-management		
Support safety and security		
Effort expectancy		
Design for people with cognitive and physical impairment		
Be unobtrusive		
Require no prior tech. knowledge		
Social influence		
Peer acceptance and sigma		
Influence from family		
Influence from doctors and service providers		
Facilitating conditions		
Tailored training		
Tailored help and support		
Continuous service provision		
Price value		
Price value		

Table 5.2: Form for evaluation acceptance of health-related ICT among seniors

Part III

Design and evaluation

6 | Concepts for implementation of Adapt

This chapter presents a set of concepts describing how the Adapt service might be designed. It corresponds to the box named ”Design of concepts” in fig. 1.1.

The concepts designed here do not need to necessarily be realisable with the technology or funds available at this time, but are more aimed at the future, and tries to describe a ’perfect solution’ for the end users.

The evaluation tool presented in *section 5.3: Evaluation tool* will be used to evaluate the acceptance of the different concepts in chapter 8.

The concepts include both new ideas that are not currently commercially available, and solutions using widely used devices, like smartphones and smartwatches. This is done partly to illustrate that the evaluation tool can be used for both of these concept types, and partly because this might provide value to the Adapt team by comparing a solution using commonly available devices to a tailored implementation using custom hardware.

Concepts A-E describes potential ways to collect sensor data from the user. Concepts F-I concerns the interface used for feedback from the system to the user, while concept J relates to the functionality offered by the system.

The target user group of the Adapt project are seniors aged between 67 and 75 years old, and this has been considered in the design work described in this chapter.

6.1 Concept A: Senor unit on everyday wearable objects

A small sensor device that can be attached to everyday wearable objects, such as glasses, jewellery, wristwatches, hearing aids, or a similar object that the user is already using on a daily basis.

This concept is the most complex and detailed one, and could potentially be split into more concepts by having some properties included in one concept, and excluded in another. But for the sake of entirety and completeness, it is all included in this concept.

COMPONENT	PURPOSE	CONNECTION TO FINDINGS IN LITERATURE REVIEW
9-axis inertial motion sensor (e.g. mCube[1])	Measure the movement data of the user. More accurate than using an accelerometer only.	Provided the unit is small and concealable enough: prevents obtrusiveness and stigmatization
Microprocessor	Make simple calculations necessary for the system to work (send data, store in memory etc.)	
Memory chip	Cache measurements if sending fails, as well as storing of code instructions	
Bluetooth low energy chip	Send measurements to receiving unit at regular intervals	
Multi-coloured LED	Display the status of the sensor unit (e.g. charging, sending, error etc.)	
Loudspeaker	Option for general feedback and motivating messages in the form of audio	
Battery supporting inductive charging	The device is charged by simply laying it down on the charging plate	
Charging plate for inductive charging	The device is charged by simply laying it down on the charging plate	Forgetfulness (elderly can often forget to put on a sensor that requires taking on an off regularly)
Receiving unit in the home (e.g. Raspberry Pi)	Receives data from the sensor unit, forwards it to a central server, receives feedback from central server, and presents feedback to user through touchscreen	See *concept G: Feedback through a touchscreen in the home.*

[1] `http://www.mcubemems.com/products/igyro/`

COMPONENT	PURPOSE	CONNECTION TO FINDINGS IN LITERATURE REVIEW
Smartphone	Used as receiving unit if sensor unit is out of range from standard receiving unit.	Supports independence (users can leave the house and data can still be transmitted, provided they bring their phone)
Central server	Collects data from all connected users, analyses data, and returns feedback to users.	Supports independence (users can stay at home while the system monitors their movement); increases feeling of safety (knowing their risk of falling is monitored)
Attachment solution	Attaching the sensor unit to an everyday object, using e.g. velcro or some form of plastic clips	Forgetfulness (see row about inductive charging)

Table 6.1: Components of concept A

For this concept to be relevant, it needs to be made small and unobtrusive enough that it is not considered uncomfortable or bothersome to the user. This will be challenging, if not impossible, to achieve with today's technology, especially with limited resources. However, in the coming years, this may be very relevant and realisable.

An existing sensor unit on the market similar to the one described in this concept, is the Axivity WAX9 [62].

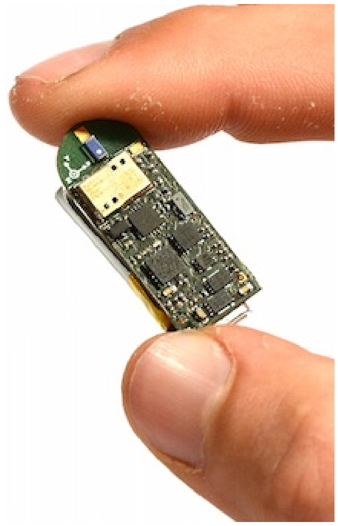

Figure 6.1: Axivity WAX9 [1]

[1]Image source: `http://axivity.com/img/products/wax9_hand_1.jpeg`

6.2 Concept B: Sensor unit with wristband

This concept is the same as the previous one, but is worn using a tailored wristband. This is a simpler solution, but presents the challenges relating to remembering to put on the wristband regularly, and the hassle it entails. However, this will make the device easier to manufacture, or existing commercial devices could be used, causing the financial cost of the device to drop, which is found to be an important factor for end user acceptance.

Existing commercial products in this category include the aforementioned Axivity WAX9 with the wristband accessory [63], or the Angel Sensor [64].

Figure 6.2: Axivity Wristband[1]

Figure 6.3: Angel Sensor[2]

[1] Image source: http://axivity.com/img/products/strap_1.jpeg
[2] Image source: http://angelsensor.com/angel/wp-content/uploads/2015/12/angel-2.jpg

6.3 Concept C: Sensors in clothing

This concept involves sowing sensors into one or more pieces of clothing belonging to the user. This should ideally be clothes that the user is wearing often, or alternatively increase the number of clothes with sensors, in order to maintain as constant monitoring as possible.

The communication should be done over Bluetooth or a similar wireless technology that requires no user interaction. Also, charging should be done wirelessly through induction, as in the previous concepts.

Sensors could also be put into shoes, typically in shoe insoles, or even sown into the shoes themselves. Several manufacturers have already developed shoe insoles with various types of sensors, like the German company Moticon [65]. However, this model does not offer wireless charging.

Provided the sensors are hidden under other pieces of clothing or designed to not be visible, this solution would not cause stigmatization. It would also be unobtrusive, and be easy to use as no user interaction is necessary except putting on the piece of clothing (assuming charging and data transfer occurs wirelessly and automatically).

Figure 6.4: The Moticon OpenGo Science sensor insole [1]

[1]Image source: http://conscienhealth.org/wp-content/uploads/2014/01/Moticon-Sensor-Insole.jpg

6.4 Concept D: Smartwatch as sensor unit

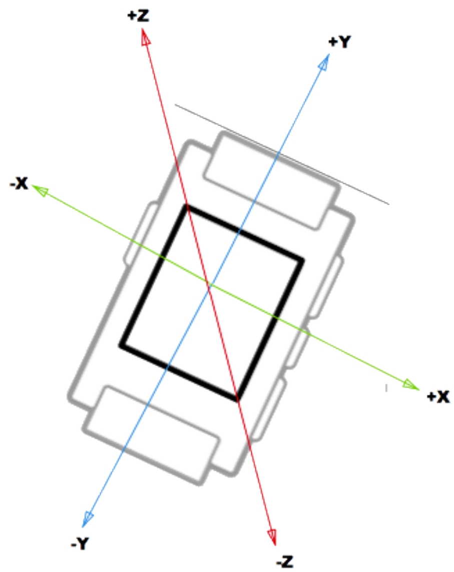

Figure 6.5: Illustration of the motion axes on a smartwatch[1]

Similar to *concept B: Sensor unit with wristband*, a smartwatch contains movement sensors inside a unit worn on the wrist. The difference is that a smartwatch has a display primarily used for showing the time, mimicking a traditional wristwatch that is familiar to most seniors.

The watch should have an e-paper display that can stay on constantly, thus preventing the user from having to press a button or performing a gesture to see the time. This provides utility and prevents frustration and hassle.

There should also be no way for the user to accidentally open a menu or in some way alter what is displayed on the screen - it should normally always show the time, and nothing more. This includes notifications from the phone (text messages, phone calls, appointments etc.), unless the user has enough technological understanding to use it and requests that this is enabled. For advanced users (e.g. those maintaining the system and its equipment), the settings can be accessed by e.g. connecting the watch to a computer, or pressing a button and/or part of the screen for a given number of seconds.

[1]Image source: `https://developer.pebble.com/assets/images/guides/pebble-apps/sensors/accel.png`

Charging of the smartwatch should be done using a docking cradle or a charging plate (not a cable), as this makes it easier for the user and is less of a hassle. If the smartwatch is powered off (e.g. after depleting the battery), it automatically powers on when being charged.

One potential obstacle to this concept is that some seniors might not want to replace their old wristwatch with something now and unfamiliar. As was presented in the literature review, many seniors typically don't see themselves in need of assistive technologies [33, 36, 41, 53, 56, 59]. If their motivation for using monitoring technology is not great enough, it is unlikely that they will choose to replace their old wristwatch with a smartwatch.

6.5 Concept E: Smartphone as sensor unit

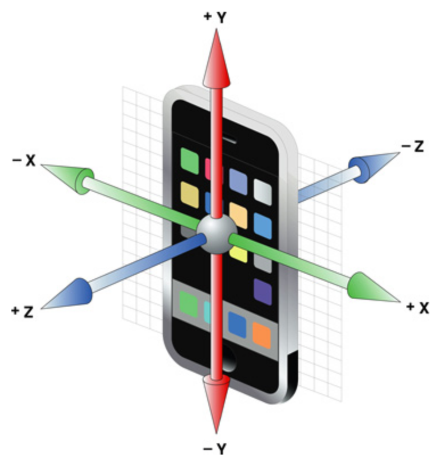

Figure 6.6: Illustration of the motion axes on a smartphone[1]

More or less all modern smartphone models are equipped with an accurate movement sensor, which can effectively track the movements of the user while the phone is attached to the user's body. Smartphones are also already widely adopted by users, which is an advantage from both an economical and usability perspective, as the service provider or end user often do not have to pay for new hardware, and the user is already familiar with the interface and how the device works.

In order to detect movements, the phone needs to follow the movements of the user. The developers of the system need to use algorithms to calculate the movement of the user based on the sensor data, and the position of the sensor on the user's body is a very important factor, and moving the sensor to another position would require a completely different algorithm. The simplest solution is therefore to use the smartphone in only one position on the user's body. In a previous, similar study called Farseeing [66], and probably in (at least the first phase of) the Adapt project as well, a waist belt with a pocket for a smartphone is used, placing the smartphone on the lower back of the user. This position was chosen because this is the best position for collecting accurate data with the algorithms currently available. This belt is shown in fig. 6.7.

[1] Image source: http://www.mindtreatstudios.com/wp-content/uploads/2012/05/device_axes.png
[1] Image source: http://www.adressa.no/nyheter/trondheim/article10171823.ece (screenshot from video)
[2] Image source: http://babycarejournals.com/wp-content/uploads/2014/07/Cell-Phone-in-Pants.jpg

Figure 6.7: Waist belt for smartphone used in the Farseeing project [66].[1]

Figure 6.8: A smartphone in a trouser pocket.[2]

However, this is a highly obtrusive solution, it may cause significant social stigma, and does not allow the user to utilize the other functionality offered by the phone while it is worn. It is likely to be far better accepted if the user is free to place the phone on other locations on the body, e.g. in a trouser pocket. This would involve more work in developing accurate algorithms, but will likely pay off in the form of significantly higher acceptance.

The system also needs to know where on the body the sensor was positioned at the time of each measurement. There exist a number of studies investigating ways to determine the phone's sensing context, including the use of an accelerometer, camera/light sensor, proximity sensor, gyroscope, compass and/or a microphone [67, 68, 69]. Another possible solution could be to use Radio-frequency identification (RFID) tags sown into the user's clothing (e.g. one in the front left pocket, front right pocket, back right pocket and back left pocket), thus allowing the phone to determine when it is placed in certain locations.

If the phone is not placed in a pocket (or similarly attached to the user's body) for an extended period of time during the day, the user should get a message on the phone reminding him/her to wear the phone while moving around.

After the monitoring app on the smartphone is started for the first time, the monitoring runs as a background process on the phone, so the user does not need to have the app open for the monitoring to work. Even when the phone is rebooted, the app will start automatically. In the case when the phone is connected to a charger after being turned off (typically after it has run out of battery), the phone will automatically boot up without the need to press any buttons. This functionality allows users who don't know (and don't want to learn) how to turn the phone on or off, and want to use the phone solely as a monitoring device, to simply plug the charging cable into the phone when they don't wear it, and not worry about having to press any buttons.

The theoretical evaluation of this concept is split in two parts: one for the lower back position using a waist belt (see subsection 8.1.5), and another where the user is free to place the phone in other positions on the body (see subsection 8.1.6).

6.6 Concept F: Feedback through an app

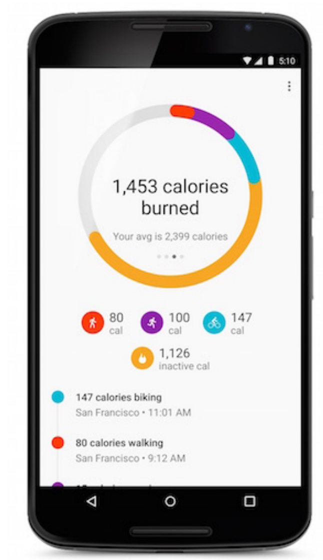

Figure 6.9: A screenshot from the Google Fit app, which also presents health-related data about the user[1]

A mobile app is one possible way to provide feedback from the system to the user. This app will present both the mobility index and other statistics from the collected sensor data. How this information will be presented is not decided at the time of writing, and is not part of these concepts.

By providing the data collected about their fitness and physical health, the system gives users the tool to better manage their own health, which is something the older adults want, as revealed in the literature review [31, 38, 40, 50, 52].

In addition to viewing the collected information, the user can also get motivational messages generated by the system.

The app can also keep track of which physical exercises the user has performed, and which ones should be performed to maintain or improve the mobility index. The system should automatically detect when an exercise is started and finished based on accelerometer data and/or geographical location/movement.

[1]Image source: http://mobihealthnews.com/sites/default/files/wp-content/uploads/2015/05/Google-Fit-update1.jpg

The user interface should require as little user interaction as possible, and user friendliness is a key element. As per the findings in the literature review, the part of the user interface that requires user interaction should use large, textual buttons. The main view of the app should display the most important information (e.g. mobility index, changes the last 24 hours, step count, motivational message, suggestion for next exercise etc.), while more information can be displayed by tapping a large button on the bottom titled e.g. ”More information”.

6.7 Concept G: Feedback through a touchscreen in the home

The same information and user interface as described in *concept F: Feedback through an app*, could also be put into a wall-mounted touchscreen, like a tablet or the Raspberry Pi Touch Display [70].

Figure 6.10: A wall mounted tablet[1]

Compared to an app on a mobile device, this device is stationary and restricted to the user's home. However, for users how do not want to get or learn how to use a smartphone or tablet, this might be a preferred choice. The user does not need to keep track of where it is, and it can be locked to only showing the user interface for the system (in contrast to a smartphone, where the user will need to deal with the Android/iOS/Windows Phone system to even open the app).

The information can be presented as multiple views constantly cycling, each transitioning into the next after a given number of seconds.

[1]Image source: `http://cdn.trendhunterstatic.com/thumbs/wall-mounted-ipads.jpeg`

6.8 Concept H: Feedback using audio

The elderly have clearly expressed the importance of human interaction and that computers should not replace computers [33, 35, 36]. However, the predictions for many areas of the world involves the elderly population greatly outnumbering the available health care professionals. A likely consequence is that computer systems of the future will have to replace humans and the take over the care responsibilities they have today. These systems should therefore be made in a way that mimics human interactions as well as possible to achieve higher acceptance. Giving feedback in the form of voice messages is one way to do this, rather than text on a display.

Ideally, the system should have a certain level of artificial intelligence, so that the user can have a conversation with the system and get relevant feedback to questions through the speakers. However, this technology seems to be too far into the future to be covered in this concept.

One can, however, imagine a solution using voice recognition and answers to certain pre-programmed questions similar to Google's ”OK Google”, Apple's ”Hey Siri”, or Microsoft's ”Hey Cortana”.

Other alternatives could be to press a button attached to the sensor or feedback device, or to have the system automatically play generated voice messages (e.g. ”*Great job! You've taken 5000 steps today. Can you beat your record from last week of 5600 steps?*”) at certain intervals while performing exercises, or when a certain goal has been reached. The latter would however require the sound to be heard only by the user, as spontaneous playback with speakers that can be heard by bystanders can easily cause stigmatization. To avoid the hassle of putting in earplugs, users of glasses could add a Bone Conduction Transducer (BCT) to the glasses, which conducts the sound waves through the bones of the skull directly to the inner ear. The Google Glass uses this technology[71].

Figure 6.11: The green circle shows the Bone Conduction Transducer (BCT) on the Google Glass[1]

[1] Image source: http://jarrodoverson.com/blog/assets/glass-bone-conduction.png

6.9 Concept I: Feedback using SMS

Figure 6.12: An SMS message on a Doro phone[1]

Despite being an old and limited technology, the Short Message Service (SMS) might be an option to consider as well, seeing as it is a widely used technology for all population groups, including the elderly population.

Many older adults do not own a smartphone. A survey has shown that among older adults aged 65 or older living in the United States, only 18% own a smartphone. [72] A likely explanation is that older adults prefer simpler phones, as they do not need the functionality of a smartphone. The ergonomics and interface design of smartphones can also be a challenge to many older adults - this is evident from the existence of companies like Doro [73], who specialize in building phones specifically tailored to the senior population. Therefore, a solution compatible with 'non-smart' phones, like SMS, should be considered.

The SMS system can regularly send out SMS text messages with results and motivational messages generated by the system.

[1] Image source: https://i.ytimg.com/vi/GPxOfU8ACYO/maxresdefault.jpg

This solution should be reserved for users who reject the other feedback solutions, and want to stick with familiar technology.

6.10 Concept J: Social platform

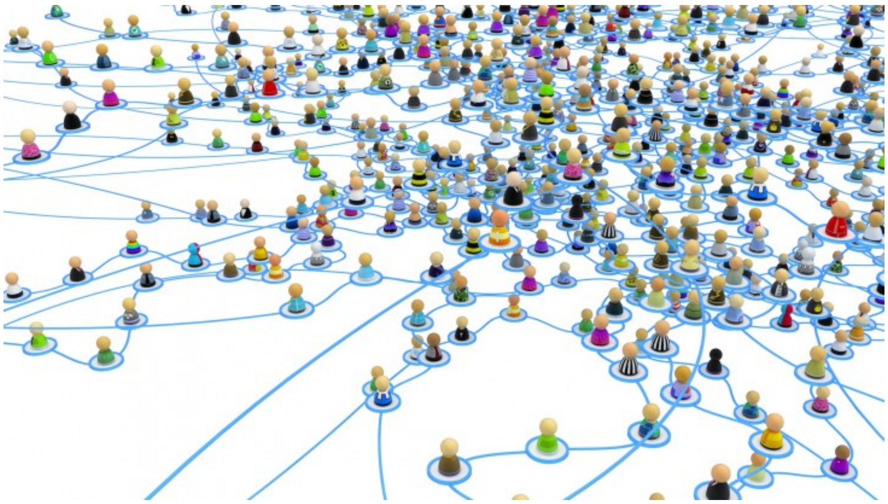

Figure 6.13: Illustration graphic of a social network[1]

The literature review revealed that socialization is an important factor for the elderly [32, 36, 50]. This system should therefore implement functionality that facilitates social interactions for the user.

The system could present the user with a list of organized exercise sessions taking place nearby, which matches the user's mobility index. This could both motivate the user to participate in the activity, and result in the user meeting other seniors on the same level of fitness, which in turn could result in future exercise sessions together, building both social bonds and mobility index.

An aspect of competition could also be added to the system, by showing anonymized data about the physical activity of the users in a given area. This can make some users more motivated by comparing their own results to the average in their area, e.g.: "*You have gone 500 steps more than the average in your neighbourhood today!*".

The system could also implement functionality to add other users as friends, and, if permission is granted, information about the user's physical activity is shared with the friends. E.g.: "*John completed the balance exercise today. Show him that you can do it too!*"

[1]Image source: http://cdn1.tnwcdn.com/wp-content/blogs.dir/1/files/2013/11/social-network-links-730x410.jpg

7 | Prototype of the Adapt web application

This chapter will discuss the development of a prototype for the Adapt system, as presented in fig. 1.1 as ”Development of prototype”.

During a meeting with Babak Farshchian and Yngve Dahl on 3 May 2016, it was decided that the author should focus on creating a mockup and a prototype implementation of a web app that will serve as the front-end interface tailored to the elderly users from whom the system is collecting movement data. The design for this web app shall be grounded in the findings from the systematic literature study.

7.1 Description

During meetings on the 3rd and 4th of May 2016 with other Adapt team members, the design of the user interface was discussed.

The most important element is an image that represents the mobility index of the user, and which changes based on the sensor values and the calculated mobility index. These images should present the mobility index value to the users in an understandable way, and also, if possible, motivate the users to increase this value, making them less prone to fall-related injuries. Exactly how these images should be designed in order to achieve this, was something the adapt team had not decided, and is not within the scope of this master thesis. The images used in the mockup and prototype are merely examples of how this *could* look.

Secondly, the users should be presented with some statistics showing their recent physical activity, e.g. how many steps they have taken, or how many calories they have burned over the course of a day. Contrary to the mobility index image, which illustrates the '*quality*' of their movement, this shows the *amount* of physical activity. For instance, one could walk fairly long distances in a day, but still be prone to falling, which can be detected based on *how* the user moves.

However, regular physical activity could also reduce the risk of falling, especially over an extended period of time [74]. A presentation of their recent activity, potentially combined with messages encouraging users to try to beat their previous '*records*' to introduce an element of competition, could motivate users to exercise more.

The last element of the interface is a section for motivating messages to the user, which aims to inspire more physical activity and balance exercises that could increase the mobility index. These messages could either be auto-generated by the system based on sensor data, or be manually inputted by a fall risk assessor who is reviewing the sensor data.

A separate page should house the settings for the application, most importantly which set of images should be used to represent the mobility index. The user should be able to select from a selection of image representations, to find the one that is most understandable and has the highest motivating effect. Other settings could include e.g. if the chart is displayed, and if so, what data it presents.

The system should have a separate front-end view for the fall risk assessors and other expert users of the system. However, this is not a priority in this phase of the Adapt project, and will not be a part of this master thesis.

The same applies to the proposed social functionality (e.g. comparing results with other users). This has been discussed and will likely be added in the final version of the system. However, the subject supervisor agreed that it is not needed to integrate this functionality into the prototype.

7.2 Mockup

The *Balsamiq Mockups* software [75] was used to create a wireframe mockup of a potential GUI layout.

Figure 7.1: Mockup of the main page

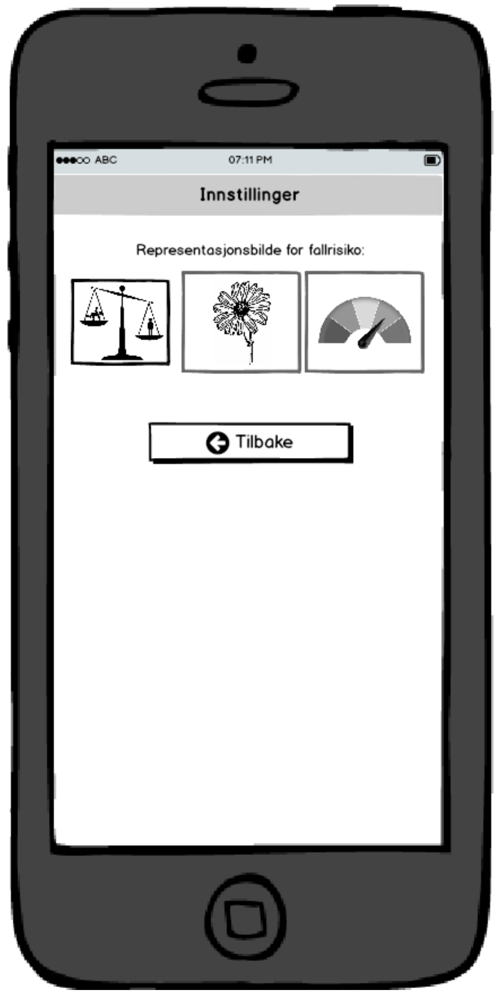

Figure 7.2: Mockup of the settings page

This kind of model can be very useful in the early stages of development by getting feedback from the participants. Unlike a full implementation, which can often make stakeholders focus on details such as colours or fonts, the mockup presents a sketch of the layout, and aims to make the viewer focus on the basic elements of the interface, if these are needed/useful, and if a certain functionality should be implemented in another way.

In this mockup, all the elements are fitted to the screen dimensions, so the user does not need to scroll in order to see all the elements of the system. This will give the user one less thing to deal with when using the system.

For a description of the different elements in the mockup, see the previous section, *section 7.1: Description*.

7.3 Prototype

7.3.1 Technologies

The prototype of the web app was created using HyperText Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript. In addition, several third-party frameworks and libraries were used both in order to make development easier, but most importantly to increase the usability of the web app.

7.3.1.1 jQuery

A cross-platform JavaScript library designed to simplify the client-side scripting of HTML.

7.3.1.2 jQuery Mobile

jQuery Mobile is a JavaScript library for creating web applications for mobile devices, optimized for a wide variety of smartphones and tablets with touchscreen interfaces. It is an extension of the jQuery library.

7.3.1.3 Bootstrap

Bootstrap is a popular front-end framework for developing responsive web sites. CSS media queries are used to scale the web site so that it fits perfectly on a wide array of devices. It is well tested and works in all modern web browsers. Bootstrap is also free and open source.

7.3.1.4 Highcharts

Highcharts is a JavaScript library used to create interactive and dynamic charts for web applications.

7.3.2 Details

The web app was created using the Responsive web design (RWD) approach, meaning that it automatically adjusts the size of the content to fit any screen size. This way, issues such as horizontal scrolling are prevented when viewing the webapp on a device with a small screen, which in turn requires less user interaction. This is a factor found to increase acceptance [51].

Also, the web app was developed as a Single-page Application (SPA), meaning that it consists of a single web page, while the user can switch between multiple views in the web app. Rather than reloading a new page for each action, client side technology is used to manipulate the Document Object Model (DOM). This is done to create a more fluid user experience by eliminating the round trip delays of loading a new web page when a new view is requested.

The topmost and largest element is the mobility index image, which represents the user's mobility index, i.e. the risk of falling. This image changes when new sensor data indicates a change in the mobility index. As stated earlier, the images used in this current version are just examples of how these *could* look, but the idea is to make these images as understandable as possible, while presenting the mobility index in a way that motivates the user to try to increase the index.

In the middle section of the main page is a chart presenting the number of steps measured in the past seven days. Options for what is displayed and the intervals could be added to the settings page in the future. When the user hovers the mouse over (or, on a touch device: taps) one of the columns in the chart, a tooltip appears, presenting the x and y values with a larger font size.

The bottom element is a box for motivating messages, either created automatically or manually by an expert user. This box is updated dynamically when a new message is created.

The footer contains some text telling how long ago the data was updated (since

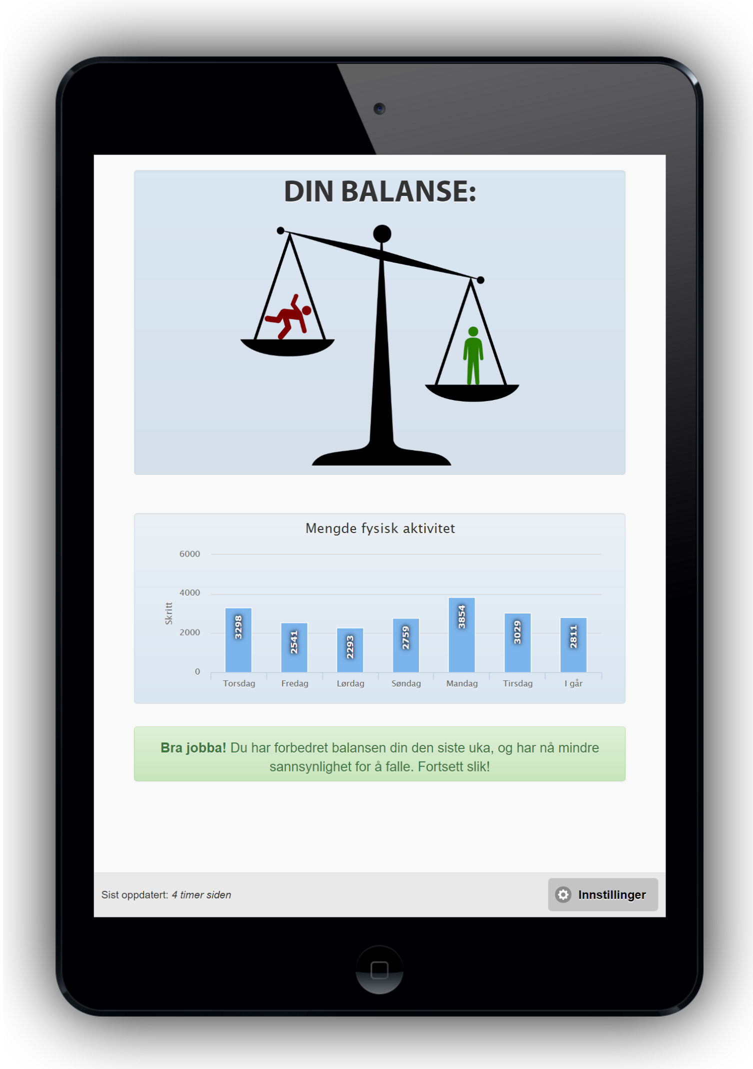

Figure 7.3: The main page of the prototype web app

the sensor data was calculated by the server and sent back to the user), and a settings button. A recommendation for future work is to hide the footer on devices with small screens, to make room for the main elements. The footer can appear for a few seconds when the user touches the screen, or a similar interaction.

The settings button is deliberately made relatively small, despite the general rule of using large user interface elements in systems designed for senior users. The

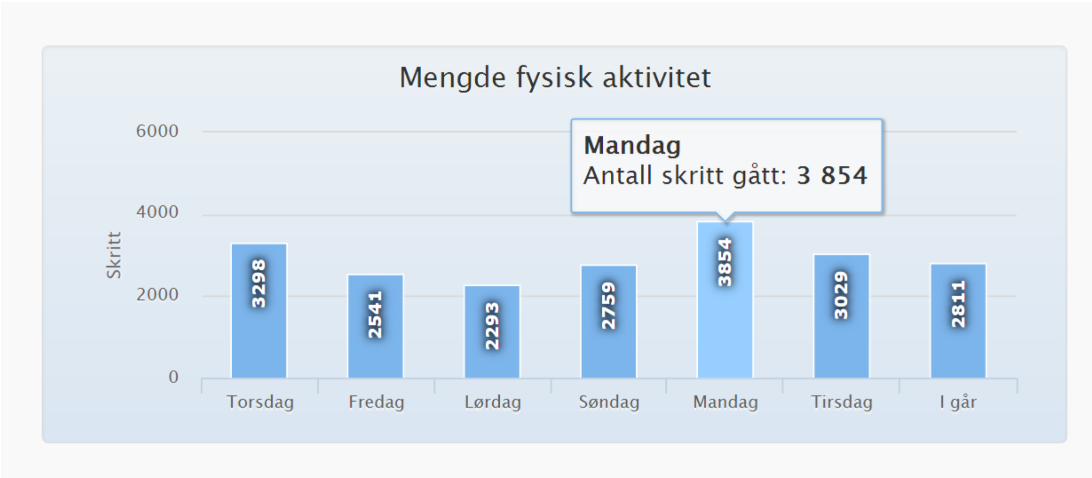

Figure 7.4: A tooltip in the chart

reason for this is that few users will need to access the settings view, and creating it as a large element might cause many users to accidentally push the button, could then have trouble returning back to the main view.

When the settings button is pressed, a flip transition occurs, showing the ”backside” of the main page, where the settings for the web app can be adjusted. This animation was chosen because it gives the illusion that there is something on the other side of the main page, and this seems like a logical location for the system settings.

Currently, only the option to select the mobility index image is implemented, but more will likely come here later. There are currently three images to choose from, but more can easily be added by simply adding new img-tags in the HTML page. The image that is currently active has a ticker border than the others and are slightly smaller, illustrating that it is ’pushed in’, like a button. This can be further improved in the future, by adding shadows and other effects that provides a better sense of depth. When the user is hovering the mouse over the other images, a transition starts, shrinking the image to the same size as the active image (but without the thick border). When this image is clicked/tapped, it gets the thick border, while the previously active image loses it and is restored to the original size.

Below the image selection area, is a *back* button. When clicked, the user is

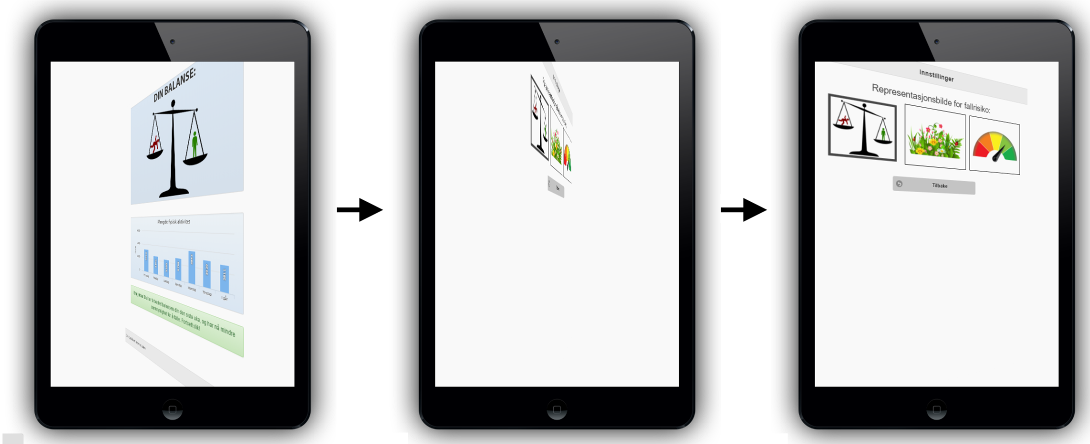

Figure 7.5: The flip transition when opening the settings page

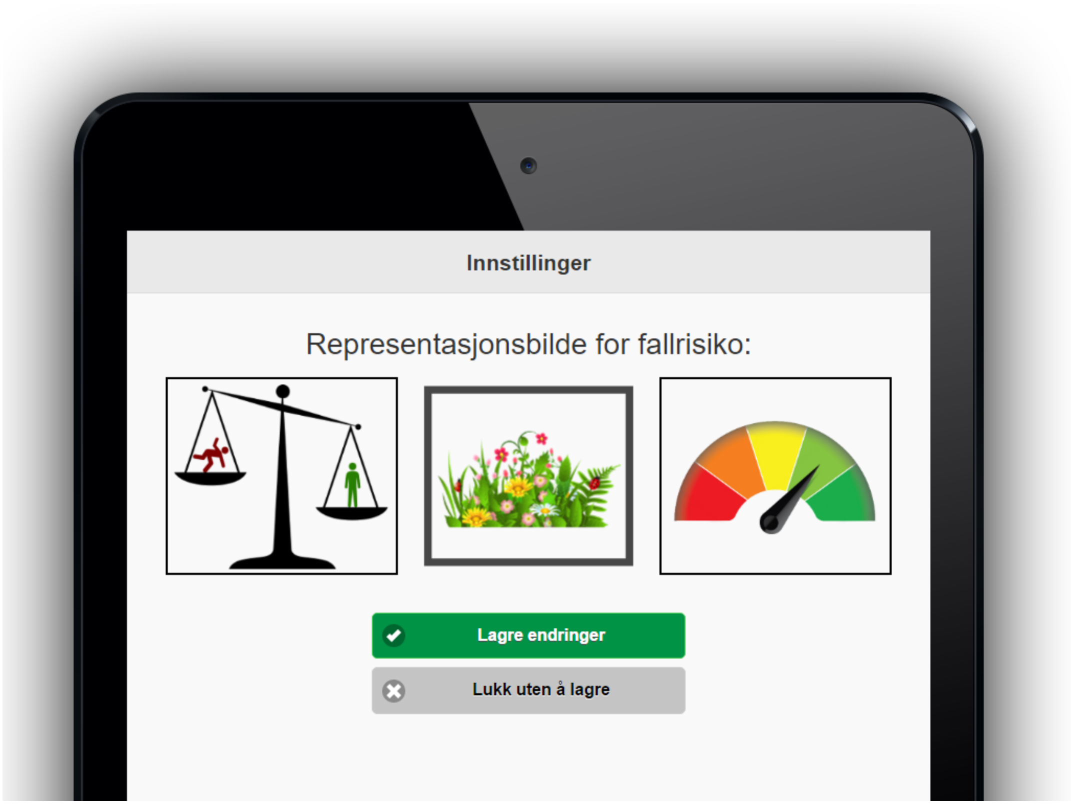

Figure 7.6: The settings page with selection of mobility index image

returned to the main page, using the flip transition. However, when a change has been committed, like the one described above, the back button is replaced with a *save* and a *discard and close* button. The *save* button does the same as the *back* button - the DOM has already been updated with the new settings when the image button was clicked. However, when the *discard and close* button is clicked, a dialog appears, asking the user to confirm this choice. If *no* is clicked, the dialog is closed, but if the user selects *yes*, the changes to the DOM is rolled back to the old settings, and the flip animation takes the user back to the main page.

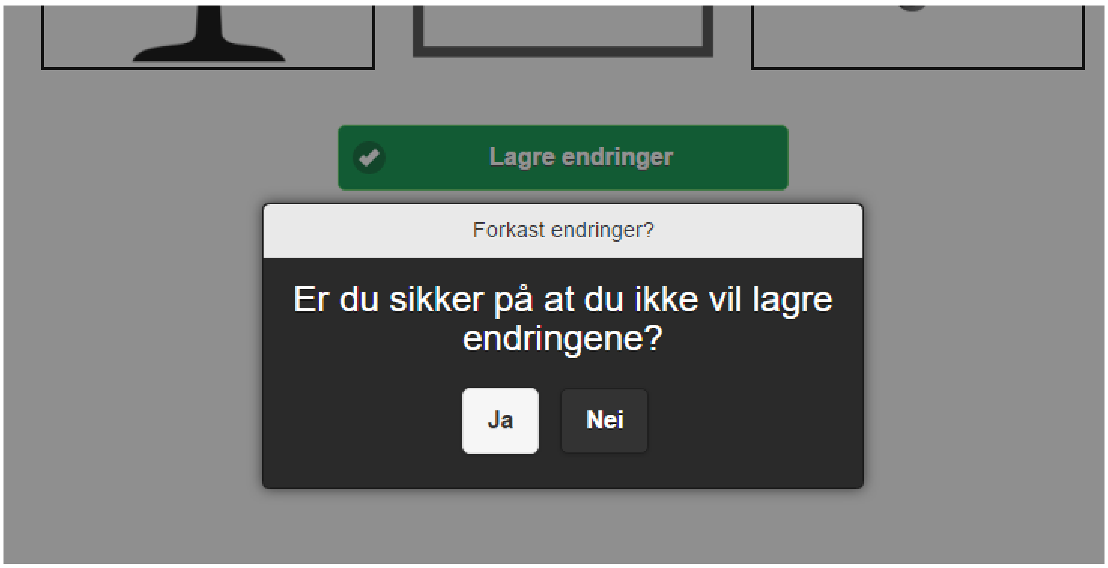

Figure 7.7: The confirm dialog when attempting to close settings page without saving

7.3.3 Web hosting

The project is hosted at GitHub.[1] Additionally, the webapp itself can be accessed online for testing[2]. Note that this site may not be updated to newer versions of the Adapt system after this thesis is submitted, as this site is hosted on the author's personal web hosting service, and is not controlled by the Adapt team. In that case, the newest version is available on the GitHub page.

[1] https://github.com/larstva/Adapt-frontend
[2] http://vavit.no/adapt/

7.4 Grounding in literature review findings

A system like Adapt would help prevent fall accidents in the future, which studies have found is something the elderly population values and leads to higher acceptance of ICT equipment [31, 33, 36, 37, 39, 45, 49, 51, 54, 56].

The system is designed in a way that does not require the user to leave the home or community where he/she lives to use the system, which gives the user more independence; a factor important to many elderly [33, 35, 37, 41, 46, 50]. The fact that the user interface is specifically tailored to the older adults, and displays the information in a simple and understandable way, means that the user can play a more active role in his/her own health situation by seeing the current status and suggestions for how to improve it. The literature review found that being able to manage their own health is seen as positive by older adults [31, 38, 40, 50, 52]. In two studies, some participants stated that they want to have the ability to access their own data collected from sensors [53, 56].

The web app is intentionally designed with few system functions and a simple user interface, as elderly users are more prone to cognitive overload than younger users, and too many system functions can lead to confusion [57].

The decision to fit all major elements of the web app on one page without the need to scroll or press buttons (except the settings button), was based on the large number of studies showing that the elderly population with functional limitations have trouble using ICT interfaces [32, 49, 50, 51, 54, 57].

8 Evaluation of concepts and prototype

This chapter presents a structured overview of the theoretical evaluation of the concepts and the prototype that was developed in the design phase of the project (i.e. ”Evaluation of concepts and prototype” and ”Evaluation results” in fig. 1.1).

Some evaluation was also presented in the description of the various concepts and prototype, but this was not very structured. Here, the evaluation tool presented in section 5.3 is used on each of the concepts and the prototype. Finally, the evaluation is summarised, and the different concepts are compared.

8.1 Evaluation of concepts

8.1.1 Concept A: Senor unit on everyday wearable objects

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The user is not geographically restricted while using the system, as long as the sensor unit connects to a device with Internet connection to send data with regular intervals. The system depends on the user wearing the sensor device regularly, but by placing the sensor on an object that the user puts regularly anyway, this issue is more or less eliminated.	**Yes**
Support social inclusion	No social functionality is provided, but the user is free to perform social activities while wearing the sensor unit.	**Indirectly**
Support health self-management	By using the sensor monitoring device, the system is able to calculate the user's mobility index and present this, along with other health-related data, back to the user.	**Yes**
Support safety and security	Long-term safely is increased by the collecting and analysis of movement data to detect and alert about potential high risk of falling. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	Other than needing to remember to charge the device, this concept presents no cognitive or physical challenges, as the sensor unit is attached to an object that the user is going to put on anyway.	**Yes**
Be unobtrusive	The sensor unit should be small enough, or well enough integrated into the wearable object, that the user is not even aware that it is there.	**Yes**
Require no prior tech. knowledge	Apart from needing to charge the sensor device, no user interaction is needed. The user only puts on the wearable object that has the sensor unit attached, and everything to do with sensor recording and data transmission happens 'behind the scenes'.	**Yes**
Social influence		
Peer acceptance and sigma	The sensor unit is small enough and attached to the other object in a way that makes it difficult to see, thus preventing peers from seeing that the user is using assistive technology.	**Yes**

Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only need to learn how to charge the sensor device, which will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the device malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	Provided the user charges and wears the sensor unit, the sensor should continuously gather and transmit data.	**Yes**
Price value		
Price value	This concept is significantly more expensive than the other sensor monitoring concepts. This is a result of the extra work required in designing and developing a solution that can be attached to everyday objects, while remaining small and unobtrusive.	**No**

Table 8.1: Evaluation of concept A

8.1.2 Concept B: Sensor unit with wristband

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The user is not geographically restricted while using the system, as long as the sensor device connects to a device with Internet connection to send data with regular intervals. However, the system depends on the user having to wear the sensor device regularly, which the user might see as a slight loss of independence.	**Partly**
Support social inclusion	No social functionality is provided, but the user is free to perform social activities while wearing the wristband.	**Indirectly**
Support health self-management	By using the sensor monitoring device, the system is able to calculate the user's mobility index and present this, along with other health-related data, back to the user.	**Yes**
Support safety and security	Long-term safely is increased by the collecting and analysis of movement data to detect and alert about potential high risk of falling. The concept could also be extended to include an alarm button (either physical or on-screen), although this would increase the complexity and cognitive challenge of using the device. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	Some users might have difficulty remembering to put on the wristband sensor, especially if they are not used to wearing a wristwatch or a similar wristband sensor. Charging the device is another factor easily forgotten by users. Also, some might have difficulty putting the wristband on due to reduced fine motor skill. Otherwise, this concept poses no major cognitive or physical challenges.	**Partly**
Be unobtrusive	Compared to a wristwatch/smartwatch, a wristband sensor does not show the time or offer any other functionality than to monitor movement, and might therefore be considered to be 'in the way' as the user gets no immediate value from wearing it.	**Yes**
Require no prior tech. knowledge	Apart from needing to charge the sensor device, no user interaction with the sensors is needed. The user simply puts on the wristband, and everything to do with sensor recording and data transmission happens 'behind the scenes'.	**Yes**
Social influence		

Peer acceptance and sigma	Some peers might see this as assistive technology, while others might see it as an activity tracker used for fitness purposes, given its similarity.	**Partly**
Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only need to learn how to charge the sensor device and put on the wristband, which will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the device malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	Provided the user charges and wears the wristband sensor, the sensor should continuously gather and transmit data.	**Yes**
Price value		
Price value	This type of sensor device is relatively cheap compared to most of the alternatives.	**Yes**

Table 8.2: Evaluation of concept B

8.1.3 Concept C: Sensors in clothing

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The user is not geographically restricted while using the system, as long as the sensor chip connects to a device with Internet connection to send data with regular intervals. However, the system depends on the user having to wear the sensor device regularly, which the user might see as a slight loss of independence.	**Partly**
Support social inclusion	No social functionality is provided, but the user is free to perform social activities while wearing the sensory piece of clothing.	**Indirectly**
Support health self-management	By using the sensor monitoring device, the system is able to calculate the user's mobility index and present this, along with other health-related data, back to the user.	**Yes**
Support safety and security	Long-term safely is increased by the collecting and analysis of movement data to detect and alert about potential high risk of falling. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	The user will have to remember to charge the sensor(s) embedded in the clothing. Also, users must remember to put on a piece of clothing that has a sensor embedded, and prevent the scenario of not wearing any sensory clothing. This issue could be solved if the user wears the same piece of clothing or clothing accessory every day, e.g. shoes. However, in many cultures it is not common to wear shoes indoors, and other pieces of clothing should not be worn for an extended period of time without being washed. Another solution would be to have sensors in enough of the user's clothing that whatever combination of clothing pieces the user chooses from his/her wardrobe, at least one of them have embedded sensors. This can, however, get very expensive. Otherwise, this concept poses no major cognitive or physical challenges.	**Partly**
Be unobtrusive	The sensor is not visible to the user, and is small enough not to be experienced as uncomfortable.	**Yes**
Require no prior tech. knowledge	Apart from needing to charge the sensor device(s), no user interaction with the sensors is needed. The user only puts on the piece of clothing, and everything to do with sensor recording and data transmission happens 'behind the scenes'.	**Yes**

Social influence		
Peer acceptance and sigma	The sensors are hidden from sight, so that peers cannot see that the user is using assistive technology.	**Yes**
Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only need to learn how to charge the sensor module(s), which will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If a sensor module malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	Provided the user wears at least one sensory piece of clothing with charged sensor module(s), the sensor(s) should continuously gather and transmit data.	**Yes**
Price value		
Price value	This form of sensor monitoring will be more costly than other alternatives, as few commercial products matching this description exist, and the senor modules will likely have to be created specifically for this purpose. Also, multiple pieces of clothing will often need to be equipped with sensors to get continuous monitoring.	**No**

Table 8.3: Evaluation of concept C

8.1.4 Concept D: Smartwatch as sensor unit

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The user is not geographically restricted while using the system, as long as the smartwatch connects to a device with Internet connection to send data with regular intervals. However, the system depends on the user having to wear the sensor device regularly, which the user might see as a slight loss of independence.	**Partly**
Support social inclusion	No social functionality is provided, but the user is free to perform social activities while wearing the smartwatch.	**Indirectly**
Support health self-management	By using the sensor monitoring device, the system is able to calculate the user's mobility index and present this, along with other health-related data, back to the user.	**Yes**
Support safety and security	Long-term safely is increased by the collecting and analysis of movement data to detect and alert about potential high risk of falling. The concept could also be extended to include an alarm button (either physical or on-screen), although this would increase the complexity and cognitive challenge of using the device. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Other	In addition to providing sensor monitoring of the user's movement, the smartwatch also shows the time. This is an extra utility that will likely increase the perceived usefulness of the system for many users, and can also be seen as a support for daily activities.	**Yes**
Effort expectancy		
Design for people with cognitive and physical impairment	Some users might have difficulty remembering to put on the smartwatch, especially if they are not used to wearing a wristwatch. Also, some might have difficulty putting the watch on due to reduced fine motor skill. Otherwise, the use of a smartwatch does not pose any cognitive or physical challenges.	**Partly**
Be unobtrusive	The smartwatch is designed like a normal wristwatch with a relatively small form factor. Thus, it should not be seen as bulky or obtrusive.	**Yes**

Require no prior tech. knowledge	Apart from needing to be charged, the smartwatch behaves just like a normal watch, and does not require any technical skill or knowledge. Everything to do with sensor recording and data transmission happens 'behind the scenes'.	**Yes**
Social influence		
Peer acceptance and sigma	The smartwatch appears like a normal watch, and thus, peers will not realise that it is used as assistive technology.	**Yes**
Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only need to learn how to charge the smartwatch, which will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the smartwatch malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	Provided the user keeps the smartwatch charged and wears it, the watch should continuously gather and transmit sensor data.	**Yes**
Price value		
Price value	A smartwatch is more expensive than other types of sensor monitoring, e.g. a wristband sensor described in *concept B: Sensor unit with wristband*, but is cheaper than creating an ICT solution developed and tailored specifically for sensor monitoring of seniors, e.g. *concept A: Senor unit on everyday wearable objects*.	**Partly**

Table 8.4: Evaluation of concept D

8.1.5 Concept E-1: Smartphone as sensor unit - lower back position

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The user is not geographically restricted while using the system, as long as the smartphone connects to the Internet to send data with regular intervals. However, the system depends on the user having to wear the sensor device regularly, which the user might see as a slight loss of independence.	**Partly**
Support social inclusion	No social functionality is provided (unless combined with *concept J: Social platform*), but the user is free to perform social activities while wearing the smartphone.	**Indirectly**
Support health self-management	By using the sensor monitoring device, the system is able to calculate the user's mobility index and present this, along with other health-related data, back to the user.	**Yes**
Support safety and security	Long-term safely is increased by the collecting and analysis of movement data to detect and alert about potential high risk of falling. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Other	As the smartphone is placed in a waist belt, it is highly inconvenient if the user wants to use the other functionality of the phone. This will reduce the perceived usefulness for users with high enough technological self-efficacy to utilize this functionality.	**No**
Effort expectancy		
Design for people with cognitive and physical impairment	Some users might have difficulty remembering to charge the phone, and/or to put on the belt, and thus preventing sensor data from being recorded. Otherwise, this concept poses no major cognitive or physical challenges.	**Partly**
Be unobtrusive	Wearing a waist belt with a smartphone for an extended period of time would undoubtedly feel unwieldy and uncomfortable for some users, especially compared to the alternative concepts presented here.	**No**

Require no prior tech. knowledge	Apart from needing to charge the smartphone, no user interaction with the phone itself is needed. The user simply puts on the waist belt with the phone attached, and everything to do with sensor recording and data transmission happens 'behind the scenes'.	**Yes**
Social influence		
Peer acceptance and sigma	Seeing a peer wearing a smartphone in a belt around the waist will in most cases immediately reveal that the user is using assistive technology, and can cause significant social stigma.	**No**
Influence from family	Although most family members will likely approve of the overall goal of the concepts of lowering the risk of falling, they might not prefer this solution over the alternatives, as it is not designed for the user to utilize the communication functionality offered in a smartphone, like phone calls and text messaging. This will make it more difficult for family members to get in contact with the user. However, this argument is irrelevant if the user does not have the required knowledge and technological self-efficacy to use this functionality. If this is the case, the user still needs to have a positive attitude towards using the service. If not, the user might use the pressured towards using the service without wanting to, lowering the acceptance.	**No**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only need to learn how to charge the smartphone and put on the belt, which will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the smartphone malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	Provided the user keeps the smartphone charged and wears the belt with the phone attached, the phone should continuously gather and transmit sensor data.	**Yes**
Price value		

Price value	A smartphone is more expensive than other types of sensor monitoring, e.g. a wristband sensor described in *concept B: Sensor unit with wristband*, but is cheaper than creating an ICT solution developed and tailored specifically for sensor monitoring of seniors, e.g. *concept A: Senor unit on everyday wearable objects*.	**Partly**

Table 8.5: Evaluation of concept E-1

8.1.6 Concept E-2: Smartphone as sensor unit - multiple positions

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The user is not geographically restricted while using the system, as long as the smartphone connects to the Internet to send data with regular intervals. However, the system depends on the user having to wear the sensor device regularly, which the user might see as a slight loss of independence.	**Partly**
Support social inclusion	No social functionality is provided (unless combined with *concept J: Social platform*), but the user is free to perform social activities while wearing the smartphone.	**Indirectly**
Support health self-management	By using the sensor monitoring device, the system is able to calculate the user's mobility index and present this, along with other health-related data, back to the user.	**Yes**
Support safety and security	Long-term safely is increased by the collecting and analysis of movement data to detect and alert about potential high risk of falling. The concept could also be extended to include an alarm button (either physical or on-screen), although this would increase the complexity and cognitive challenge of using the device. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Other	In addition to providing sensor monitoring of the user's movement, the user can also use the smartphone's primary functionality: making phone calls, communicating using SMS messages, and using other applications e.g. for communication or entertainment. This is an extra utility that will likely increase the perceived usefulness of the system for users with the technological self-efficacy to utilize this functionality, and can also be seen as a support for daily activities.	**Yes**
Effort expectancy		
Design for people with cognitive and physical impairment	Some users might have difficulty remembering to charge and/or put the smartphone near their body, and thus preventing sensor data from being recorded. Otherwise, this concept poses no major cognitive or physical challenges.	**Partly**

Be unobtrusive	A smartphone is a large device compared to other sensor devices, and can easily be perceived as too bulky and unwieldy to carry around all day. Many might also object to having to carry the phone close to their body, and not e.g. in a purse/bag, in a jacket pocket, or lying on a table while they move around the house, which might be perceived as more convenient and comfortable. However, users who are used to carrying a smartphone around e.g. in a trouser pocket, this will likely not be seen as obtrusive.	**Partly**
Require no prior tech. knowledge	If the phone is used only as a sensor device, the user only needs to worry about charging the phone. The sensor recording and data transmission happens 'behind the scenes', the phone automatically boots when being charged (when turned off/battery depleted), and the app responsible for sensor monitoring and transmission of the data, starts when the phone boots. If the user wants to use the other functionality of the phone, some experience with smartphones is recommended, but this is not part of this concept.	**Yes**
Social influence		
Peer acceptance and sigma	Smartphones have become common among all age groups, including seniors, and thus prevents peers from realising that the phone is used as assistive technology. The exception would be if peers realise that the user is not using the primary functionality of the smartphone, and are using it solely as assistive technology.	**Yes**
Influence from family	In addition to approving of the goal of lowering the risk of falling, most family members will likely prefer the senior user to choose a smartphone over other sensory devices, as this option offers additional communication functionality, that allows them to easily get in contact with the senior user. The user could, of course, use another type of sensor device and bring a phone as well, but it is more convenient to have both functions in the same device. This argument is only relevant if the user has the knowledge and technological self-efficacy to use the smartphone as a communication device. Either way, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**

Facilitating conditions		
Tailored training	The user need to learn how to charge the smartphone, and what position(s) on the body the smartphone can be placed for the system to gather analysable sensor data. This will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the smartphone malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	Provided the user keeps the smartphone charged and wears it close to the body, the phone should continuously gather and transmit sensor data.	**Yes**
Price value		
Price value	A smartphone is more expensive than other types of sensor monitoring, e.g. a wristband sensor described in *concept B: Sensor unit with wristband*, but is cheaper than creating an ICT solution developed and tailored specifically for sensor monitoring of seniors, e.g. *concept A: Senor unit on everyday wearable objects*.	**Partly**

Table 8.6: Evaluation of concept E-2

8.1.7 Concept F: Feedback through an app

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The app can be used from any location as long as it has an Internet connection. Also, by providing feedback about the fall risk and the amount of physical activity, the users are better informed to decide for themselves when they need to visit a doctor.	**Yes**
Support social inclusion	N/A (social functionality involving the feedback data is discussed in *concept J: Social platform*))	**N/A**
Support health self-management	The user will get feedback about the current risk of falling, as well as other monitored health data, and motivating messages for improving the mobility index.	**Yes**
Support safety and security	The feedback solution provides a level of safety in the sense that it informs the user of the current risk of falling, allowing the user to take action to prevent future fall injuries. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	An app might not be a good solution if the user has significant cognitive impairment, as the user needs to remember to regularly charge the device, and remember several steps needed to open the app and get the feedback information. Also, users with physical impairments might find the screens of the devices challenging to interact with, especially on smaller smartphone models. Tablets have the advantage of a smaller screen, but is more of a hassle to move around with due to its larger form factor.	**No**
Be unobtrusive	Unless this concept is combined with *concept E: Smartphone as sensor unit*, the users do not need to keep the mobile device close to the body, and are free to keep the phone wherever they prefer. This makes it much less obtrusive.	**Yes**
Require no prior tech. knowledge	It is recommended to have basic knowledge of how a smartphone/tablet works before using the system, as the learning curve may be quite steep otherwise, and the user could have trouble navigating the operative system menus and might even 'get lost' trying to open the app.	**No**
Social influence		

Peer acceptance and sigma	Smartphones and tablets have become common among all age groups, including seniors, and thus prevents peers from realising that the device is used as assistive technology. The exception would be if peers realise that the user is not using the primary functionality of the device, and are using it solely as assistive technology.	**Yes**
Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only needs to learn the basics of how to charge and interact with the mobile device, and how the feedbackapp works. This will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the device malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	As long as the user keeps providing data about their physical activity and movement, the system will provide feedback and motivating messages.	**Yes**
Price value		
Price value	A smartphone or tablet is fairly costly to purchase to use primarily as a feedback device, but many seniors already own a smartphone, and it can also be used as a sensor unit if this concept is combined with *concept E: Smartphone as sensor unit.*	**Partly**

Table 8.7: Evaluation of concept F

8.1.8 Concept G: Feedback through a touchscreen in the home

Mechanism	Connection	Supported
Performance expectancy		
Support independence	By providing feedback about the fall risk and the amount of physical activity, the users are better informed to decide for themselves when they need to visit a doctor. However, as the screen is wall-mounted, it is restricted to the house and the user cannot get feedback from the system while being elsewhere. The user can still use the sensor monitoring aspect of the system from any location, but needs to go home to see the feedback about the activity.	**Partly**
Support social inclusion	N/A (social functionality involving the feedback data is discussed in *concept J: Social platform*)	**N/A**
Support health self-management	The user will get feedback about the current risk of falling, as well as other monitored health data, and motivating messages for improving the mobility index.	**Yes**
Support safety and security	The feedback solution provides a level of safety in the sense that it informs the user of the current risk of falling, allowing the user to take action to prevent future fall injuries. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	The system is designed to work without user interaction, and the device is connected to a power outlet, so the user does not need to worry about charging. Also, the screen is fairly large, to help users with physical impairment, like poor eyesight, better see the feedback messages.	**Yes**
Be unobtrusive	The wall-mounted touchscreen is not primarily designed to be unobtrusive, but rather to present the user with feedback without needing any user interaction. The screen should obviously be placed in the part of the home where the user prefers it to be, thus reducing the level of obtrusiveness somewhat.	**No**
Require no prior tech. knowledge	The screen should present feedback without requiring any user interaction or relevant knowledge.	**Yes**

Social influence		
Peer acceptance and sigma	Visitors to the user's home might see the wall-mounted touchscreen and the information it presents. This might cause some stigmatization, which can be prevented by setting the screen to black after a few seconds of inactivity, and turn back on when the screen is touched.	**Partly**
Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only need to learn how the feedback app works, which will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the device malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	As long as the user keeps providing data about their physical activity and movement, the system will provide feedback and motivating messages.	**Yes**
Price value		
Price value	Depending on the solution, the concept could be quite costly. For instance, a tablet would cost significantly more than a solution like the Raspberry Pi Touch Display [70].	**Partly**

Table 8.8: Evaluation of concept G

8.1.9 Concept H: Feedback using audio

Mechanism	Connection	Supported
Performance expectancy		
Support independence	Provided the audio feedback solution has an Internet connection, it can be used from any location. Also, by providing feedback about the fall risk and the amount of physical activity, the users are better informed to decide for themselves when they need to visit a doctor.	**Yes**
Support social inclusion	N/A (social functionality involving the feedback data is discussed in *concept J: Social platform*)	**N/A**
Support health self-management	The user will get feedback about the current risk of falling, as well as other monitored health data, and motivating messages for improving the mobility index.	**Yes**
Support safety and security	The feedback solution provides a level of safety in the sense that it informs the user of the current risk of falling, allowing the user to take action to prevent future fall injuries. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	The device is ideal for users with physical impairment (provided this impairment is not with the user's hearing), as there are no screens to view or buttons to press (except a button to activate audio feedback, if no voice recognition solution is implemented). Using voice recognition, the problem of remembering which buttons to press in order to achieve certain functionality is also eliminated - instead the user can simply ask the device for information. The only major cognitive issue is to remember to charge the device.	**Yes**
Be unobtrusive	The device is designed to have a small form factor and not be obtrusive.	**Yes**
Require no prior tech. knowledge	The device is designed to not require any technological knowledge to use.	**Yes**
Social influence		
Peer acceptance and sigma	The level of stigma depends on the way the audio is played. A bone conduction transducer would not cause any stigma, while a speaker can cause significant stigma, and should only be used when the user is alone or is comfortable with the other people present hearing the audio feedback.	**Partly**

Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only need to learn how they should interact with the system in order to get audio feedback. This will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the device malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	As long as the user keeps providing data about their physical activity and movement, the system will provide feedback and motivating messages.	**Yes**
Price value		
Price value	The cost of this concept varies depending on how it is implemented, as it presents several alternative ways to achieve audio feedback. However, anything but the most basic implementation (pressing a button to get pre-recorded voice messages) would involve much work to develop, and will thus be costly. Also, the hardware cost will be significant if a technology such as a bone conduction transducer is used, compared to a speaker or earphones.	**No**

Table 8.9: Evaluation of concept H

8.1.10 Concept I: Feedback using SMS

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The SMS service can be used anywhere, as long as there is cellular network coverage. Also, by providing feedback about the fall risk and the amount of physical activity, the users are better informed to decide for themselves when they need to visit a doctor.	**Yes**
Support social inclusion	N/A (social functionality involving the feedback data is discussed in *concept J: Social platform*)	**N/A**
Support health self-management	The user will get feedback about the current risk of falling, as well as other monitored health data, and motivating messages for improving the mobility index.	**Yes**
Support safety and security	The feedback solution provides a level of safety in the sense that it informs the user of the current risk of falling, allowing the user to take action to prevent future fall injuries. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	The phones need to be charged regularly, and has often a less intuitive menu system than smartphones, which can be a challenge for cognitively impaired users. Typically, these phones also have relatively small screens and buttons, making it harder to use for the physically impaired.	**No**
Be unobtrusive	Many older/basic phone models are generally smaller than smartphones. The users also have the freedom to place the phone wherever they want.	**Yes**
Require no prior tech. knowledge	Apart from knowing how to read SMS messages, which is assumed for the users in this concept, no further technological knowledge is required.	**Yes**
Social influence		
Peer acceptance and sigma	Basic ('non-smart') phone models are very common among seniors, and a user should not feel stigmatized by using such technology.	**Yes**

Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of family members will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	N/A. This concept targets users who are already using SMS text messaging and are familiar with how it works.	**N/A**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the device malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	As long as the user keeps providing data about their physical activity and movement, the system will provide feedback and motivating messages.	**Yes**
Price value		
Price value	Since basic mobile phones are already widely adopted among seniors, the service provider would not need to purchase more advanced devices, e.g. smartphones. There will be some costs for the service provider associated with the sending of large numbers of SMS messages, but this will be a small sum compared to having to buy hardware for each user.	**Yes**

Table 8.10: Evaluation of concept I

8.1.11 Concept J: Social platform

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The level of geographical freedom related to accessing the social functionality varies depending on the device used (see earlier concepts). However, the system encourages the user to participate in social activities and group exercises, and is thus supporting independence.	**Yes**
Support social inclusion	The essence of this concept is to integrate a social aspect into the fall risk assessment system, aiming at motivating the users to be more physically active by participating in group activities or competing with other users, in addition to facilitating social activity in general.	**Yes**
Support health self-management	N/A. The functionality for managing own health is not related to the socialization functionality.	**N/A**
Support safety and security	By facilitating more social activity and communication between peers, there is a higher chance that emergencies and emerging illnesses will be discovered and help is provided, than if the user often is all alone in his/her home without much interaction with other people.	**Yes**
Effort expectancy		
Design for people with cognitive and physical impairment	N/A. The different physical devices and interfaces that can be used to access the social functionality are described in the previous concepts.	**N/A**
Be unobtrusive	N/A. The different physical devices and interfaces that can be used to access the social functionality are described in the previous concepts.	**N/A**
Require no prior tech. knowledge	N/A. The different physical devices and interfaces that can be used to access the social functionality are described in the previous concepts.	**N/A**
Social influence		
Peer acceptance and sigma	The participation in social activities is essential to peer acceptance. Since all the users of the system are in the same situation (in risk of falling), no stigmatization should occur.	**Yes**

Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. Also, they will likely approve of the idea of facilitating socialization with peers. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. Also, they will likely approve of the idea of facilitating socialization with peers. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	N/A. The different physical devices and interfaces that can be used to access the social functionality are described in the previous concepts.	**N/A**
Tailored help and support	N/A. The different physical devices and interfaces that can be used to access the social functionality are described in the previous concepts.	**N/A**
Continuous service provision	N/A. The different physical devices and interfaces that can be used to access the social functionality are described in the previous concepts.	**N/A**
Price value		
Price value	N/A. The different physical devices and interfaces that can be used to access the social functionality are described in the previous concepts.	**N/A**

Table 8.11: Evaluation of concept J

8.2 Evaluation of prototype

Mechanism	Connection	Supported
Performance expectancy		
Support independence	The user is not geographically restricted while using the system, as long as the device (smartphone, tablet, computer etc.) has an Internet connection when the user accesses the webapp. Also, by providing feedback about the fall risk and the amount of physical activity, the users are better informed to decide for themselves when they need to visit a doctor.	**Yes**
Support social inclusion	The prototype does not have any functionality for socialization, as the Adapt team stated that this was not a priority at this time. However, the user is free to perform social activities while using the system.	**Indirectly**
Support health self-management	The user will get feedback about the current risk of falling, as well as other monitored health data, and motivating messages for improving the mobility index.	**Yes**
Support safety and security	The feedback solution provides a level of safety in the sense that it informs the user of the current risk of falling, allowing the user to take action to prevent future fall injuries. On the other hand, the health data about the user can be accessed by fall risk assessors and others with access privileges, which the user might not be comfortable with, and thus lower the acceptance.	**Partly**
Effort expectancy		
Design for people with cognitive and physical impairment	Users with a physical impairment may choose to use the web app with a device more tailored to their impairment, e.g. a tablet instead of a smartphone for people having trouble seeing the text on a small screen, or pressing small on-screen buttons. However, the web app might cause problems for users with cognitive impairment, as the user might forget the process of opening the webapp, what the representations of data means. This effect could be counteracted by providing a basic manual and on-screen help/tutorial. Also, if the user is using a mobile device, the user needs to remember to charge it.	**Partly**
Be unobtrusive	The user may choose to view the web app on a small device if this is preferred, and the device does not need to be in a specific location - the user can move it around freely to the least obtrusive location.	**Yes**

Require no prior tech. knowledge	It is recommended to have basic knowledge of how a smartphone/tablet works before using the system, as the learning curve may be quite steep otherwise, and the user could have trouble navigating the operative system menus and might even 'get lost' trying to open the app. However, the app itself is designed to be as user-friendly as possible to users with no technological experience, with no need to interact with the screen at all except when changing settings.	**Partly**
Social influence		
Peer acceptance and sigma	Smartphones, tablets and computers have become common among all age groups, including seniors, and thus prevents peers from realising that the device is used as assistive technology. The exception would be if peers realise that the user is not using the primary functionality of the device, and are using it solely as assistive technology.	**Yes**
Influence from family	On a general level, family members will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Influence from doctors and service providers	On a general level, healthcare providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their patients. However, the affect on acceptance depends on the user's attitude towards the idea. If the user is already positive, the approval of a doctor or service provider will likely further increase acceptance. However, if the user does not want to use the ICT solution, but feels pushed towards using it, acceptance will be low.	**Depending**
Facilitating conditions		
Tailored training	The user only needs to learn the basics of how to interact with the device, and how the web app works. This will be explained and demonstrated thoroughly, and the users should have the opportunity to ask questions in case anything is unclear.	**Yes**
Tailored help and support	The user can contact a support team over the phone during normal business hours, or consult a supplied manual. If the device malfunctions or the user has another problem that cannot be solved on his/her own, a member of the support team can come to the user's home.	**Yes**
Continuous service provision	As long as the user keeps providing data about their physical activity and movement, the system will provide feedback and motivating messages.	**Yes**
Price value		

Price value	A webapp has the advantage of working both on mobile devices and a desktop/laptop computer. It is probable that some of the users already own at least one of these types of devices, reducing the need to purchase new devices for this purpose.	**Yes**

Table 8.12: Evaluation of the prototype

8.3 Summary and comparison

This section presents a summary of the evaluation results, and the different concepts are compared to highlight the strengths and weaknesses of each concept.

Firstly, note that the decision to develop the prototype as a web app was made by the Adapt team, and neither the design of the concepts nor the evaluation of these factored into this decision. Thus, the prototype was not chosen to be implemented as a web app based on any evaluation of alternative solutions (at least not that is presented in this thesis) - it was simply the wish of the Adapt team for this author to develop a web app.

8.3.1 Similarities among concepts

Several of the mechanisms from the UTAUT2 mapping model have very similar or even identical evaluation against them from all of the concepts and the prototype. These are summarised below.

8.3.1.1 Support social inclusion

None of the sensor monitoring concepts (A-E) or feedback concepts (F-I) include any functionality that facilitates socialization. Instead, a separate concept describes the social functionality that could be integrated into the system. *Concept J: Social platform* obviously support the *Support social inclusion* mechanism, but also the sensor monitoring concepts can be seen as supporting socialization, by allowing the user to socialize while the sensor device collects data.

8.3.1.2 Support health self-management

All the concepts, including the prototype, support health self-management. One of the core requirements for the Adapt system is to give the users access to see their own mobility index and other related health data.

8.3.1.3 Support safety and security

All the concepts facilitate long-term safety by either collecting and analysing movement data, or by giving feedback about fall risk to the user. In the case of *concept J: Social platform*, more social interaction increases the chance of emergencies being detected.

However, this functionality also involves that fall risk assessors and others who might have been granted access can see to the health data about each user. This could be seen as an invasion of privacy by some users, and thus lower the acceptance.

8.3.1.4 Influence from family & Influence from doctors and service providers

The factors of social influence from family and doctors/service providers were also evaluated the same way for all concepts and the prototype: both family members, doctors and service providers will in most cases encourage the use of an ICT solution that aims at preventing fall-related injuries to their elderly family member, as they will all generally have the user's best interests at heart.

In addition, in the case of the socialization concept, they will all likely approve of the idea of facilitating socialization with peers. The exception to this would be *concept E-1*, where the phone is put in a waist belt. This does not facilitate the use of the smartphone for communication, which some family members might object to, as most wish to be able to easily get in touch with the user. *Concept E-2*, however, has the opposite effect, further increasing the approval of the family members as the concept entails convenient communication with the user.

But the way these stakeholder influence acceptance depends greatly on the attitude of the intended user towards the ICT service. If the user has a positive or neutral attitude towards using it, the approval of others will in most cases further increase acceptance. However, if the user does not really want to use the service (e.g. if he/she does not perceive any value from wearing a sensor device), but feel pressured towards using it because it pleases the family members/doctor/service provider, acceptance will be low.

8.3.1.5 Tailored training

Most of the concepts require fairly little training, as most were designed to be intuitive and require little user interaction, but it is nonetheless assumed that thorough explanations and demonstrations will be provided by an instructor, and the users should have the opportunity to ask questions in case anything is unclear. The exception is *concept I: Feedback using SMS*, where it is assumed that the user is already familiar with this technology. The reasoning for this is that if the user does not know how to read SMS messages, but is still insistent on wanting to use the system, the user should be instructed how to use a more modern and provident solution than the fairly old and limited SMS technology.

8.3.1.6 Tailored help and support

For all the concepts, it is assumed that the future Adapt service will have a support team that can answer questions over the phone during normal business hours, and can also visit the user in his/her home if a problem cannot be solved over the phone.

8.3.1.7 Continuous service provision

Here, the evaluation is also the same for all concepts plus the prototype: the system will be operational and feedback will be provided to the user as long as the user uses the sensor device correctly, i.e. keeps it charged, has it turned on, and places it in a correct position.

8.3.2 Differences among concepts

8.3.2.1 Support independence

All the feedback concepts and the prototype all increases independence by providing the user with data about the fall risk and the amount of physical activity, which enables the user to make an informed decision on whether or not to visit a doctor.

Having the freedom to move around geographically is also a theme here. Except for one concept, all the concepts and the prototype can be used in any geographic location, as long as it has an Internet connection to send/receive data. The concept in question is *concept G: Feedback through a touchscreen in the home*, which restricts the user geographically to the stationary position of this touchscreen inside the user's home. The user can of course leave the house, but need to come back to see the feedback from the physical activity that is performed.

Also, the sensor monitoring concepts vary slightly in another way that is relevant to this mechanism. With all these devices, the user is required to wear the sensor in order for the system to function. Some users could see this requirement to put on a sensor monitoring device on a regular basis as a loss of independence. However, *concept A* describes a solution where the sensor is attached to an object that the user will put on anyway (e.g. glasses), and thus making this barrier fairly irrelevant.

8.3.2.2 Design for people with cognitive and physical impairment

The different concepts differ considerably when it comes to this factor. All the devices except the wall-mounted touchscreen requires the user to remember to charge it regularly. For some concepts, this is the only drawback relating to this mechanism, like *concept A: Senor unit on everyday wearable objects* and *concept H: Feedback using audio*.

A common issue is to remember to put the sensor device on, which is the case for all sensor monitoring concepts except *concept A: Senor unit on everyday wearable objects*. Some might also have difficulty managing to put these sensor devices on due to reduced fine motor skill.

There are also some concepts with more unique issues here, like making sure to wear a piece of clothing that has sensors embedded (*concept C: Sensors in clothing*), and having more challenging interaction design solutions (*concept I: Feedback using SMS*).

The web app developed in the prototype implementation has the advantage of being compatible with different types of mobile devices in addition to standard computers, allowing users to access the web app with the device that are best suited for their impairment, if they have any.

8.3.2.3 Be unobtrusive

The wall-mounted touchscreen described in *concept G*, as well as the waist belt in concept E-1, are considered fairly obtrusive as they are both fairly large and hard to conceal.

All the other concepts concerning physical devices (which is all of them except *concept J*) and the prototype, are all using devices that are relatively small and easy to conceal if desired, making these less obtrusive.

8.3.2.4 Require no prior tech. knowledge

Most of the concepts require no technological knowledge or experience to use. The exception is when the user needs to use the interface of a mobile device, like a smartphone or a tablet to access information, like in *concept E: Smartphone as sensor unit* and the prototype. In this case, it is an advantage to have some experience using such devices, to avoid a too steep learning curve. It is also a bonus if the user knows how to charge the device, but this can be easily learned before starting to use the service.

8.3.2.5 Peer acceptance and sigma

Most concepts aim to use devices that are small and concealable, and/or commonly used among this user group, as to not be perceived as assistive technology by peers. However, if peers realise that the user is using the device, e.g. a smartphone or a tablet, purely as an assistive technology (not using functionality like e.g. phone calls on a smartphone), stigmatization may occur.

Also, for some of the concepts, the level of peer acceptance and stigma will depend on how the user uses the device(s) described in the concept. For instance, if the user wears the waist belt from concept E-1 in a way that is visible to others, or uses the speaker functionality from *concept H: Feedback using audio* in public, some degree of stigmatization will likely occur.

8.3.2.6 Price value

The cost of the various concepts varies significantly. The most important moderating factor for the cost is whether the hardware used is commercially available, or if it is a product that needs to be custom built specifically for this purpose. The advantage of the latter is, obviously, that it can be tailored to this specific use case, and have the functionality, form factor, and other attributes as requested by the end users.

Some of the concepts, like *concept A: Senor unit on everyday wearable objects*, *concept C: Sensors in clothing*, and *concept H: Feedback using audio*, describes products that are not commonly available on the current market, but should still be feasible to develop today or in the near future. These will, however, be considerably more costly to develop than commercially available products.

Generally, there is a correlation between the cost and the acceptance of the product. Thus, the service providers need to evaluate how much they are willing to fund a given project in order to achieve high acceptance.

8.3.2.7 Other *performance expectancy* factors

Some of the concepts were further evaluated against the *performance expectancy* construct, as they had some unique qualities or drawbacks that did not fit with any other mechanism.

Concept D: Smartwatch as sensor unit provides the extra utility of showing the user the time without requiring any addition user interaction. This increases the perceived usefulness of the system, and can also be seen as a support for daily activities.

The two variations of *concept E: smartphone as a sensor unit* differs in the way they facilitate the utilization of the other functionality of the phone, like making phone calls. Concept E-1 makes this hard, as the phone has to be placed in a waist belt to perform monitoring, and it is inconvenient to take it out and put it back for each time the phone is used.

Concept E-2, however, facilitates the use of these other functions, increasing the perceived usefulness of the system for users with the technological self-efficacy to utilize this functionality.

8.4 Discussion of evaluation

8.4.1 Concepts

It is hard to rank the different concepts by which one is best suited for achieving acceptance, as they all have strengths and weaknesses. It is important to consider the personal preferences of the end users, and how important each of the mechanisms discussed above are to them. For instance, some users might not mind using technologies that causes stigmatisation, as they value the benefit they get from using the service more. The cost is another factor that can have vastly different importance to users, depending on their financial situation (for this factor to affect acceptance, we assume the end users need to pay for the service themselves).

Ideally, the users should be presented with the choice between several of the solutions presented here, to better satisfy the different needs and requirements of the different individual users. However, this will in most cases not be feasible due to economic and development time restrictions.

If one sensor monitoring concept has to be recommended, it is the opinion of this author that this will be *concept A: Senor unit on everyday wearable objects*. Despite having a high cost compared to the alternatives, it is believed that the benefit of removing the hassle and cognitive issue of remembering to put on a separate monitoring device, especially over a long period of time, will greatly increase the acceptance and uptake of the device.

As for the feedback device, *concept F: Feedback through an app* is probably the best option for most users. Despite requiring a certain level of user interaction and knowledge to utilize, the device is small and does not cause stigmatization, and can be used in any geographic location that has an Internet connection.

The social functionality described in *concept J: Social platform* should also be implemented in the app, as this will likely be a major motivator to use the service for many users.

8.4.2 Prototype

The evaluation of the prototype shows that it relates well to most of the mechanisms, but some of them could be better supported.

Currently, no social functionality is incorporated into the prototype, and the Adapt team has stated that this is not a priority at this stage in the project. However, it is desired that such functionality should be added before the launch of the system to the public.

Using a web app means the user will need to have basic knowledge of how to operate the device used to access it, typically either a smartphone, a tablet, or a computer. All of these could be unfamiliar technology to some seniors. Also, some users might have trouble remembering how to use the service properly: how to open the web app, how to interpret the illustrations used to represent the fall risk, and, in the case of mobile devices, how to charge the device.

Other than these mentioned factors, the prototype appear to score relatively high in the theoretical evaluation.

Part IV

Conclusion

9 Conclusion

This chapter presents a discussion of the findings and the work conducted throughout the entire master's thesis project. The limitations of the research are listed, and a number of suggestions for further work on this topic is presented.

9.1 Discussion

During the literature review, a large amount of empirical evidence about acceptance and older adults was analysed and summarized in this thesis. This knowledge proved very useful for the remainder of the study, both in aiding the author in the creation of relevant concepts and the prototype, and, obviously, in the creation of the theoretical evaluation tool.

This tool could potentially be very useful, especially for healthcare service providers who are tasked with finding new ICT solutions to deal with the growing number of senior citizens in many parts of the world. For them, it is of great importance that the ICT solutions that are developed will be accepted by the end users, to avoid economic losses and not being able to help the senior citizens in need of assistive technologies.

An evaluation tool like the one presented here, could be used to assess different alternatives to design of a system early on in the process. Thus, the stakeholders can easily get a picture of which solutions are most likely to be accepted by the end users.

Developing an acceptance model specifically for ICT use among elderly would further facilitate this. By doing the mapping to UTAUT2 and presenting how the findings correspond to the existing model, some indications are provided showing how it might be adapted to work for an older age group (see also *section 9.3: Further work*).

9.2 Limitations

In the coding phase of the systematic literature review, both authors should ideally have cooperated in this work. However, this would have proven difficult to manage, given the limited time of the co-author, who was occupied with several other research projects at SINTEF.

9.3 Further work

By continuing the research on this topic, a theoretical framework for ICT acceptance specifically tailored to the needs of the older adults could be developed. This could serve as a great tool for everyone who develop ICT solutions for older adults.

However, this would probably require an even more thorough review of existing data. Here, the scope should be broader than in this review, e.g. by searching more databases, including other publications than journal articles, and including quantitative research.

Also, several of the findings in this review are based on older adults' opinions about health ICT and its effect on their lives, rather than real-life experience with such technologies. More research where the older adults actually use different types of health ICT solutions should therefore be done to get even more rigorous data.

Creating an acceptance model for ICT use among older adults would be a valuable tool for researchers and practitioners working with ICT systems for older adults. The mapping to UTAUT2 (presented in section 5.1) presents some improvements to this model, and is thus a step in this direction, but much more research is required in order to create a specialized and operationalized model.

The evaluation questionnaire presented in this thesis should be altered to ask for a numerical value for each row, and a formula should be created to calculate a total acceptance score for the concept being evaluated. Also, each mechanism should have a question that the evaluator answeres, e.g. "*To what extent does the technology support independence?*".

In the case of the Adapt project, the work done in the design phase should be empirically evaluated and compared to the theoretical evaluation, to get more data on the evaluation method used and the way acceptance is assessed. This empirical evaluation could be a part of the workshop planned by the Adapt team. Ideally, data from such an evaluation should have been presented in this thesis, but unfortunately, the Adapt team was unable to organize the workshop before the deadline of this thesis.

During the development of the Adapt system, user-centred design should be used in order to get regular feedback from the potential users. This will hopefully result in a final system that is well accepted by the end users, and new knowledge in the field of ICT acceptance might also be gained in the process.

The prototype version of the front-end of the Adapt system needs considerably more work before it is complete. Currently, a list of issues on the GitHub page[1] lists what needs to be done. Functionality that ought to be included before the service is launched, but has low priority for the trial period, includes some form of social functionality, e.g. like described in *concept J: Social platform*.

[1] `https://github.com/larstva/Adapt-frontend`

Part V

Appendices

A | Systematic literature review

This appendix presents the systematic literature review that was the product of the first phase of the thesis project. The version presented is the one which was submitted to the IJHCI on 1 May 2016.

Acceptance of health-related ICT among elderly people living in the community: A systematic review of qualitative evidence

Lars Tore Vassli, Norwegian University of Science and Technology, Trondheim, Norway, larstva@stud.ntnu.no

Babak Farshchian, Stiftelsen SINTEF Trondheim, Norway, Babak.Farshchian@sintef.no

Abstract

There is a growing number of seniors and a growing need for healthcare ICT solutions to allow them live independently in their own homes. We need to have a better understanding of how and why seniors use or do not use healthcare-related ICT in order to be able to improve our solutions. In order to synthesise existing knowledge we did a systematic literature review using Scopus and PubMed. Our search was limited to secondary studies, and primary qualitative studies. 11 review articles and 31 primary research articles were included in the study. We structured our findings using the UTAUT2 acceptance model. Our findings show that seniors want health ICT that gives them independence, safety and security, allows them to socialize, manage their own health, aid them in their daily activities. They need to easily get help if they have problems using the service, tailored training, and help during use. Lack of privacy and safety, and stigma are some of the reported barriers. More research needs to be done in order to develop a specialized and operationalized acceptance model for ICT use among seniors. Our mapping to UTAUT2 is a step in this direction, and suggests some improvements to this model.

Keywords: Acceptance; older adults; health ICT; community-dwelling; UTAUT2

1. Introduction

Western populations are undergoing radical demographic changes. The proportional number of elderly citizens is increasing because of increased life expectancy and reduced birth rates. By 2050, the number of people aged 60 or above is expected to more than double, and the number of people over 80 is expected to triple, compared to 2015 (United Nations, 2015). These demographic changes have profound consequences for healthcare systems. These systems are already under pressure because of the prevalence of non-communicable diseases, increased expectations from the citizens, and the large variety of costly interventions that are in demand. As we age, our needs for healthcare and wellbeing services also increase. We need innovative solutions that will allow us to restructure our healthcare systems and think differently about how we will provide healthcare services in the future.

One of the structural changes within healthcare has been to distribute health- and care-related duties into community and home. A number of these services are now partly provided at home. This is in particular true of elderly and people with chronic diseases. Studies have shown that elderly want to live in their own home or residence of choice for as long as possible, thus maintaining their independence (DeJonge, Taler, & Boling, 2009). By enabling the elderly to stay safely in the community for a as long as possible, the society as a whole also benefits economically, as there is less need to increase capacity and workers in nursing homes and institutions (Mostashari, 2011).

One way to accomplish this "aging in place" is to utilize innovative technologies in order to assist elderly who would have needed healthcare support otherwise. Fitness-related technologies can be used to keep elderly physically active. Social computing can be used to facilitate social interaction in local communities and with family members. Sensors can be used to monitor health conditions and dispatch help in emergency cases. Large public initiatives, such as the Active and Assisted Living (AAL) research program funded by the European Union, are trying to apply ICT solutions to address the consequences of an aging population.

One of the challenges of using innovative ICT solutions to assist elderly to live independently is related to the acceptance of the ICT solutions. The current generation of frail elderly are not affluent users of technologies such as wearables and social computing. We can assume that this situation will change in the near future, as baby boomers seem to value mobile data services more (Yang & Jolly, 2008). However, there are also other aspects of aging that can affect ICT acceptance. No matter how motivated or trained elderly are in using ICT, physiological and biomechanical changes that are a natural part of the aging process will put limitations on the use of technology (Farshchian & Dahl, 2015). Moreover, the underlying values held by elderly can be different from those of healthcare providers. This might apply to e.g. time to learn to use a system, privacy, and perceived benefit.

Our understanding of the parameters that influence ICT acceptance among elderly is limited. Generic acceptance models—such as the UTAUT2 model (Venkatesh, Thong, & Xu, 2012) referred to in this article—do not teach us much about the specific aspects of ICT acceptance among elderly. A number of systematic reviews of literature exist (we provide an overview in the next section). However, the majority of these reviews focus on impact analysis. They tell us what works or not, but say little about why or how some technology is accepted or rejected by elderly. There is an emerging literature of qualitative studies of ICT acceptance among elderly—the focus of our research—which is not available to researchers in a synthesized form.

Our research question is: *What empirical evidence from qualitative research do we have regarding the acceptance of health-related ICT among elderly people living in the community?* As a theoretical framework for analysing and representing our results we have used the UTAUT2 (Unified Theory of Acceptance and Use of Technology 2) model of technology acceptance, devised by Venkatesh et al. (2012). This is an extension of the original UTAUT model (Venkatesh, Morris, Davis, & Davis, 2003), which described acceptance and use of technology in an organizational context. UTAUT2 extends UTAUT to make it fit a consumer context. The UTAUT2 model is illustrated in *Figure 1* below. We believe this model provides a suitable framework for structuring our findings. It is widely used, is easy to understand, and takes into account both organizational and consumer-oriented aspects of ICT acceptance.

However, although according to the model age is a contributing parameter to acceptance of ICT, UTAUT2 does not go into details of how this contribution is distributed. We aim to identify mechanisms that affect the constructs identified in UTAUT2, in the context of older adults living in the community, and using health ICT. This is similar to the mechanisms presented in the proposed extension of UTAUT2 in a healthcare context by Slade et al. (Slade, Williams, & Dwivedi, 2013), but limited to older adults living in the community.

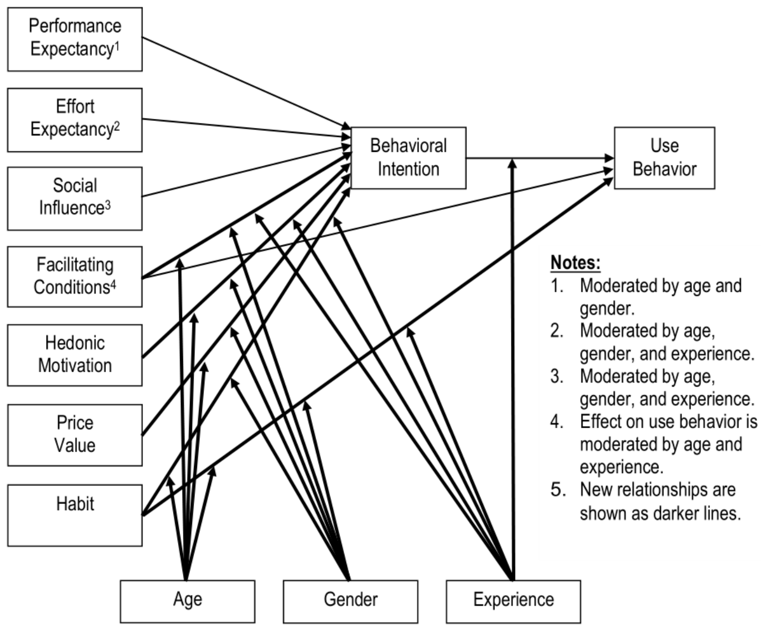

Figure 1: UTAUT2 Model

The rest of this paper is organized as follows. In the next section we will provide a motivation for why our review is needed and what it adds to existing knowledge. We will then describe the method we have used to conduct the review. Our findings from the literature are then presented. This is followed by a discussion of the findings.

2. The need for this review

Doing health-related research with elderly is costly, especially when we want to evaluate the acceptance of some form of technology. It is therefore important to reuse prior research results as often and as much as possible. This need is reflected in the comparatively large number of literature reviews in the field that have emerged in the recent years.

The question then comes to mind: why a new literature review. We also asked the same question before conducting our review. As we will show later, our review consists of two parts. One is a short analysis of existing reviews (secondary studies), and one is the main review of the primary studies that were included. We analysed 11 existing reviews in order to find out how well they addressed our research question, and whether there was a need for a new review.

We found that the majority of existing reviews are impact-oriented. They address the question of what works and what does not work but provide little knowledge about why and how. This limitation of the systematic review method is also recognised by other researchers (Dixon-Woods, 2006) and qualitative methods have been proposed as a complementary approach (Wolfswinkel, Furtmueller, & Wilderom, 2011). Acceptance of technology is a topic where the *why* and *how* questions are important. In order to address this gap, our review does two things. First, we include only primary studies that use qualitative methods to investigate ICT acceptance. Second, we use a mixed method approach to analyse these studies. In addition to the standard—quantitative—coding process, where articles are coded with an a priori coding scheme, we use a second level of bottom-up coding based on the grounded theory approach (Wolfswinkel, Furtmueller, & Wilderom, 2011). This is evident from the number of quotations we have included in the text.

In addition, existing reviews seldom attempt to build theory. They often start with clear research questions, but do not investigate causal relations among their findings. This makes it difficult for practitioners to use the results. Theories—when they are simple and understandable—are invaluable as design and evaluation tools for practitioners. A widely known example of such a theory is the family of technology acceptance models developed over the years by Viswanath Venkatesh and others (Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, Thong, & Xu, Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology, 2012). In our paper, we use the latest incarnation of these models—as shown in Figure 1—as a framework for representing our findings. The UTAUT 2 model is not built for addressing acceptance among elderly. Our contribution is to validate the model in the field of ICT acceptance among elderly living independently in the community.

3. Review Method

The review consisted of two main parts: first we conducted a review of existing literature reviews on the topic (secondary sources), and then we looked into primary sources. Both parts used the same databases and search string.

We have followed the main steps defined for systematic reviews in software engineering (Kitchenham & Charters, 2007), which are 1) definition of research questions, 2) definition of search phrases and inclusion and exclusion criteria, 3) search and retrieval of sources, 4) data extraction and analysis, and 5) data synthesis. During the definition of the research question, we have additionally identified a candidate theory (UTAUT 2). We do not use this theory for data extraction and analysis, but for representing the findings during the synthesis phase. In addition, during data extraction we employ a mixed-method approach. We do code papers using an a priori coding scheme, as is common in systematic reviews. However, in addition to this a priori coding, we also use grounded theory approach (Wolfswinkel, Furtmueller, & Wilderom, 2011) to extract topics from the primary studies. These additional steps are performed only for the primary studies and not for the review papers.

3.1. Data sources and search strategy

During the design of our study, we spent effort on constructing the right research question and the inclusion and exclusion criteria. We developed several versions of the search string, studied the results from search engines, and refined the search string. *Table 1* shows the final version of the keywords that made up the search string for this study. It consists of five columns. We first created sub-searches joining all the keywords in each column using the OR logical operator. The results from each sub-search were then joined with other columns using the AND logical operator (except the *Exclusion* category, which used AND NOT).

We used the Scopus and PubMed databases to search for relevant articles. Scopus is the largest online database of academic literature, and covers most major journals in the field of information systems and computer science. PubMed is the largest online database of medical and healthcare publications. The Scopus search gave 745 hits, and we got 107 hits on PubMed. The further process of screening is illustrated in Figure 2.

AND →

OR ↓

INTERVENTION	PURPOSE	USER	TECHNOLOGY	EXCLUSION
Acceptance	Healthcare	Elderly	ICT	Hospital
Willingness	Health care	Seniors	Information technology	Nursing home
Usability	Health-related	Senior citizens	Smartphone	Institution
Perception	Well-being	Aged population	Wearable	
Perceptive behaviour	Independence	Aging population	Mobile	
Attitude	Autonomy	Old people	Phone	
Ease of use	Comfort	Old adults	Sensor	
Easy to use	Happiness	Older adults	Telemedicine	
Approval	Welfare	Old age	Pervasive	
Concern	Aging in place	Elders	Ubiquitous	
Satisfaction	Geriatrics		Wireless sensor network	
Human-computer interaction	Gerontology		WSN	
HCI			Smartwatch	
Acceptability			Activity tracker	
User experience			Fitness wristband	
User-experience			Activity monitoring device	
Perceived value			Health information technology	
Human factors			Health IT	
Barriers			Ambient Assisted Living	
			Smart home	
			E-health	

Table 1: Search query

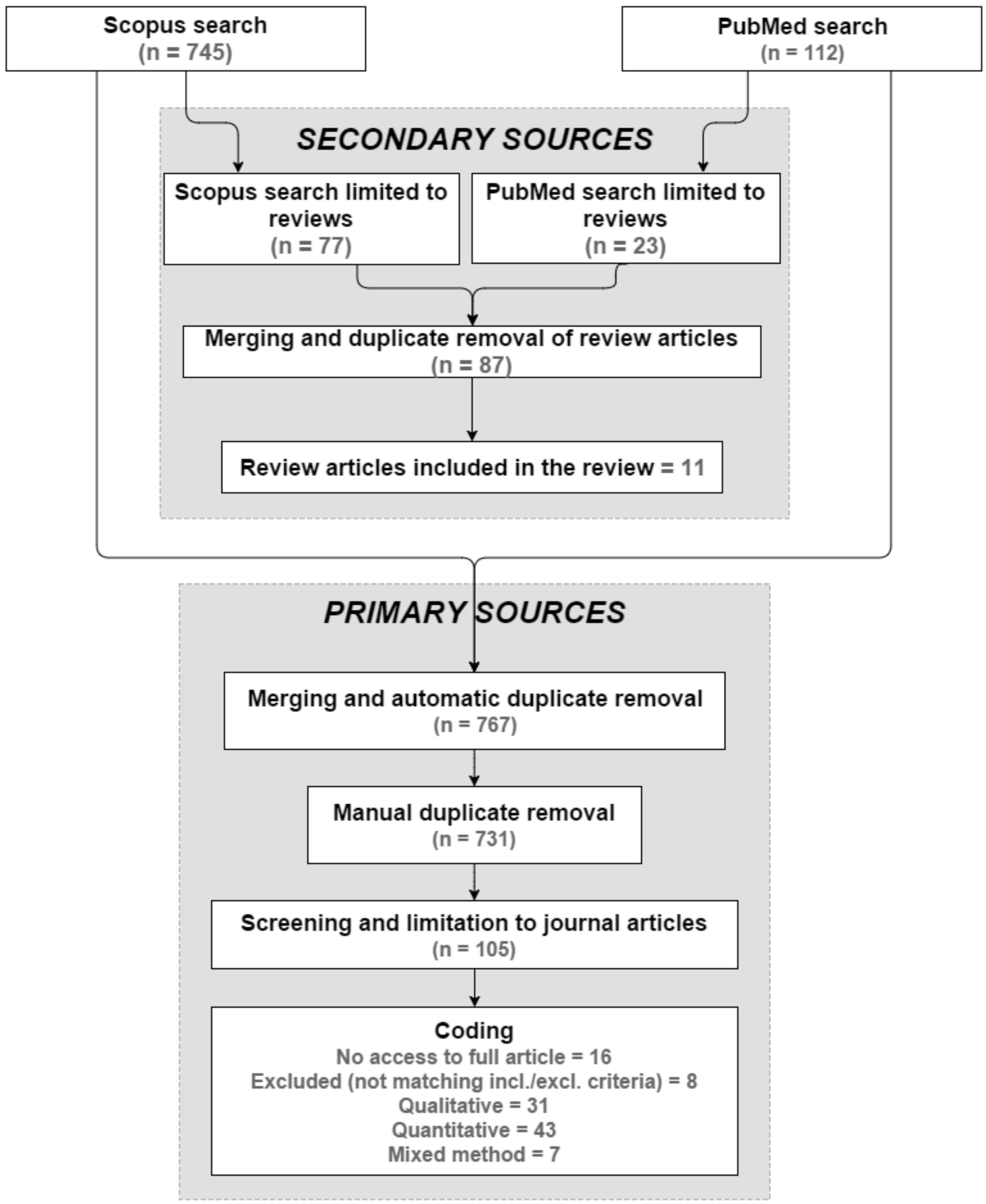

Figure 2: Diagram of search strategy

3.1.1. Literature reviews (secondary sources)

We used the feature of the search engines that allows the user to limit searches to literature reviews (available in both Scopus and PubMed). This gave us n=100 hits in total (Scopus n=77 and PubMed n=23). The results were then merged and duplicates were removed, leaving n=85 review articles. The first author then reviewed the remaining articles and screened these using the inclusion and exclusion criteria presented below. After the screening phase, n=75 articles were excluded because they did not match the inclusion/exclusion criteria, or we did not gain access to the full text of the article. This left us with n=11 review articles, see Table 4.

3.1.2. Primary sources

For the primary sources (initially n=767, see Figure 2) we started by merging the results from both databases, and then removing duplicates (both with an automatic tool—EndNote bibliography software—and manually). We were then left with n=731 articles. Next, each author independently screened the articles by reading their abstracts and deciding whether they were relevant to our research question and matched our inclusion/exclusion criteria. The articles that were excluded by one author but not the other were then reviewed once more until we had a consensus about included articles. The total number of included articles after screening was n=105. Of these, n=16 were excluded because we could not find the full text article[1], leaving us with n=81 articles. After a top-down coding of these articles—coding for type of methodology, type of ICT, sample properties etc. See (Vassli & Farshchian, 2016) for detailed data—we categorised n=31 articles as qualitative, n=43 as quantitative, and n=7 as mixed method. Only the qualitative research is analysed further in this article[2].

For the n=31 qualitative articles we performed a grounded theory analysis (Wolfswinkel, Furtmueller, & Wilderom, 2011). We analysed the text in these articles, looking for emerging categories of barriers and facilitating factors for ICT acceptance. During this process, we did not use UTAUT 2 nor other theories, allowing categories to emerge directly from the text. We present and discuss these emerging categories later in the article.

3.2. What was included and excluded

Table 2 shows the inclusion and exclusion criteria for the review of secondary sources (literature reviews). *Table 3* shows the criteria for the primary sources review.

Table 4 lists the included literature reviews, while *Table 5* shows how these reviews differs from this one, by classifying each review in several categories. These categories are as follows:

- **Focus on elderly:** whether or not the review focuses on the elderly population
- **Focus on ICT:** whether or not the review focuses on an ICT-related intervention
- **Focus on acceptance of ICT:** whether or not the review focuses on the user acceptance of a specific ICT intervention
- **Reviews data collected from elderly people:** whether or not the papers reviewed collected data from elderly people. A "no" here could for instance mean that the review only looked at papers about the technological aspects of an ICT intervention, without collecting data from the potential end users. Or that the paper looked at the opinion of professional caregivers.
- **Looks at the general use of ICT in healthcare:** whether or not the review investigates the use of ICT in healthcare in general, not a specific intervention. For instance, a review about ICT interventions specifically related to fall detection has a too narrow scope.

[1] We searched only online, and did not attempt to order paper copies of these articles.
[2] We did not exclude quantitative studies during the initial screening because our future work includes a comparative analysis of the different methodologies. This comparison is not part of the current article.

- **Looks at ICT in general:** whether or not the review investigates all kinds of ICTs, not a specific type of ICT. For instance, a review limited to monitoring technology has a too narrow scope.
- **Systematic literature review:** whether or not the literature review was done systematically. A "no" here could still mean that it is a thorough literature review, but it might for instance not include a well-documented search process.

Table 5 also shows that our review has a larger and more general scope than the previous reviews on this topic. The most similar one to our review is Jimison et al. (2008), but it differs in that it investigates interactive consumer health IT, while this review encompasses all types of health-related ICT. Additionally, our review includes almost a decade of new literature.

INCLUSION CRITERIA	EXCLUSION CRITERIA
It is a literature review, presenting the findings from multiple primary sources.	The review is addressing elderly people not living in the community (e.g. nursing home, institution, hospital).
The review investigates the acceptance of health and well-being ICT.	It reviewed sources that are not research papers (e.g. commentary, editorial, workshop summary, expert opinion, conference proceeding).
The review focuses on elderly people.	Duplicate (not detected by bibliography software).
The review is published in English.	Unable to gain access to free version of full article.
The findings in the review must be based on empirical evidence.	

Table 2: Inclusion/exclusion criteria for the secondary sources.

INCLUSION CRITERIA	EXCLUSION CRITERIA
It is a research paper, reporting on a specific study of using ICT.	The research is addressing elderly people not living in the community (e.g. nursing home, institution, hospital).
The research investigates the acceptance of health and well-being ICT.	It is not a research paper (e.g. commentary, editorial, workshop summary, expert opinion, conference proceeding).
The research focuses on elderly people and data relevant for acceptance is collected from elderly people.	The research is on acceptance but is not based on empirical data collected from elderly.
The research is published in English.	Duplicate (not detected by bibliography software).
The findings in the research must be based on empirical evidence.	Unable to gain access to free version of full article.
The research is qualitative.	
The research is published as a journal article.	

Table 3: Inclusion/exclusion criteria for the primary sources.

Title	Ref.	Year
A Review of Monitoring Technology for Use With Older Adults	(Wagner, Basran, & Dal Bello-Haas, 2012)	2012
Acceptance and use of health information technology by community-dwelling elders	(Fischer, David, Crotty, Dierks, & Safran, 2014)	2014
Ambient Assisted Living healthcare frameworks, platforms, standards, and quality attributes	(Memon, Wagner, Pedersen, Beevi, & Hansen, 2014)	2014
Approaches to understanding the impact of technologies for aging in place: A mini-review	(Connelly, Mokhtari, & Falk, 2014)	2014
Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved	(Jimison, et al., 2008)	2008
Does smart home technology prevent falls in community-dwelling older adults: a literature review	(Pietrzak, Cotea, & Pullman, 2014)	2014
eHealth literacy and older adults: A review of literature	(Rios, 2013)	2013
Enabling patient-centered care through health information technology	(Finkelstein, et al., 2012)	2012
Fall detection devices and their use with older adults: A systematic review	(Chaudhuri, Thompson, & Demiris, 2014)	2014
Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review	(Hawley-Hague, Boulton, Hall, Pfeiffer, & Todd, 2014)	2014
Review of ICT-based services for identified unmet needs in people with dementia	(Lauriks, et al., 2007)	2007

Table 4: List of included literature reviews

Title	**Focus on elderly**	**Focus on ICT**	**Focus on acceptance of ICT**	**Reviews data collected from elderly people**	**Looks at the general use of ICT in healthcare *(not at a specific intervention)***	**Looks at ICT in general *(not a specific type of ICT)***	**Systematic literature review**
A Review of Monitoring Technology for Use With Older Adults	Yes	Yes	Partially	No	No *(fall detection and health monitoring)*	No *(monitoring tech)*	No
Acceptance and use of health information technology by community-dwelling elders	Yes	Yes	Yes	Yes	Yes	Yes	No
Ambient Assisted Living healthcare frameworks, platforms, standards, and quality attributes	Yes	Yes	Partially	Yes	Yes	No *(AAL)*	No
Approaches to understanding the impact of technologies for aging in place: A mini-review	Yes	Yes	Yes	No	Yes	Yes	No
Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved	Yes	Yes	Yes	Yes	Yes	Somewhat *(interactive consumer health IT)*	Yes
Does smart home technology prevent falls in community-dwelling older adults: a literature review	Yes	Yes	Partially	Yes	No *(fall detection and prevention)*	No *(smart home and monitoring tech)*	No
eHealth literacy and older adults: A review of literature	Yes	Yes	Partially	Yes	No *(eHealth literacy)*	Yes	No
Enabling patient-centered care through health information technology	Yes	Yes	Partially	Yes	Somewhat *(Patient-centered care)*	Yes	Yes
Fall detection devices and their use with older adults: A systematic review	Yes	Yes	Yes	Yes	No *(fall detection)*	No *(fall detection devices)*	Yes
Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review	Yes	Yes	Yes	Yes	No *(falls prevention, detection and monitoring)*	Yes	Yes
Review of ICT-based services for identified unmet needs in people with dementia	Yes	Yes	Yes	Yes	No *(dementia)*	Yes	No

Table 5: Overview of relevance of included literature reviews

Title	Ref.	Authors	Year
Acceptance of Swedish e-health services	(Jung & Loria, 2010)	Jung et al.	2011
Advocacy of home telehealth care among consumers with chronic conditions	(Lu, Chi, & Chen, 2014)	Lu et al.	2014
An ethnographical study of the accessibility barriers in the everyday interactions of older people with the web	(Sayago & Blat, 2011)	Sayago et al.	2011
An extended view on benefits and barriers of ambient assisted living solutions	(Jaschinski & Allouch, 2015)	Jaschinski et al.	2015
Assessing older adults' perceptions of sensor data and designing visual displays for ambient environments	(Reeder, Chung, Le, Thompson, & Demiris, 2014)	Reeder et al.	2014
Attitudes Toward Information and Communication Technology (ICT) in Residential Aged Care in Western Australia	(Loh, Flicker, & Horner, 2009)	Loh et al.	2009
Bridging the digital divide in older adults: A study from an initiative to inform older adults about new technologies	(Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015)	Wu et al.	2015
Defining the user requirements for wearable and optical fall prediction and fall detection devices for home use	(Gövercin, et al., 2010)	Govercin et al.	2010
Diabetes management assisted by telemedicine: Patient perspectives	(Trief, et al., 2008)	Trief et al.	2008
Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare	(Steele, Lo, Secombe, & Wong, 2009)	Steele et al.	2009
Exploring an informed decision-making framework using in-home sensors: Older adults' perceptions	(Chung, et al., 2014)	Chung et al.	2014
Exploring barriers to participation and adoption of telehealth and telecare within the Whole System Demonstrator trial: A qualitative study	(Sanders, et al., 2012)	Sanders et al.	2012
Findings from a participatory evaluation of a smart home application for older adults	(Demiris, Oliver, Dickey, Skubic, & Rantz, 2008)	Demiris et al.	2008
Impact of monitoring technology in assisted living: Outcome pilot	(Alwan, et al., 2006)	Alwan et al.	2006
Implementing technology-based embedded assessment in the home and community life of individuals aging with disabilities: A participatory research and development study	(Chen, Harniss, Patel, & Johnson, 2014)	Chen et al.	2014
Indoor and outdoor social alarms: understanding users' perspectives	(Sjölinder & Avatare Nöu, 2014)	Sjolinder et al.	2014
Keeping silver surfers on the crest of a wave - Older people's ICT learning and support needs	(Damodaran, Olphert, & Phipps, 2013)	Damodaran et al.	2013
Making sense of mobile- and web-based wellness information technology: cross-generational study	(Kutz, Shankar, & Connelly, 2013)	Kutz et al.	2013
Meeting seniors' information needs: Using computer technology	(Campbell, 2008)	Campbell	2008
Older adults are mobile too! Identifying the barriers and facilitators to older adults' use of mHealth for pain management	(Parker, Jessel, Richardson, & Reid, 2013)	Parker et al.	2013
Older adults' acceptance of a community-based telehealth wellness system	(Demiris, et al., 2012)	Demiris et al.	2013
Older adults' attitudes towards and perceptions of "smart home" technologies: a pilot study	(Demiris, et al., 2004)	Demiris et al.	2004
Older adults' perceptions of usefulness of personal health records	(Price, Pak, Müller, & Stronge, 2013)	Price et al.	2013
Older adults' privacy considerations for vision based recognition methods of eldercare applications	(Demiris, Oliver, Giger, Skubic, & Rantz, 2009)	Demiris et al.	2009
Passive sensor technology interface to assess elder activity in independent living	(Alexander, et al., 2011)	Alexander et al.	2011
Privacy and senior willingness to adopt smart home information technology in residential care facilities	(Courtney, 2008)	Courtney	2008

Title	Ref.	Authors	Year
Senior residents' perceived need of and preferences for "smart home" sensor technologies	(Demiris, Hensel, Skubic, & Rantz, 2008)	Demiris et al.	2008
Use of information and communication technology to provide health information: What do older migrants know, and what do they need to know?	(Goodall, Ward, & Newman, 2010)	Goodall et al.	2010
What matters to older people with assisted living needs? A phenomenological analysis of the use and non-use of telehealth and telecare	(Greenhalgh, et al., 2013)	Greenhalgh et al.	2013
Willing but Unwilling: Attitudinal barriers to adoption of home-based health information technology among older adults	(Young, Willis, Cameron, & Geana, 2014)	Young et al.	2014
You get reminded you're a sick person: Personal data tracking and patients with multiple chronic conditions	(Ancker, et al., 2015)	Ancker et al.	2015

Table 6: List of included primary sources

4. Findings

In this section we present our findings from the studied literature. We first shortly presents some of the findings from the secondary sources. The main part of the findings are from the primary studies, presented next in order of frequency.

4.1. Findings from secondary sources

The review studies have identified and discussed several barriers for technology acceptance among community-dwelling elderly, including issues with *privacy* (Fischer, David, Crotty, Dierks, & Safran, 2014; Memon, Wagner, Pedersen, Beevi, & Hansen, 2014; Pietrzak, Cotea, & Pullman, 2014), *usability/ease of use* (Wagner, Basran, & Dal Bello-Haas, 2012; Memon, Wagner, Pedersen, Beevi, & Hansen, 2014; Jimison, et al., 2008; Pietrzak, Cotea, & Pullman, 2014; Finkelstein, et al., 2012; Hawley-Hague, Boulton, Hall, Pfeiffer, & Todd, 2014), *reliability* (Memon, Wagner, Pedersen, Beevi, & Hansen, 2014; Hawley-Hague, Boulton, Hall, Pfeiffer, & Todd, 2014), *data presentation accuracy* (Memon, Wagner, Pedersen, Beevi, & Hansen, 2014), *cost of technology ownership* (Memon, Wagner, Pedersen, Beevi, & Hansen, 2014; Finkelstein, et al., 2012), *security* (Memon, Wagner, Pedersen, Beevi, & Hansen, 2014), *obtrusiveness* (Wagner, Basran, & Dal Bello-Haas, 2012; Chaudhuri, Thompson, & Demiris, 2014), *social stigma* (Wagner, Basran, & Dal Bello-Haas, 2012), *familiarity with technology* (Fischer, David, Crotty, Dierks, & Safran, 2014), *willingness to ask for help* (Fischer, David, Crotty, Dierks, & Safran, 2014), *trust in the technology* (Fischer, David, Crotty, Dierks, & Safran, 2014), *technology design challenges* (Fischer, David, Crotty, Dierks, & Safran, 2014), *access* (Finkelstein, et al., 2012), *lack of training* (Finkelstein, et al., 2012), and *low computer literacy* (Rios, 2013; Finkelstein, et al., 2012).

Important motivating factors for the use of technology include *increased independence* (Hawley-Hague, Boulton, Hall, Pfeiffer, & Todd, 2014), *safety* (Hawley-Hague, Boulton, Hall, Pfeiffer, & Todd, 2014), *control* (Hawley-Hague, Boulton, Hall, Pfeiffer, & Todd, 2014), *satisfaction* (Finkelstein, et al., 2012), *usefulness* (Finkelstein, et al., 2012), *efficiency* (Finkelstein, et al., 2012), and *convenience* (Jimison, et al., 2008).

The importance of technical support and supervision is emphasized by (Memon, Wagner, Pedersen, Beevi, & Hansen, 2014; Pietrzak, Cotea, & Pullman, 2014). At least one review suggests that the user interface needs to be tailored to and tested by the elderly users (Pietrzak, Cotea, & Pullman, 2014). Informational websites need to be better attuned to users with dementia, and should offer personalized information (Lauriks, et al., 2007).

Systems that are considered intrusive or causing infringement on privacy might still be accepted by older adults if their health needs are great enough, according to (Pietrzak, Cotea, & Pullman, 2014).

Many older adults consider monitoring technology suitable for "others" or "someone else who may need it", indicating that they have a different perception of their own health needs compared to their caregivers and family members (Wagner, Basran, & Dal Bello-Haas, 2012).

Low computer literacy is common among older adults and a major barrier to technology acceptance. Having access to health information and skills to effectively find and use information to solve health problems have been found to be very important in increasing eHealth literacy (Rios, 2013).

In the case of fall detection, the elderly want devices that can accurately detect falls, while at the same time be as unobtrusive as possible (Chaudhuri, Thompson, & Demiris, 2014).

When evaluating the acceptance of technology in an aging-in-place context, it is often not sufficient to use a single evaluation method. A wide range of evaluation techniques should be considered in order to provide the richest insights for a particular project: "*In addition to the normal measures for health outcomes, there is a need to be able to measure the users' experiences with technology: when, how and why will older adults and their caregivers use technology? Such questions require a multimodal approach to evaluation to gain deeper insights into how we may design technologies that are acceptable to people"* (Connelly, Mokhtari, & Falk, 2014).

4.2. Findings from primary sources

In multiple studies, the elderly have expressed that they generally have a positive attitude towards ICT (Lu, Chi, & Chen, 2014; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Chung, et al., 2014; Demiris, Oliver, Dickey, Skubic, & Rantz, 2008; Alwan, et al., 2006; Chen, Harniss, Patel, & Johnson, 2014; Demiris, et al., 2004; Demiris, Hensel, Skubic, & Rantz, 2008). However, there are many factors affecting acceptance, both in positive and negative ways. This section will take an in-depth look into the different categories that affect acceptance of health ICT the most, summarizing the findings from the primary sources. We first review factors that seem to increase acceptance, and the present barriers to acceptance.

4.2.1. Factors increasing acceptance

4.2.1.1. Support for independence

In many of the studies, participants emphasised the importance of being able to live independently in their own homes for as long as possible (Jaschinski & Allouch, 2015; Loh, Flicker, & Horner, 2009; Gövercin, et al., 2010; Sanders, et al., 2012; Damodaran, Olphert, & Phipps, 2013; Demiris, et al., 2012). In one study, the participants got a feeling of accomplishment when they managed to carry out an activity on their own, and they all aspired to use the Internet without relying on anyone (Sayago & Blat, 2011). In another, the elderly envisioned a telehealth kiosk as a tool that can enhance their independence and control over their health status (Demiris, et al., 2012).

However, some issues regarding technologically aided independence were also reported. In one study, the authors write: "*Most respondents indicated that they associated the use of telehealth and telecare with a high degree of dependency and ill health. In the majority of cases, respondents seemed to want to distance themselves from negative connotations of old age, sickness and dependence, and instead depicted themselves as having a strong sense of personal responsibility for maintaining health, self-care and independence that could be threatened by the interventions. (...) Responses commonly indicated a strong sense of personal responsibility for health, illness and self care; and the interventions threatened to undermine such a sense of 'control' and current approaches to managing health problems*" (Sanders, et al., 2012). Similarly, participants in another study reported that they did not use assistive technologies because they viewed them as something that belonged in a hospital, and felt that it brought them one step closer to institutional care or death (Greenhalgh, et al., 2013).

4.2.1.2. Support for socialisation

Elderly users wish to use ICT to socialize and play a more active role in society (Sayago & Blat, 2011; Jaschinski & Allouch, 2015; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Demiris, et al., 2012). "*A key and common motivation for all the participants to use the web was to socialize. They did not want to do activities that could isolate them.*" (Sayago & Blat, 2011). Elderly users value the ability to communicate with family and friends through ICT (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Damodaran, Olphert, & Phipps, 2013) and are positive toward using ICTs to prevent social isolation (Sayago & Blat, 2011; Jaschinski & Allouch, 2015). Most want to learn more about ICT in order to maintain an active engagement in life and society (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015). By getting the elderly out of the house and be more socially active, they can get back a sense of life, as well as stimulate their activity level (Jaschinski & Allouch, 2015).

In one study (Steele, Lo, Secombe, & Wong, 2009), participants did not perceive any ICT system to impose any changes on their social lives, and stated that their social trends would not be affected by such a system. They strongly opposed to the idea of notifying family members about lack of social activities, and similar functionalities.

4.2.1.3. Increased safety and security

Studies reported a feeling of safety and security as a result of using ICTs, and/or a desire to use ICTs to prevent or detect accidents and medical emergencies (Lu, Chi, & Chen, 2014; Jaschinski & Allouch, 2015; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Gövercin, et al., 2010; Steele, Lo, Secombe, & Wong, 2009; Sjölinder & Avatare Nöu, 2014; Parker, Jessel, Richardson, & Reid, 2013; Demiris, et al., 2004; Alexander, et al., 2011; Demiris, Hensel, Skubic, & Rantz, 2008).

In two of the studies, the participants emphasized the importance of facilitating communication between the patient and healthcare providers or emergency services when they needed help (Sjölinder & Avatare Nöu, 2014; Parker, Jessel, Richardson, & Reid, 2013). "*The lack of feedback reduced the feeling of safety and increased the uncertainty regarding whether someone would help.*" (Sjölinder & Avatare Nöu, 2014)

There was also a wish for social alarms to work outside the home, which would let the elderly go out without feeling unsafe (Sjölinder & Avatare Nöu, 2014; Demiris, et al., 2004). Another study found that the elderly wanted devices or sensors that can detect a range of different emergencies (Demiris, et al., 2004).

However, safety and security seem to exist in a context that includes more than just being monitored by the healthcare provider. Sharing health-related information with family members and healthcare providers was a requested feature (Kutz, Shankar, & Connelly, 2013; Price, Pak, Müller, & Stronge, 2013). In cases where assistive technologies have a limited uptake and use, one explanation could be that the solution focuses purely on providing safety to the user, but does not improve the lived experience of impairment: "*Many of the assistive technologies in this study (e.g. blood pressure monitoring, falls detectors, alarms) had been supplied after an acute event (e.g. stroke, fall). They served, at best, to provide objective information (biometric data, emergency alerts) to health and/or social care providers. But they did not improve the lived experience of impairment. Indeed, they were not designed to do so - but therein may lie one explanation for their limited uptake and use.*" (Greenhalgh, et al., 2013).

4.2.1.4. Managing own health

Elderly users are positive towards using ICT to help manage their own health, by getting information about their current health status (Lu, Chi, & Chen, 2014; Trief, et al., 2008; Chung, et al., 2014; Demiris, et al., 2012; Price, Pak, Müller, & Stronge, 2013). The perceived benefit is that this will make them less dependent on their physician, and make them more aware of their own health problems and underlying causes. One study (Price, Pak, Müller, & Stronge, 2013) lists the following desired functionality for a "magic box" tool for managing their health information:

> *"Participants expressed a need for a tool that will store all their health information in one place and allow them to share this information with healthcare providers and family members. The e-health tool should be interactive, and help users manage appointments, medications, bills, and statements. It should provide reminders for various health tasks, and provide a diagnosis or answer questions about a concern based on the personal health information stored within the tool. They want a tool that would track their health status over time, and give general health advice based on their personal health information. Older adults indicated that they would prefer to have the responsibility of entering information into the "magic box", rather than giving this responsibility to their doctor. It should provide easy accessibility to their records for healthcare providers".*

4.2.1.5. Access to online information

In two of the studies, participants valued the ability to use the Internet for information searching (Damodaran, Olphert, & Phipps, 2013; Campbell, 2008). In (Campbell, 2008), the participants stated that they felt the Internet was "*good for finding information that the physicians don't tell you about or forget.*" However, in another study, some participants considered it a social injustice that people have no choice but to use new technologies to get access to information and services (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015).

4.2.1.6. Support for daily activities

In three of the studies, participants stated that they used ICTs to aid them in their daily activities, and appreciated this ability. Activities that the technology assists the elders with includes chores and reminders (e.g. medicine and important appointments) (Jaschinski & Allouch, 2015), online banking, shopping online, writing letters and financial budgeting (Damodaran, Olphert, & Phipps, 2013), and enhancing their lives and increasing their productivity in general (Campbell, 2008).

4.2.1.7. Perceived usefulness

The elderly population generally find the functionality offered by health ICT systems useful (Jung & Loria, 2010; Lu, Chi, & Chen, 2014; Trief, et al., 2008; Steele, Lo, Secombe, & Wong, 2009; Demiris, et al., 2012; Alexander, et al., 2011; Demiris, Hensel, Skubic, & Rantz, 2008). This might be linked with their desire for increased independence and/or quality of life: "*Determination in sustaining one's independence can affect a WSN [Wireless Sensor Network] system's PU [perceived usefulness] and any indication on WSN's ability to improve an elderly individual's quality of life would appear to have a positive impact on the system's PU.*" (Steele, Lo, Secombe, & Wong, 2009).

However, one study found that the elderly "*did not uniformly accept the smart home IT shown and most indicated a preference for being able to select only the technologies they perceived they needed*" (Courtney, 2008). As an example of what can be perceived as useful, the following factors were identified as affecting usefulness of sensor data (Reeder, Chung, Le, Thompson, & Demiris, 2014):

- Participants' desires to understand personal activity patterns
- Changes in health status
- Living situation

- The availability of contextual information about sensor data
- Age
- Time when health monitoring begins
- Perceived interest level of others in accessing data
- Accessibility of data to others

4.2.1.8. Availability of proper training

Generally, the elderly find it important to get sufficient training and coaching in the usage of the ICT system (Sayago & Blat, 2011; Steele, Lo, Secombe, & Wong, 2009; Chung, et al., 2014; Damodaran, Olphert, & Phipps, 2013; Parker, Jessel, Richardson, & Reid, 2013; Demiris, et al., 2004). Tailored training was considered as the best way to bridge the gap of the digital divide (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015). However, the quality of these training sessions can vary. In one of the studies, the majority of the participants stated that they still did not know how to use the system after the training session (Lu, Chi, & Chen, 2014). In this specific case, the reasons were too little training, and lack of access to any kind of help on how to use the device afterwards.

Some users' perception is that the system is more complicated to operate than it actually is (Sanders, et al., 2012). This might cause users to give up on even trying participating in training sessions. Some users state that they have no interest in learning how to use computers (Goodall, Ward, & Newman, 2010).

The number of ICT training courses exclusively available for older adults is limited, and information about ICT training opportunities is generally poorly publicised (Damodaran, Olphert, & Phipps, 2013). Some people get training from their family and friends (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015). However, one study found that the children of the elderly are generally not the most appropriate teachers, as they tend to be impatient and speak computer jargon without explaining the meaning of technical terms (Sayago & Blat, 2011).

When learning how to use an ICT system, an expert should sit down with the user and guide him/her systematically through the operating process (Lu, Chi, & Chen, 2014). Repetition is also crucial, since the elderly are more prone to cognitive conditions and thus have a harder time remembering how to perform certain tasks (Lu, Chi, & Chen, 2014) (See also section *4.2.2.3 Memory and cognitive*).

A trainer should be patient, have perseverance, and use understandable language (Sayago & Blat, 2011). The training itself should be accessible, timely, affordable, tailored, local, and in a welcoming and safe environment (Damodaran, Olphert, & Phipps, 2013). The elderly also want an instruction manual that they can consult when they are unsure how to perform a certain task (Steele, Lo, Secombe, & Wong, 2009; Demiris, et al., 2004). This manual should be designed specifically for senior citizens, written in an understandable language (Demiris, et al., 2004).

4.2.1.9. Support / help

Several studies found a distinct correlation between the support available to the user, and the users' acceptance and attitudes towards the ICT system (Steele, Lo, Secombe, & Wong, 2009; Damodaran, Olphert, & Phipps, 2013; Greenhalgh, et al., 2013). In one of the studies, the authors write: "*The availability of help and support has emerged as a key factor of paramount importance to sustaining connection. (...) Human support and encouragement was reported by a significant number (25.2 per cent) of survey respondents to be the most important thing to help them use technology successfully. Most of this help and support was gained informally from family and friends.*" (Damodaran, Olphert, & Phipps, 2013). Another study states: "*Most participants pointed out that the availability and quality of user support is crucial in determining whether users can interact successfully with the technology.*" (Steele, Lo, Secombe, & Wong, 2009).

4.2.2. *Factors preventing acceptance*

4.2.2.1. Violation of privacy

Many studies found that some or all participants have concerns about privacy (Jaschinski & Allouch, 2015; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Gövercin, et al., 2010; Steele, Lo, Secombe, & Wong, 2009; Parker, Jessel, Richardson, & Reid, 2013; Demiris, et al., 2004; Price, Pak, Müller, & Stronge, 2013; Demiris, Oliver, Giger, Skubic, & Rantz, 2009; Courtney, 2008; Demiris, Hensel, Skubic, & Rantz, 2008) (Greenhalgh, et al., 2013; Young, Willis, Cameron, & Geana, 2014). "*Privacy was the bigger barrier to adoption, more so than usability*" (Price, Pak, Müller, & Stronge, 2013). One of the most cited reasons is that the technology makes the elderly feel observed (Jaschinski & Allouch, 2015; Steele, Lo, Secombe, & Wong, 2009; Demiris, et al., 2004; Demiris, Oliver, Giger, Skubic, & Rantz, 2009; Demiris, Hensel, Skubic, & Rantz, 2008), e.g. by the use of optical sensors and video surveillance (Demiris, et al., 2004; Demiris, Oliver, Giger, Skubic, & Rantz, 2009; Demiris, Hensel, Skubic, & Rantz, 2008; Gövercin, et al., 2010). "*All participants felt that the use of cameras within their homes for the purpose of identifying falls or other accidents was 'obtrusive' and would be violating the resident's privacy.*" (Demiris, et al., 2004).

The elderly want to be able to control the frequency and location of monitoring (Demiris, Oliver, Giger, Skubic, & Rantz, 2009). Some would like to be able to turn the system off (Jaschinski & Allouch, 2015; Demiris, Oliver, Giger, Skubic, & Rantz, 2009), and some would even like the option to "get rid of it" when desired (Steele, Lo, Secombe, & Wong, 2009). However, some think such a surveillance system would only work to its full potential when it cannot be switched off (Jaschinski & Allouch, 2015). One study reported cameras that only detected shadows or silhouettes and movements, and thus hid identifiable features. The elderly perceive this as less obtrusive compared to a conventional video surveillance system (Demiris, et al., 2004; Demiris, Oliver, Giger, Skubic, & Rantz, 2009).

Elderly users want to control what data to share and with whom (Jaschinski & Allouch, 2015). Most would grant access rights to their healthcare providers and others who need to process the information for the purposes of monitoring (Demiris, Oliver, Giger, Skubic, & Rantz, 2009; Demiris, Hensel, Skubic, & Rantz, 2008). Some expressed that they wanted to grant access to their family members (Demiris, Oliver, Giger, Skubic, & Rantz, 2009; Demiris, Hensel, Skubic, & Rantz, 2008), while others expressed privacy issues with family members having access rights (Demiris, Oliver, Giger, Skubic, & Rantz, 2009). Some users want to have the ability to access their own data collected from sensors (Demiris, Oliver, Giger, Skubic, & Rantz, 2009; Demiris, Hensel, Skubic, & Rantz, 2008). In one study, the participants thought their physicians ought to be able to see how much activity they were engaged in, while they did not think their caregivers, spouses or children would be interested in that level of detail (Chen, Harniss, Patel, & Johnson, 2014).

The elderly population lacks knowledge about computer security (Damodaran, Olphert, & Phipps, 2013). They are worried that their information is not stored securely (Price, Pak, Müller, & Stronge, 2013; Young, Willis, Cameron, & Geana, 2014), and fear that it can be hacked (Young, Willis, Cameron, & Geana, 2014). Some accepted that they had to trade privacy and security for perceived utility (Young, Willis, Cameron, & Geana, 2014).

Despite there being many barriers relating to privacy, several studies found that the participants did not have any issues with privacy (Jung & Loria, 2010; Chung, et al., 2014; Demiris, Oliver, Dickey, Skubic, & Rantz, 2008; Chen, Harniss, Patel, & Johnson, 2014; Parker, Jessel, Richardson, & Reid, 2013; Demiris, et al., 2012). They expressed that they had no concerns about the use of cameras (Demiris, Oliver, Giger, Skubic, & Rantz, 2009), GPS tracking (Sjölinder & Avatare Nöu, 2014), or wireless transmission of health data (Steele, Lo, Secombe, & Wong, 2009). Reasons for this include that they trust the service provider (Jung & Loria, 2010), that the monitoring provides pease of mind (Demiris, Oliver, Dickey, Skubic, & Rantz, 2008), and that they value security over privacy (Steele, Lo, Secombe, & Wong, 2009; Courtney, 2008). Therefore, there needs to be a balance between the benefits of monitoring and the perceived invasion of privacy (Demiris, Oliver, Dickey, Skubic, & Rantz, 2008; Demiris, Hensel, Skubic, & Rantz, 2008).

4.2.2.2. Interaction design

Some elderly users have both physical and cognitive impairments, and are not good at learning to use new technology. It is important that the system is user friendly and requires minimal to no user action (Demiris, et al., 2004). Several factors relating to ease of use and HCI were found, that have a negative impact on acceptance when such impairments are present (see also the following two sections). For instance, visual communication in a graphical user interface can be challenging. Icons are confusing, and some users prefer text terms (Sayago & Blat, 2011). Buttons can be too small (Chen, Harniss, Patel, & Johnson, 2014; Goodall, Ward, & Newman, 2010). Users have low confidence and are afraid of doing something wrong, and do things slowly to minimize chance (Sayago & Blat, 2011). Cognitive overload can be a larger problem for elderly users than younger users, e.g. too many system functions can lead to confusion (Goodall, Ward, & Newman, 2010). There is also a tendency to automate some tasks so users won't need to be involved in the interaction: "*An elderly person's preference on the system design, personal preferences and several external factors it appears can affect a user's PEOU [perceived ease of use] of the system. An embedded solution with an easy to understand and good usability is the most accepted implementation among the participants, suggesting that interaction with the system may be 'an automatic thing' or 'as simple as 'push the button''.*" (Steele, Lo, Secombe, & Wong, 2009).

4.2.2.3. Memory and cognitive abilities

Several studies found that elderly people often forget how to use the technology, or forget to use it at all, due to age-related cognitive decay. This includes keeping track of devices (Parker, Jessel, Richardson, & Reid, 2013), putting on wearable sensors (Steele, Lo, Secombe, & Wong, 2009), charge battery-driven devices (Chen, Harniss, Patel, & Johnson, 2014), and remembering passwords and steps in a process (Damodaran, Olphert, & Phipps, 2013).

ICT can be used to compensate for these cognitive difficulties (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Demiris, et al., 2012). However, this kind of functionality can also have negative effects: "*For some, reminders about appointments or to take medicine were seen as unnecessary or even insulting, an indication that one could not manage health affairs without assistance.*" (Young, Willis, Cameron, & Geana, 2014).

4.2.2.4. Physical abilities and ergonomics

A recurring theme in several studies was that interfaces, including computer mice and small buttons, were not tailored to the elderly population with functional limitations (Sayago & Blat, 2011; Damodaran, Olphert, & Phipps, 2013; Parker, Jessel, Richardson, & Reid, 2013; Demiris, et al., 2012; Demiris, et al., 2004; Alexander, et al., 2011; Goodall, Ward, & Newman, 2010). "*The majority of interfaces [of new technological devices] are not designed to take into consideration the functional limitations that come with age. As a result, some tasks requiring the use of technological devices become even more difficult for the older adult."* (Demiris, et al., 2004)

One study found that the elderly preferred using the keyboard instead of the mouse, due to normal age-related changes in precision and manual dexterity (Sayago & Blat, 2011). They did not want to use alternative input devices in order to avoid stigmatisation, and they had issues with using accessibility tools for making text and elements larger, since this increased cognitive demands by moving or removing elements.

4.2.2.5. Comprehension and awareness

Several of the studies found that participants had problems with understanding the technology and/or the terminology (Steele, Lo, Secombe, & Wong, 2009; Damodaran, Olphert, & Phipps, 2013; Alexander, et al., 2011; Goodall, Ward, & Newman, 2010; Greenhalgh, et al., 2013). They often have trouble understanding how to use the technology, and/or its purpose.

- "*Responses suggested that participants did not understand the technology.*" (Goodall, Ward, & Newman, 2010)
- "*Many had a hazy understanding of their assistive technologies, and we found one fully installed and functioning alarm system (with pendant) of which the intended user claimed to be unaware.*" (Greenhalgh, et al., 2013)
- "*Many participants reported that they had difficulties understanding technical 'jargon'.*" (Damodaran, Olphert, & Phipps, 2013)
- "*It is evident that the functionalities and benefits of WSN systems is a concept some elderly persons find hard to grasp. (...) They [participants] expressed their frustration in not being able to understand what happened when error occurs and hence expressed a desire for the system to have 'common sense' and give out meaningful and easy to understand error messages.*" (Steele, Lo, Secombe, & Wong, 2009)

4.2.2.6. Obtrusiveness / intrusiveness

It is important to the elderly that system components should be unobtrusive (Gövercin, et al., 2010; Steele, Lo, Secombe, & Wong, 2009; Chung, et al., 2014; Demiris, et al., 2004; Demiris, Hensel, Skubic, & Rantz, 2008). Generally, smaller devices are perceived as less intrusive, and technological devices installed in the home should be hidden or hard to see for visitors (Demiris, Hensel, Skubic, & Rantz, 2008). The use of cameras for video surveillance is considered "too intrusive" (Steele, Lo, Secombe, & Wong, 2009; Demiris, et al., 2004). In the case of wearable devices, the elderly prefer to wear them on their wrist, and women want sensors that can be worn as jewellery (Gövercin, et al., 2010).

In several studies, the participants answered that they were not bothered by the technology, and/or that it did not interfere with their daily activities, which would indicate that the developers succeeded in creating an unobtrusive system (Chung, et al., 2014; Demiris, Oliver, Dickey, Skubic, & Rantz, 2008; Chen, Harniss, Patel, & Johnson, 2014; Demiris, Hensel, Skubic, & Rantz, 2008). In one study, participants pointed out that some people are 'technophobes', and refuse to utilize new technologies (Demiris, et al., 2004). See also section *4.2.3 Other findings*.

4.2.2.7. Fear, anxiety, and discomfort with use

Many elderly people might experience discomfort, anxiety or even fear while using ICT (Sayago & Blat, 2011; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Steele, Lo, Secombe, & Wong, 2009; Alwan, et al., 2006; Damodaran, Olphert, & Phipps, 2013; Greenhalgh, et al., 2013; Young, Willis, Cameron, & Geana, 2014). In one study, participants stated that they are "terrified of a computer" (Steele, Lo, Secombe, & Wong, 2009). Possible causes for these feelings include a low level of comfort with and control of technology, age-related cognitive difficulties, or a lack of familiarity (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Steele, Lo, Secombe, & Wong, 2009; Young, Willis, Cameron, & Geana, 2014). Elders are afraid of not getting help quickly if they were to fall while using a fall detection service (Alwan, et al., 2006). At the same time, they might be uncomfortable using such a service because of many different reasons:

> *"Others viewed the pendant alarm as potentially exposing them to sinister intrusion or surveillance by unwanted strangers, or as threatening to precipitate dramatic scenarios that*

> *were embarrassing (e.g. ambulance arriving when they were not dressed), socially disruptive (e.g. disturbing their children at work) or personally threatening (e.g. leading to unwanted hospital admission). When such perceptions were held, the device was rarely, if ever, activated." (Greenhalgh, et al., 2013).*

One study found that connectivity could increase older adults' comfort with technology in general (Parker, Jessel, Richardson, & Reid, 2013).

4.2.2.8. Low technological self-efficacy

Elderly users often doubt their own abilities to understand and properly use ICT solutions (Jung & Loria, 2010; Steele, Lo, Secombe, & Wong, 2009; Sanders, et al., 2012). One possible reason for this could be that many have had negative experiences with technology in the past, where they were unable to interact with the technology properly (Steele, Lo, Secombe, & Wong, 2009). However, one study found that even those with the least Internet experience and lowest self-efficacy in the study, reported being confident in their ability to use the services once they had tried them (Jung & Loria, 2010).

4.2.2.9. Digital divide and generational differences

Elderly people are concerned about using technologies that can make them look different and frail, and they want to be able to use the same technology as their children and grandchildren are using, both to feel closer to them, and to dispel stereotypes they could have about them (Sayago & Blat, 2011). However, most elderly people are unable to follow the technological trends, which might make some feel labelled as old fashioned and obsolete, which in turn can make them feel inferior or powerless (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015).

> *"They [participants] frequently reported social pressure that pushes them to use technologies in order to fit in with the society. Otherwise, they would be excluded from it." (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015)*

One study found an exception to the theory that the digital divide is a significant barrier to the adoption of e-health tools:

> *"Older adults in this study were more likely to adopt some form of technology than younger adults (e.g., create a medication list within a word document). Older adults' willingness to adopt some form of technology may reflect the perceived usefulness and importance of the task of remembering medications, as well as the usefulness of being able to easily edit and print the same information to a multitude of healthcare providers." (Price, Pak, Müller, & Stronge, 2013)*

4.2.2.10. Stigmatization and pride

The installation of heathcare ICT solutions may cause some elders to feel stigmatized or ashamed (Jaschinski & Allouch, 2015; Steele, Lo, Secombe, & Wong, 2009; Demiris, et al., 2004; Demiris, Hensel, Skubic, & Rantz, 2008).

> *"While assistance with chores was well perceived by a few older adults, others felt no need for assistance and almost felt insulted by the idea (...). We observed that some older adults were very proud of their independence and therefore, rejected anything which would imply otherwise." (Jaschinski & Allouch, 2015)*

They do not want to be seen wearing a health monitoring device, as they were afraid it would stigmatize them as frail or needing special assistance. (Steele, Lo, Secombe, & Wong, 2009; Demiris, et al., 2004).

4.2.2.11. Financial cost

Generally, elderly people see the cost of a health-related ICT solution as an important concern when deciding if they want to buy it (Lu, Chi, & Chen, 2014; Jaschinski & Allouch, 2015; Steele, Lo, Secombe, & Wong, 2009; Damodaran, Olphert, & Phipps, 2013; Parker, Jessel, Richardson, & Reid, 2013; Demiris, et al., 2004; Goodall, Ward, & Newman, 2010; Young, Willis, Cameron, & Geana, 2014). ”*Cost was the most significant concern to the elderly participants.*” (Steele, Lo, Secombe, & Wong, 2009). ICT systems need to be affordable for elderly people living on a pension if it is to get a large user base. However, in one of the studies, cost savings for the user was mentioned as a benefit, as it is cheaper (or even free) to use the ICT solution once it is installed, rather than get an appointment with a doctor (Jung & Loria, 2010).

4.2.2.12. Lack of human interaction

An ICT system should not replace human contact. The elderly emphasised the importance of having human care and human interaction, and the thought of replacing this with a computer caused concern (Jaschinski & Allouch, 2015; Loh, Flicker, & Horner, 2009; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015).

> *“The need for human contact and a warm relationship appeared paramount to the residents. This was simply and forcefully expressed by a resident who said simply: 'We are not robots here.' More importantly the residents were 'one voice' and in consensus about human contact.” (Loh, Flicker, & Horner, 2009)*

4.2.2.13. Reliability and trust

Elders often have some degree of mistrust or concern about the reliability of an ICT system (Lu, Chi, & Chen, 2014; Jaschinski & Allouch, 2015; Steele, Lo, Secombe, & Wong, 2009; Parker, Jessel, Richardson, & Reid, 2013; Demiris, et al., 2004; Demiris, Hensel, Skubic, & Rantz, 2008; Young, Willis, Cameron, & Geana, 2014). These concerns involve the accuracy of devices (including false alarms) (Lu, Chi, & Chen, 2014; Jaschinski & Allouch, 2015; Steele, Lo, Secombe, & Wong, 2009; Demiris, Hensel, Skubic, & Rantz, 2008), uncertainty about whether a device is malfunctioning or not (Lu, Chi, & Chen, 2014; Steele, Lo, Secombe, & Wong, 2009), depleted batteries (Steele, Lo, Secombe, & Wong, 2009), delivering information to providers in a timely manner (Parker, Jessel, Richardson, & Reid, 2013), and trusting that the computer would do its job (Young, Willis, Cameron, & Geana, 2014).

4.2.2.14. Readiness to adopt technology

Many of the elderly are reluctant or not at all interested in using the ICT solution after getting a presentation, demonstration or having tried it themselves (Jaschinski & Allouch, 2015; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Steele, Lo, Secombe, & Wong, 2009; Demiris, Hensel, Skubic, & Rantz, 2008; Goodall, Ward, & Newman, 2010; Young, Willis, Cameron, & Geana, 2014). They find they have no need for it in their current situation (Jaschinski & Allouch, 2015; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Young, Willis, Cameron, & Geana, 2014), and think of it as something more appropriate for people who are older, frailer, less independent, less active, less healthy and/or more isolated than themselves (Jaschinski & Allouch, 2015; Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015; Sanders, et al., 2012; Demiris, Oliver, Giger, Skubic, & Rantz, 2009; Demiris, Hensel, Skubic, & Rantz, 2008; Young, Willis, Cameron, & Geana, 2014). Some acknowledge that they soon will be in need of such technology (Wu, Damnée, Kerhervé, Ware, & Rigaud, 2015), while others find this hard to imagine (Jaschinski & Allouch, 2015). Some perceive computers as something only young people use (Goodall, Ward, & Newman, 2010).

4.2.2.15. Other barriers

Some elderly people are worried that a wearable sensor system can have negative effects on their health, like getting cancer from radio waves used for wireless communication, getting allergic reactions, or the pain caused by having a sensor underneath their skin (Steele, Lo, Secombe, & Wong, 2009). One study investigating self-tracking of data (Ancker, et al., 2015) found that elders who tracked their health data themselves recognized this as work, and judged themselves as “good” or “bad” for their data and their diligence in collecting it, and noted that data should be considered within the patient’s personal context. Medical data often reminded patients of the negative aspects of their illness, which made many give up self-tracking.

4.2.3. Other findings

Elderly people are generally positive towards sensor monitoring in their home (Demiris, et al., 2004). The process of adoption and acceptance of sensor technologies included three phases: familiarization, adjustment and curiosity, and full integration (Demiris, Oliver, Dickey, Skubic, & Rantz, 2008).

Sensor technologies can be divided into three main categories: wearable sensors (sensors worn on the body, e.g. pendant alarms, smartwatches, or sensors embedded into clothing), ambient sensors (stationary sensors installed in the home, e.g. cameras), and embedded sensors (placing sensors under the skin of the user).

The elderly report positive attitudes towards wearable sensors (Gövercin, et al., 2010; Steele, Lo, Secombe, & Wong, 2009). They do not mind the concept of wearing sensors on their body (Steele, Lo, Secombe, & Wong, 2009), and prefer wearable sensors over an optical system (ambient monitoring) (Gövercin, et al., 2010). A wristband sensor is well accepted (Gövercin, et al., 2010), and having sensors embedded into clothing accessories such as rings or watches was also requested (Steele, Lo, Secombe, & Wong, 2009). Women want to be able to wear sensors as jewellery (Gövercin, et al., 2010). Some problems identified with wearable sensors include that users might refuse to wear them at all times, and might end up not wearing it in an emergency, and they have limited mobility as the sensor functions only within a certain area (Demiris, et al., 2004).

In the case of ambient monitoring, the elderly are uncertain whether a pure ambient implementation is adequate to ensure that an elderly person is monitored at all times. Some suggest a hybrid solution consisting of both ambient and embedded sensors may be better for solving perceived problems (Steele, Lo, Secombe, & Wong, 2009). The elderly are reported in one study to be positive towards the idea of having embedded sensors placed under their skin, as long as the pain is not significant, and the chip did not need to be taken out regularly e.g. for battery replacement (Steele, Lo, Secombe, & Wong, 2009).

5. Discussion

In this section, we will structure and discuss the findings. We will first do a mapping of our findings onto the UTAUT2 model, as outlined in the introduction. We will then present those findings that do not map or only partly map onto UTAUT2. We will then discuss the implications for theory.

5.1. Mapping to UTAUT2

5.1.1. Performance expectancy

Performance expectancy is defined as "*the degree to which using a technology will provide benefits to consumers in performing certain activities*" (Venkatesh, Thong, & Xu, 2012). Our findings show that senior users expect specific benefits from technologies; these benefits might be different from other user groups. Senior users expect assistive technologies to support them in staying independent, and staying an active member of the society. Becoming dependent on others is a fear that most seniors have. It might be that general attitudes in the society towards getting old amplifies this fear. For instance, elderly are often seen as a cost to the society. Technologies that can alleviate this fear seem to be valued and expected by seniors. This can be technologies for performing daily activities and chores, technologies for managing own health as much as possible, technologies for staying safe without posing a burden on others, and technologies for keeping socially involved and included—with family and in society. Our specific user group—seniors living in the community—might have an amplified attitude towards these benefits. At the same time, performance expectancy is an important aspect in the community setting. If seniors living in the community cannot see a benefit in using the technology, they will not use it.

5.1.2. Effort expectancy

Effort expectancy is defined as "*the degree of ease associated with consumers' use of technology*" (ibid.). Many of our findings show that seniors put emphasis on perceived and real ease-of-use. A major factor contributing to increased effort to use technology is impairment, both physical and cognitive. Technologies that are developed for physically and mentally healthy adults can be perceived as too difficult or impossible to use for many seniors. The studied literature mentions a number of specific usability issues, such as icons and symbols, font size, and number of functions. At the same time, we need to avoid stigmatization by creating dumb technology that we label "senior-friendly".

Our data also shows that seniors appreciate unobtrusive technology, i.e. technology that can operate in the background without the need for much user intervention. This might be technology that a doctor needs for health monitoring, or technology that is used for monitoring safety of e.g. people with dementia. In general, seniors might perceive low technological self-efficacy. It is therefore important to consider the amount of prior technical knowledge required to use a technology, even if the technology itself is easy to use. For instance, a wearable technology that requires the use of a new type of smartphone might require too much effort for some age groups.

5.1.3. Social influence

Social influence is "*the extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology*" (ibid.). In a peer network, stigmatisation and jeopardising personal pride are two strong social influencers. Several studies show that if a technology is developed to look like or function in a stigmatising way, it will have low acceptance. Seniors tend to want to use technology that younger generations use. At the same time, there are generational differences in some well-accepted technologies, which might mean that peer acceptance or perceived value is stronger than potentially stigmatising effect.

At a non-peer network, it seems that family members and healthcare personnel have some level of influence on seniors.

5.1.4. Facilitating conditions

Facilitating conditions refer to "*consumers' perceptions of the resources and support available to perform a behavior*" (ibid.). There are two central sets of findings. First, seniors might need substantial training and support in using assistive technologies. Second, using some forms of assistive technology is connected to trust and safety, which might imply continuous support by a service provider.

Many assistive technologies are introduced into the lives of seniors at a relatively late point in time, often when impairment has already made it difficult for them to learn new skills. This means that training and help when using the technology become essential facilitating factors. Our findings show that learning to use new technology needs highly tailored courses and training. At the same time, it is important to provide support also after the training is over and technology is in use.

Seniors show a lack of trust in technology, and are often uncertain whether it works or not. This might be partly because the technology is not designed well—e.g. it does not provide proper feedback to the user. However, we also believe it shows a need to be assured that a service provider is "watching over" them. In particular, safety-related technologies such as fall detection create an expectation that a service provider is continuously monitoring and will react in emergencies.

5.1.5. Price value

Healthcare systems in different countries have different reimbursement practices. It is therefore difficult to say much about how the price of an assistive technology is valued by seniors. In Norway, for instance, the majority of assistive services and technology are paid by the state-owned health insurance. While in other countries such as USA this is vastly different. We have not mapped our studies onto country-specific reimbursement systems. However, most of the studied that mention cost at all consider it as a major issue for the seniors.

5.1.6. Hedonic motivation and Habit

The two other constructs in UTAUT2 are hedonic motivation ("the fun or pleasure derived from using a technology) and habit ("the extent to which people tend to perform behaviors automatically because of learning"). Our findings do not show any direct evidence of their importance to seniors.

One hypothesis that can explain the lack of hedonic aspects is the patient-centeredness of assistive technologies. Most assistive technology is designed "to solve a problem" and therefore might lack any "fun factor". The emergence of gamification and game-based assistive technologies might make hedonic motivation a stronger aspect of acceptance in the near future.

We were, however, surprised that habit does not show up as a relevant factor in our included studies. It might be that many of the barriers that are identified—e.g. fear of technology, low self-efficacy—are actually symptoms of a habit of not using technology. It might also be that the studied seniors have rarely used assistive technologies enough in order to allow for habit creation.

5.1.7. Moderating conditions

Regarding the moderating conditions in UTAUT2, i.e. age, gender and experience, we find of course support for age, partly for experience, but not for gender. Obviously, age is a strong moderator in our studies because we focused on age as an inclusion criteria for our literature survey. So all the findings aim to illustrate how age affects acceptance. It is however surprising for us that gender does not show up as a topic in the included studies. Initial studies on UTAUT and UTAUT2 mention gender as a major moderator.

Experience is neither a topic in the included studies. The majority of studies in this review focused on users with very little to no prior experience with a certain type of ICT, or with ICT in general. Thus, we cannot draw any conclusions regarding the experience moderator. Until now seniors have not belonged to the "Internet generation", and have not used mobile technology as adults. It might also be that researchers assume a lack of experience and therefore do not collect data about prior experience. Another theory can be that many assistive technologies demonstrate a departure from "normal" ICT

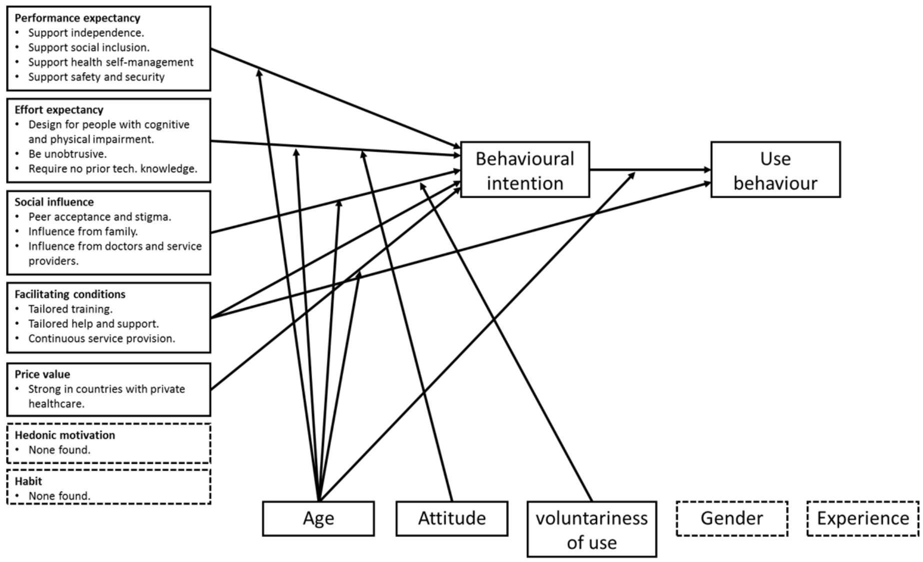

Figure 3: Mapping of the findings to UTAUT2.

platforms that seniors are potentially familiar with. Many assistive technologies resemble more medical devices than domestic ICT. In other words, it becomes irrelevant to talk about prior experience because you enter a new ICT world when you become senior.

5.2. Findings that are not mapped to UTAUT2

Our findings show that privacy and information security emerge as a major topic. We see both positive and negative attitudes towards sharing of private and health-related data. The same applies to perceived usefulness of assistive technologies. Some seniors find it very useful while some are very sceptical. It is difficult for us to see how UTAUT2 can express these variations. We believe a moderating condition called "attitude" might help. Attitude was included a parameter in a number of acceptance models that were reviewed in the original UTAUT article (Venkatesh, Morris, Davis, & Davis, 2003), but its authors eliminated this parameter in the favour of performance expectancy.

Another observation we have is related to the moderating condition "voluntariness of use" that was part of the original UTAUT model. This parameter is removed from UTAUT2 because its authors believe it is irrelevant for consumer ICT. We always buy and use consumer ICT voluntarily. This is correct. However, we believe assistive technologies are not completely consumer ICT. They are neither completely "institutional" ICT. For instance, seniors might be motivated to use assistive technology if an authoritative person such as a doctor recommends the technology. In the same way, in many countries with public welfare services, assistive technologies are the only option available—e.g. in case of personal emergency response systems for monitoring of falls and accidents. In these cases it is important to be able to measure how a low or high level of voluntariness can affect the acceptance of assistive technologies at home.

5.3. Limitations of the study

We have searched in two major databases, and included only journal papers. The scope of the search can be increased to include more databases and papers from top conferences. We have neither done a proper appraisal of the methodological quality of the included papers. We have assumed that most of the journals indexed in Scopus and PubMed have done proper appraisal. We acknowledge however that more can be done to create a more specialized appraisal model for the type of research that we have focused on. For instance, we could have included only longitudinal studies.

6. Conclusions

In this paper, we have presented our findings from a systematic literature review on acceptance of ICT among community-dwelling seniors. We have included qualitative studies only, in order to be able to answer some questions about how and why seniors use assistive technologies. We have presented a number of topics as motivators or barriers to use assistive technologies. We used UTAUT2 acceptance model as a framework to present and discuss the findings.

Our work contributes to a technology acceptance model for seniors using assistive technologies. We have specialized some of the UTAUT2 constructs such as performance and effort expectancy. We believe this study can help researchers to gain better understanding of how seniors use technology. At the same time, we hope a more operationalised UTAUT2 model can assist designers in making design decisions for this user group. Our long-term research goal is to create a fully operationalised and evolving acceptance model.

The study has revealed some areas for further research in the framework of UTAUT2. We could not find any evidence for age being a moderating factor for acceptance. We see a strong influence of attitudes and underlying values and beliefs that might not be supported properly by UTAUT2. Additionally, voluntariness of use that existed in UTAUT but was removed in UTAUT2 might again be relevant for assistive technologies that lie somewhere between organizational and consumer ICT.

7. References and Appendices

Alexander, G., Wakefield, B., Rantz, M., Skubic, M., Aud, M., Erdelez, S., & Ghenaimi, S. (2011). Passive sensor technology interface to assess elder activity in independent living. *Nursing Research, 60*(5), 318-325.

Alwan, M., Dalal, S., Mack, D., Kell, S., Turner, B., Leachtenauer, J., & Felder, R. (2006). Impact of monitoring technology in assisted living: Outcome pilot. *IEEE Transactions on Information Technology in Biomedicine, 10*(1), 192-198.

Ancker, J., Witteman, H., Hafeez, B., Provencher, T., Van de Graaf, M., & Wei, E. (2015). "You get reminded you're a sick person": Personal data tracking and patients with multiple chronic conditions. *Journal of Medical Internet Research, 17*(8), e202.

Campbell, R. (2008). Meeting seniors' information needs: Using computer technology. *Home Health Care Management & Practice, 20*, 328-335.

Chaudhuri, S., Thompson, H., & Demiris, G. (2014). Fall detection devices and their use with older adults: a systematic review. *Journal of geriatric physical therapy, 37*(4), 178-196.

Chen, K.-Y., Harniss, M., Patel, S., & Johnson, K. (2014). Implementing technology-based embedded assessment in the home and community life of individuals aging with disabilities: A participatory research and development study. *Disability and Rehabilitation: Assistive Technology, 9*(2), 112-120.

Chung, J., Reeder, B., Lazar, A., Joe, J., Demiris, G., & Thompson, H. (2014). Exploring an informed decision-making framework using in-home sensors: Older adults' perceptions. *Informatics in primary care, 21*(2), 73-77.

Connelly, K., Mokhtari, M., & Falk, T. (2014). Approaches to Understanding the Impact of Technologies for Aging in Place: A Mini-Review. *Gerontology, 60*(3), 282-288.

Connelly, K., Siek, K., Mulder, I., Neely, S., Stevenson, G., & Kray, C. (n.d.). Evaluating pervasive and ubiquitous systems. *Pervasive Computing, IEEE, 7*(3), 85-88.

Courtney, K. (2008). Privacy and senior willingness to adopt smart home information technology in residential care facilities. *Methods of Information in Medicine, 47*(1), 76-81.

Damodaran, L., Olphert, W., & Phipps, S. (2013). Keeping silver surfers on the crest of a wave - Older people's ICT learning and support needs. *Working with Older People, 17*(1), 32-36.

DeJonge, K., Taler, G., & Boling, P. (2009). Independence at home: community-based care for older adults with severe chronic illness. *Clinics in geriatric medicine, 25*(1), 155-169.

Demiris, G., Hensel, B., Skubic, M., & Rantz, M. (2008). Senior residents' perceived need of and preferences for "smart home" sensor technologies. *International Journal of Technology Assessment in Health Care, 24*(1), 120-124.

Demiris, G., Oliver, D. P., Dickey, G., Skubic, M., & Rantz, M. (2008). Findings from a participatory evaluation of a smart home application for older adults. *Technology and Health Care-European Society for Engineering and Medicine, 16*(2), 111-118.

Demiris, G., Oliver, D. P., Giger, J., Skubic, M., & Rantz, M. (2009). Older adults' privacy considerations for vision based recognition methods of eldercare applications. *Technology and Health Care, 17*(1), 41-48.

Demiris, G., Rantz, M., Aud, M., Marek, K., Tyrer, H., Skubic, M., & Hussam, A. (2004). Older adults' attitudes towards and perceptions of "smart home" technologies: a pilot study. *Informatics for Health and Social Care, 29*(2), 87-94.

Demiris, G., Thompson, H., Boquet, J., Le, T., Chaudhuri, S., & Chung, J. (2012). Older adults' acceptance of a community-based telehealth wellness system. *Informatics for Health and Social Care, 38*(1), 27-36.

Dixon-Woods, M. (2006). How Can Systematic Reviews Incorporate Qualitative Research? A Critical Perspective. *Qualitative Research, 6*(1), 27–44.

Farshchian, B., & Dahl, Y. (2015). The Role of ICT in Addressing the Challenges of Age-Related Falls: A Research Agenda Based on a Systematic Mapping of the Literature. *Personal and Ubiquitous Computing*(19), 649–66.

Finkelstein, J., Knight, A., Marinopoulos, S., Gibbons, M., Berger, Z., Aboumatar, H., . . . Bass, E. (2012). Enabling patient-centered care through health information technology.

Fischer, S., David, D., Crotty, B., Dierks, M., & Safran, C. (2014). Acceptance and use of health information technology by community-dwelling elders. *International journal of medical informatics, 83*(9), 624-635.

Goodall, K., Ward, P., & Newman, L. (2010). Use of information and communication technology to provide health information: What do older migrants know, and what do they need to know? *Quality in Primary Care, 18*(1), 27-32.

Greenhalgh, T., Wherton, J., Sugarhood, P., Hinder, S., Procter, R., & Stones, R. (2013). What matters to older people with assisted living needs? A phenomenological analysis of the use and non-use of telehealth and telecare. *Social Science & Medicine, 93*, 86-94.

Gövercin, M., Költzsch, Y., Meis, M., Wegel, S., Gietzelt, M., Spehr, J., . . . Steinhagen-Thiessen, E. (2010). Defining the user requirements for wearable and optical fall prediction and fall detection devices for home use. *Informatics for health and social care, 35*(3-4), 177-187.

Hawley-Hague, H., Boulton, E., Hall, A., Pfeiffer, K., & Todd, C. (2014). Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review. *International journal of medical informatics, 83*(6), 416-426.

Jaschinski, C., & Allouch, S. (2015). An extended view on benefits and barriers of ambient assisted living solutions. *International Journal on Advances in Life Sciences, 7*(1-2), 40-53.

Jimison, H., Gorman, P., Woods, S., Nygren, P., Walker, M., Norris, S., & Hersh, W. (2008). Barriers and drivers of health information technology use for the elderly, chronically III, and underserved.

Jung, M.-L., & Loria, K. (2010). Acceptance of Swedish e-health services. *Journal of Multidisciplinary Healthcare, 3*, 55-63.

Kitchenham, B., & Charters, S. (2007). *Guidelines for Performing Systematic Literature Reviews in Software Engineering.* Keele, UK: EBSE . Hentet fra http://www.dur.ac.uk/ebse/resources/Systematic-reviews-5-8.pdf

Kutz, D., Shankar, K., & Connelly, K. (2013). Making sense of mobile- and web-based wellness information technology: cross-generational study. *Journal of medical Internet research, 15*(5).

Lauriks, S., Reinersmann, A., Van der Roest, H., Meiland, F., Davies, R., Moelaert, F., . . . Dröes, R.-M. (2007). Review of ICT-based services for identified unmet needs in people with dementia. *Ageing research reviews, 6*(3), 223-246.

Loh, P.-K., Flicker, L., & Horner, B. (2009). Attitudes Toward Information and Communication Technology (ICT) in Residential Aged Care in Western Australia. *Journal of the American Medical Directors Association, 10*(6), 408-413.

Lu, J.-F., Chi, M.-J., & Chen, C.-M. (2014). Advocacy of home telehealth care among consumers with chronic conditions. *Journal of clinical nursing, 23*(5-6), 811-819.

Memon, M., Wagner, S., Pedersen, C., Beevi, F., & Hansen, F. (2014). Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes. *Sensors, 14*(3), 4312-4341.

Mostashari, F. (2011). *Aging in place: the national broadband plan and bringing health care technology home.* Technical report. Statement to the Senate Special Committee on Aging and the United States House of Representatives by the Senior Advisor to the Office of the National Coordinator for Health IT. Retrieved from http://www.hhs.gov/asl/testify/2010/04/t20100422e.html

Parker, S., Jessel, S., Richardson, J., & Reid, M. (2013). Older adults are mobile too! Identifying the barriers and facilitators to older adults' use of mHealth for pain management. *BMC Geriatrics, 13*(1), 43.

Pietrzak, E., Cotea, C., & Pullman, S. (2014). Does smart home technology prevent falls in community-dwelling older adults: a literature review. *Source of the DocumentInformatics in Primary Care, 21*(3), 105-112.

Price, M., Pak, R., Müller, H., & Stronge, A. (2013). Older adults' perceptions of usefulness of personal health records. *Universal access in the information society, 12*(2), 191-204.

Reeder, B., Chung, J., Le, T., Thompson, H., & Demiris, G. (2014). Assessing Older Adults' Perceptions of Sensor Data and Designing Visual Displays for Ambient Assisted Living Environments: An Exploratory Study. *Methods of information in medicine, 53*(3), 152-159.

Rios, G. (2013). eHealth literacy and older adults: A review of literature. *Topics in Geriatric Rehabilitation, 29*(2), 116-125.

Sanders, C., Rogers, A., Bowen, R., Bower, P., Hirani, S., Cartwright, M., . . . Newman, S. (2012). Exploring barriers to participation and adoption of telehealth and telecare within the Whole System Demonstrator trial: A qualitative study. *BMC Health Services Research, 12*(1), 220.

Sayago, S., & Blat, J. (2011). An ethnographical study of the accessibility barriers in the everyday interactions of older people with the web. *Universal Access in the Information Society, 10*(4), 359-371.

Sjölinder, M., & Avatare Nöu, A. (2014). Indoor and outdoor social alarms: understanding users' perspectives. *JMIR mHealth and uHealth, 2*(1).

Slade, E., Williams, M., & Dwivedi, Y. (2013). An extension of the UTAUT 2 in a healthcare context. *Proceeding of the UK Academy for Information Systems*.

Steele, R., Lo, A., Secombe, C., & Wong, Y. (2009). Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare. *International journal of medical informatics, 78*(12), 788-801.

Trief, P., Sandberg, J., Izquierdo, R., Morin, P., Shea, S., Brittain, R., . . . Weinstock, R. S. (2008). Diabetes management assisted by telemedicine: Patient perspectives. *Telemedicine and e-Health, 14*(7), 647-655.

United Nations. (2015). *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables.* New York: United Nations.

Vassli, L., & Farshchian, B. A. (2016, May 1). Background material for systematic review of literature on ICT acceptance among community dwelling elderly. doi:10.5281/zenodo.50293

Venkatesh, V., Morris, M., Davis, G., & Davis, F. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.

Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MIS quarterly, 36*(1), 157-178.

Wagner, F., Basran, J., & Dal Bello-Haas, V. (2012). A review of monitoring technology for use with older adults. *Journal of geriatric physical therapy, 35*(1), 28-34.

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. (2011). Using Grounded Theory as a Method for Rigorously Reviewing Literature. *European Journal of Information Systems*, 1–11.

Wu, Y.-h., Damnée, S., Kerhervé, H., Ware, C., & Rigaud, A.-S. (2015). Bridging the digital divide in older adults: A study from an initiative to inform older adults about new technologies. *Clinical Interventions in Aging, 10*, 193-201.

Yang, K., & Jolly, L. D. (2008). Age Cohort Analysis in Adoption of Mobile Data Services: Gen Xers versus Baby Boomers. *Journal of Consumer Marketing, 25*(5), 272–80.

Young, R., Willis, E., Cameron, G., & Geana, M. (2014). "Willing but Unwilling": Attitudinal barriers to adoption of home-based health information technology among older adults. *Health Informatics Journal, 20*(2), 127-135.

B | Details about the Adapt system

B.1 Introduction

This appendix presents a detailed description of how the Adapt team planned the design and implementation of the Adapt system, as of March 2016.

The Adapt team was open to other ideas as to how it could be designed, which was one of the reasons for developing the different concepts described in chapter 6. However, this description is what the Adapt team has been working with, and is probably how the forthcoming trial period of the system will be designed.

Note that this is based purely on documentation and descriptions by the Adapt team, and is not influenced by any of the work done in this thesis.

B.2 Detailed description

The Adapt system consists of two main components: the sensor device that measures the movement, and the back-end (server + database) system that stores the collected data, analyses it, and presents the results to both the elderly user and the fall risk assessors, and possibly other stakeholders.

As of now, the sensor device is planned to be positioned on the lower back of the user while collecting data. This position was chosen because of the algorithm used to calculate how the user moves from the sensor data, which is optimized for this position. If an algorithm is developed in the future that provides equal or higher accuracy for another position on the body compared to the current algorithm, the team will consider using this position instead.

The sensor device will be worn by the user over a period of 3-4 days. The sensor will continuously collect data about how the user moves, in the form of multiple variables. Examples of such variables are listed below, which were used in a previous study called FARAO:

- Total, maximum and median duration of locomotion bouts
- Number of strides
- Stride time and length
- Mean walking speed
- Distance walked per bout
- Stride time, length and speed variability
- SD of acceleration
- Stride regularity
- Index harmonicity (spectral measure)
- Frequency variability (spectral measure)
- Harmonic ratio (spectral measure)
- Dominant frequency, amplitude and width (spectral measure)
- Sample and permutation entropy (non-linear measure)
- Local dynamic stability (non-linear measure)

The sensor device will either be a smartphone, or an external sensor with wireless connection to the smartphone. In the final version of the service, the plan is for this smartphone to send the data over an Internet connection to the back-end of the system automatically. In the trial period, however, it is more likely that this functionality is skipped, and the smartphones are collected and brought to the fall risk assessment centre, where the fall risk assessors transfer the data to the system themselves.

The back-end solution will analyse the sensor data in order to estimate the fall risk and produce a mobility index for each user. This information will then be accessible over the Internet for authorized users, primarily the elderly user for whom the data is concerning, and fall risk assessors. The fall risk assessors might suggest specific interventions (e.g. balance exercises) based on the data about the user, with the aim of reducing the user's risk of falling. This can be communicated to the user in the form of a motivating message.

These motivating messages can also be generated automatically by the system, but in the trial period it is more likely this will have to be done manually. The messages are sent to the user and displayed alongside the fall risk data calculated by the system.

In order to get more accurate calculations by the system and provide the fall risk assessors with valuable information when evaluating the fall risk of users manually, each user is asked to provide information about their health status and physical function the first time they use the system. Examples of these variables are listed below (these are also from the FARAO study):

- Age
- Gender
- Weight
- Height
- Use of walking aid
- Cognitive function (Mini–mental state examination (MMSE) score)
- Number of falls past 6 and 12 months
- Living independently
- Fear of falling [16-item efficacy scale, FES-I] (part of the sample)
- Depression [30-item geriatric depression scale, GDS] (part of the sample)

C | Physical models for workshop

During a meeting with Yngve Dahl, one of the researchers at SINTEF who is part of the Adapt team, it was decided that the author would work on planning and preparing the physical models or ”building blocks” that will be used in a workshop that was planned with potential users of the Adapt system. This workshop was postponed and is thus not part of this thesis, but the work done in preparation of this workshop is presented here.

The models would be used to illustrate the different physical objects that may be part of the final system. By using physical models instead of photos or sketches, the participants could get a better look at how the components look, and could provide more accurate feedback.

One of the objects that were discussed was a belt that had been used in a previous SINTEF project: Farseeing [66]. This belt can hold a smartphone, which was used to detect falls based on accelerometer data. Yngve would get this for the workshop.

Secondly, models of phones, sensor units and other objects should be created out of foam, or a similar material. The plan was to make models in different sizes, to find out which size receives the highest level of acceptance among the participants. In the case of smartphones, three sizes were suggested, based on real-life phone models:

- Large (150,9 x 72,6 x 7,7 mm, based on the *Samsung Galaxy S7)*
- Medium (127 x 65 x 8,9 mm, based on the *Sony Xperia Z5 Compact)*
- Small (104 x 58 x 12 mm, based on the *Samsung Galaxy Y GT-S5360)*

The Department for Product Design at NTNU [76] has equipment for making such models, and was contacted by e-mail after the meeting. However, this enquiry was not answered, and in a later meeting with Yngve Dahl and the subject supervisor, it was decided not to prioritize this.

Pairs of hook and loop fasteners (velcro) can be used to easily attach and detach models from different placements.

For testing attachment to the wrists and arms, a simple sweatband could be used, with the velcro attached to it. Also, an armband with a pocket for a phone (typically designed for use while running) could be used, and an adjustable velcro band that can be worn on multiple different places on the body.

It was planned to use post-it notes to simulate the user interface. These would be cut to match the size of the models, simulating the screen, and new notes could quickly replace old ones with updated user interfaces if this needs to change during the workshop, e.g. to show the user the updated user interface when a button is pushed.

D | Glossary and acronyms

Glossary

app A mobile application - a computer program designed to run on mobile devices such as smartphones and tablet computers.

Cascading Style Sheets A style sheet language used for describing the presentation of a document written in a markup language.

HyperText Markup Language The standard markup language used to create web pages.

JavaScript a high-level, dynamic, untyped, and interpreted programming language, typically used alongside HTML and CSS.

web app A web application - a client–server software application which the client (or user interface) runs in a web browser.

Acronyms

CSS Cascading Style Sheets.

DOM Document Object Model.

GUI Graphical user interface.

HCI Human-Computer Interaction.

HTML HyperText Markup Language.

ICT Information and communication technology.

IJHCI International Journal of Human-Computer Interaction.

MMSE Mini–mental state examination.

NTNU Norwegian University of Science and Technology.

RFID Radio-frequency identification.

RIS Research Information Systems.

RWD Responsive web design.

SINTEF Stiftelsen for industriell og teknisk forskning.

SMS Short Message Service.

SPA Single-page Application.

UTAUT Unified theory of acceptance and use of technology.

Bibliography

[1] United Nations. *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables*. Tech. rep. Working Paper No ESA/P/WP. 241, United Nations, Department of Economic and Social Affairs, Population Division, New York, 2015.

[2] K Eric DeJonge, George Taler, and Peter A Boling. "Independence at home: community-based care for older adults with severe chronic illness". In: *Clinics in geriatric medicine* 25.1 (2009), pp. 155–169.

[3] Pekka Kannus et al. "Fall-induced injuries and deaths among older adults". In: *Jama* 281.20 (1999), pp. 1895–1899.

[4] Pekka Kannus et al. "Prevention of falls and consequent injuries in elderly people". In: *The Lancet* 366.9500 (2005), pp. 1885–1893.

[5] Mary E Tinetti and Christianna S Williams. "Falls, injuries due to falls, and the risk of admission to a nursing home". In: *New England journal of medicine* 337.18 (1997), pp. 1279–1284.

[6] Viswanath Venkatesh, James YL Thong, and Xin Xu. "Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology". In: *MIS quarterly* 36.1 (2012), pp. 157–178.

[7] Stiftelsen SINTEF. *ADAPT - SINTEF*. `https://www.sintef.no/en/projects/adapt/`. [Online; accessed 27 April 2016]. 2014.

[8] Briony J Oates. *Researching Information Systems and Computing*. 1st ed. SAGE Publications Ltd, 2005. ISBN: 9781412902243.

[9] Elsevier B.V. *Scopus - Welcome to Scopus*. `https://www.scopus.com/`. [Online; accessed 13 May 2016]. 2016.

[10] NCBI. *Home - PubMed - NCBI*. https://www.ncbi.nlm.nih.gov/pubmed. [Online; accessed 13 May 2016]. 2016.

[11] Joost F Wolfswinkel, Elfi Furtmueller, and Celeste PM Wilderom. "Using grounded theory as a method for rigorously reviewing literature". In: *European Journal of Information Systems* 22.1 (2011), pp. 45–55.

[12] Viswanath Venkatesh et al. "User acceptance of information technology: Toward a unified view". In: *MIS quarterly* (2003), pp. 425–478.

[13] LLC. Dictionary.com. *Thesaurus.com | Find Synonyms and Antonyms of Words at Thesaurus.com*. http://www.thesaurus.com/. 2016.

[14] Lars Tore Vassli and Babak A. Farshchian. *Background material for systematic review of literature on ICT acceptance among community dwelling elderly*. doi:10.5281/zenodo.50293. 2016.

[15] Elsevier B.V. *Scopus | The largest database of peer-reviewed literature | Elsevier*. https://www.elsevier.com/solutions/scopus. [Online; accessed 13 May 2016]. 2016.

[16] Elsevier B.V. *Content - Scopus | Elsevier*. https://www.elsevier.com/solutions/scopus/content. [Online; accessed 13 May 2016]. 2016.

[17] Thomson Reuters. *EndNote | Thomson Reuters*. http://endnote.com/. [Online; accessed 14 May 2016]. 2016.

[18] F. Wagner, J. Basran, and V. Dal Bello-Haas. "A review of monitoring technology for use with older adults". In: *Journal of Geriatric Physical Therapy* 35.1 (2012), pp. 28–34.

[19] S. H. Fischer et al. "Acceptance and use of health information technology by community-dwelling elders". In: *International Journal of Medical Informatics* 83.9 (2014), pp. 624–635.

[20] M. Memon et al. "Ambient Assisted Living healthcare frameworks, platforms, standards, and quality attributes". In: *Sensors (Switzerland)* 14.3 (2014), pp. 4312–4341.

[21] K. Connelly et al. "Approaches to understanding the impact of technologies for aging in place: A mini-review". In: *Gerontology* 60.3 (2014), pp. 282–288.

[22] H. Jimison et al. "Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved". In: *Evidence report/technology assessment* 175 (2008), pp. 1–1422.

[23] E. Pietrzak, C. Cotea, and S. Pullman. “Does smart home technology prevent falls in community-dwelling older adults: a literature review”. In: *Inform Prim Care* 21.3 (2014), pp. 105–12.

[24] G. R. Rios. “eHealth literacy and older adults: A review of literature”. In: *Topics in Geriatric Rehabilitation* 29.2 (2013), pp. 116–125.

[25] J. Finkelstein et al. “Enabling patient-centered care through health information technology”. In: *Evidence report/technology assessment* 206 (2012), pp. 1–1531.

[26] S. Chaudhuri, H. Thompson, and G. Demiris. “Fall detection devices and their use with older adults: A systematic review”. In: *Journal of Geriatric Physical Therapy* 37.4 (2014), pp. 178–196.

[27] H. Hawley-Hague et al. “Older adults’ perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review”. In: *Int J Med Inform* 83.6 (2014), pp. 416–26.

[28] S. Lauriks et al. “Review of ICT-based services for identified unmet needs in people with dementia”. In: *Ageing Research Reviews* 6.3 (2007), pp. 223–246.

[29] researchgate.net. *ResearchGate - Share and discover research*. `https://www.researchgate.net/`. [Online; accessed 14 May 2016]. 2016.

[30] M. L. Jung and K. Loria. “Acceptance of Swedish e-health services”. In: *Journal of multidisciplinary healthcare* 3 (2011), pp. 55–63.

[31] J. F. Lu, M. J. Chi, and C. M. Chen. “Advocacy of home telehealth care among consumers with chronic conditions”. In: *Journal of Clinical Nursing* 23 (2014), pp. 811–819.

[32] S. Sayago and J. Blat. “An ethnographical study of the accessibility barriers in the everyday interactions of older people with the web”. In: *Universal Access in the Information Society* 10 (2011), pp. 359–371.

[33] C. Jaschinski and S. B. Allouch. “An extended view on benefits and barriers of ambient assisted living solutions”. In: *International Journal on Advances in Life Sciences* 7 (2015), pp. 40–53.

[34] B. Reeder et al. “Assessing older adults’ perceptions of sensor data and designing visual displays for ambient environments”. In: *Methods of Information in Medicine* 53 (2014), pp. 152–159.

[35] P. K. Loh, L. Flicker, and B. Horner. "Attitudes Toward Information and Communication Technology (ICT) in Residential Aged Care in Western Australia". In: *Journal of the American Medical Directors Association* 10 (2009), pp. 408–413.

[36] Y. H. Wu et al. "Bridging the digital divide in older adults: A study from an initiative to inform older adults about new technologies". In: *Clinical Interventions in Aging* 10 (2015), pp. 193–201.

[37] M. Govercin et al. "Defining the user requirements for wearable and optical fall prediction and fall detection devices for home use". In: *Informatics for Health and Social Care* 35 (2010), pp. 177–187.

[38] P. M. Trief et al. "Diabetes management assisted by telemedicine: Patient perspectives". In: *Telemedicine and e-Health* 14 (2008), pp. 647–655.

[39] R. Steele et al. "Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare". In: *International Journal of Medical Informatics* 78 (2009), pp. 788–801.

[40] J. Chung et al. "Exploring an informed decision-making framework using in-home sensors: Older adults' perceptions". In: *Informatics in Primary Care* 21 (2014), pp. 73–77.

[41] C. Sanders et al. "Exploring barriers to participation and adoption of telehealth and telecare within the Whole System Demonstrator trial: A qualitative study". In: *BMC Health Services Research* 12 (2012).

[42] G. Demiris et al. "Findings from a participatory evaluation of a smart home application for older adults". In: *Technology and Health Care* 16 (2008), pp. 111–118.

[43] M. Alwan et al. "Impact of monitoring technology in assisted living: Outcome pilot". In: *IEEE Transactions on Information Technology in Biomedicine* 10 (2006), pp. 192–198.

[44] K. Y. Chen et al. "Implementing technology-based embedded assessment in the home and community life of individuals aging with disabilities: A participatory research and development study". In: *Disability and Rehabilitation: Assistive Technology* 9 (2014), pp. 112–120.

[45] M. Sjolinder and A. Avatare Nou. "Indoor and outdoor social alarms: understanding users' perspectives". In: *JMIR Mhealth Uhealth* 2 (2014), e9.

[46] L. Damodaran, W. Olphert, and S. Phipps. “Keeping silver surfers on the crest of a wave - Older people’s ICT learning and support needs”. In: *Working with Older People* 17 (2013), pp. 32–36.

[47] D. Kutz, K. Shankar, and K. Connelly. “Making sense of mobile- and web-based wellness information technology: cross-generational study”. In: *Journal of medical Internet research* 15 (2013).

[48] R. J. Campbell. “Meeting seniors’ information needs: Using computer technology”. In: *Home Health Care Management and Practice* 20 (2008), pp. 328–335.

[49] S. J. Parker et al. “Older adults are mobile too!Identifying the barriers and facilitators to older adults’ use of mHealth for pain management”. In: *BMC Geriatrics* 13 (2013).

[50] G. Demiris et al. “Older adults’ acceptance of a community-based telehealth wellness system”. In: *Informatics for Health and Social Care* 38 (2013), pp. 27–36.

[51] G. Demiris et al. “Older adults’ attitudes towards and perceptions of ”smart home” technologies: a pilot study”. In: *Med Inform Internet Med* 29 (2004), pp. 87–94.

[52] M. M. Price et al. “Older adults’ perceptions of usefulness of personal health records”. In: *Universal Access in the Information Society* 12 (2013), pp. 191–204.

[53] G. Demiris et al. “Older adults’ privacy considerations for vision based recognition methods of eldercare applications”. In: *Technology and Health Care* 17 (2009), pp. 41–48.

[54] G. L. Alexander et al. “Passive sensor technology interface to assess elder activity in independent living”. In: *Nursing Research* 60 (2011), pp. 318–325.

[55] K. L. Courtney. “Privacy and senior willingness to adopt smart home information technology in residential care facilities”. In: *Methods of Information in Medicine* 47 (2008), pp. 76–81.

[56] G. Demiris et al. “Senior residents’ perceived need of and preferences for ”smart home” sensor technologies”. In: *International Journal of Technology Assessment in Health Care* 24 (2008), pp. 120–124.

[57] K. Goodall, P. Ward, and L. Newman. "Use of information and communication technology to provide health information: What do older migrants know, and what do they need to know?" In: *Quality in Primary Care* 18 (2010), pp. 27–32.

[58] T. Greenhalgh et al. "What matters to older people with assisted living needs? A phenomenological analysis of the use and non-use of telehealth and telecare". In: *Social Science and Medicine* 93 (2013), pp. 86–94.

[59] R. Young et al. ""Willing but Unwilling": Attitudinal barriers to adoption of home-based health information technology among older adults". In: *Health Informatics Journal* 20 (2014), pp. 127–135.

[60] J. S. Ancker et al. ""You get reminded you're a sick person": Personal data tracking and patients with multiple chronic conditions". In: *Journal of Medical Internet Research* 17 (2015).

[61] HCI International. *IJHCI_ Special Issue on Mobile HCI.pdf*. `http://www.hci.international/files/IJHCI_%20Special%20Issue%20on%20Mobile%20HCI.pdf`. [Online; accessed 2 May 2016]. 2016.

[62] Axivity. *Axivity | Product*. `http://axivity.com/product/wax9`. [Online; accessed 29 April 2016]. 2015.

[63] Axivity. *Axivity | Product*. `http://axivity.com/product/wrist-band`. [Online; accessed 29 April 2016]. 2015.

[64] Seraphim Sense Ltd. *Angel Sensor - Open Mobile Health Wearable | The future of health and well being*. `http://angelsensor.com/`. [Online; accessed 29 April 2016]. 2016.

[65] Moticon. *Science & Research - Moticon*. `http://www.moticon.de/products/science-research`. [Online; accessed 30 April 2016]. 2015.

[66] Stiftelsen SINTEF. *FARSEEING - SINTEF*. `https://www.sintef.no/en/projects/farseeing/`. [Online; accessed 30 April 2016]. 2014.

[67] Emiliano Miluzzo et al. "Pocket, bag, hand, etc.-automatically detecting phone context through discovery". In: *Proc. PhoneSense 2010* (2010), pp. 21–25.

[68] Jason Wiese, T Scott Saponas, and AJ Brush. "Phoneprioception: enabling mobile phones to infer where they are kept". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM. 2013, pp. 2157–2166.

[69] Jun Yang, Emmanuel Munguia-Tapia, and Simon Gibbs. “Efficient in-pocket detection with mobile phones”. In: *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication*. ACM. 2013, pp. 31–34.

[70] Raspberry Pi Foundation. *Raspberry Pi Touch Display - Raspberry Pi*. `https://www.raspberrypi.org/products/raspberry-pi-touch-display/`. [Online; accessed 30 April 2016].

[71] Google. *Audio - Google Glass Help*. `https://support.google.com/glass/answer/3311275?hl=en`. [Online; accessed 30 April 2016]. 2016.

[72] Aaron Smith. *Older Adults and Technology Use*. Tech. rep. Pew Internet & American Life Project, Pew Research Center, 2014.

[73] Doro AB. *Doro - Enkel mobiltelefon - Smartphone for senior*. `http://www.doro.no/`. [Online; accessed 30 April 2016]. 2015.

[74] David M Buchner et al. “The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults”. In: *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 52.4 (1997), pp. M218–M224.

[75] Balsamiq Studios, LLC. *Balsamiq. Rapid, effective and fun wireframing software. | Balsamiq*. `https://balsamiq.com/`. [Online; accessed 11 May 2016]. 2016.

[76] NTNU. *Department of Product Design - NTNU*. `http://www.ntnu.edu/design`. [Online; accessed 30 April 2016].