Ambient Assisted Living technology (AAL) and Its Acceptance by Elderly People

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Abstract

Ambient assisted living (AAL) is the emerging research topic due to the rapid growth of elderly population worldwide especially in Europe to be specific. European commission has been funding for the research, development and innovation projects to support active ageing in place. AAL technological solutions have been emerged with the enormous possibilities to support elderly people to live quality life and spend their time independently at their own place.

In this study, the current state of art in the field of ambient assisted living is explored. Different perspectives of technology acceptance ranging from usability engineering to technology acceptance model (TAM) have been studied to generate hypothetical model of acceptance. The model is applied to gather elderly people views via questionnaire thereby applied statistical methods such as correlation statistics and inferential statistics to discover the most influencing factors for the acceptance of technology by elderly people. Based on the feedback given by participants, recommendations are also presented for designers and implementers of AAL technology.

The results from analysis revealed that the acceptance of AAL solutions by elderly people depend on three most influencing factors namely usability, security/trust and cost. It also indicates that the socio- emotional factors and cost has less impact on elderly people's attitude towards using the technology. Further, it indicates that the use of more sample data could improve the analysis results.

Keywords: AAL, ageing in place, TAM, usability, acceptance

Preface

I would like to express my gratitude to the University of Eastern Finland, School of Computing for providing me the invaluable opportunity to conduct my thesis. My sincere appreciation goes to Prof. Markku Tukiainen for his guidance, support and supervision. Without him, my study would not have been possible. I am heartily thankful to PhD student Hooryeh Afkari, University of Eastern Finland, for her help and encouragement during my study. I would also like to convey my deep appreciation to my colleagues Edgar Cornejo (Msc student) and Azra Tayeebi (Msc student) for their valuable opinions, ideas, suggestions and support. I am indebted to all the elderly participants for their active contribution in my study.

Finally, I would like to show my gratitude towards my family and friends for their absolute love and support. Also, I would like to thank all, who have supported me directly or indirectly to pursue my research.

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Bijaya Bhandari

List of abbreviations

AAL	Ambient Assisted Living
ACM	Association for Computing Machinery
TAM	Technology Acceptance Model
UTOPIA	Usable Technology for Older People Inclusive and Appropriate
IEEE	Institute of Electrical and Electronics Engineers
SOPRANO	Service-oriented Programmable Smart Environments for Older Europeans
MIGSEP	Multimodal Interactive Guidance System for Elderly People
ADVENT	Advanced Monitoring Services of Elder via Sensor Networks
ALLADIN	Autonomous Learning Agents for Decentralized Data and Information Networks
HCI	Human Computer Interaction
EOU	Ease of Use
U	Usefulness
BI	Behavioral Intention
ANOVA	Analysis of Variance

Contents

1 Introduction

1.1 Overview

Globally, the number of elderly people (aged 60 years or over) is expected to more than double, from 841 million people in 2013 to more than 2 billion in 2050 (United Nations, 2013). Over the last 50 years, the growth of elderly population is tripled and it is anticipated that it will more than triple again in next 50 years. As a consequence, it will be difficult to provide adequate health care solutions for them. Additionally it has been expected that most of the people when they will turn old will prefer to live alone especially in European region due to the higher life expectancy. Thus, there is an increasing concern about active ageing as elderly population is growing in a very fast pace.

Ageing problem is appearing these days as a challenging issue to technical society. The main challenge is to build up highly effective, automated intelligent solution which allows elderly people to spend their time independently at their own preferred location. This condition has led to the requirement of new technological solutions aiming at improving independence, quality of life, and active ageing of elderly population. To address the need of elderly people, researchers proposed the term Ambient Intelligent to refer to the systems having capability to deliver its services in a responsive, context sensitive manner and are integrated into the environment unobtrusively (Aarts & Wichert, 2009).

According to (Aarts & Wichert, 2009), Ambient Intelligent system is a new generation system with the characteristics of being Invisible meaning embedded in clothes, watches, glasses etc., Mobile meaning being carried around, Spontaneous meaning adhoc communication among the nodes, Heterogeneous and hierarchical, meaning they compromise different kinds of system nodes regarding their computational power and rendered functionality, Context-aware meaning they are aware of their local environment and spontaneously exchange information with similar nodes in their neighborhood and Anticipatory meaning acting on their own without explicit extrinsic requests. Furthermore, the system should be able to communicate naturally

with users by voice and gestures instead of keyboard, mouse or text on screens as well as interact naturally by means of devices that are used e.g.: clothing, watches, TV, telephone and household appliances to become ambient. These devices are equipped with some kind of intelligence having adaptive capability i.e. adept of reaching to all abnormal and exceptional situations in a flexible way. Ambient assisted living (AAL) is the concept utilizing ambient assisted technology.

"Ambient Assisted Living (AAL) comprises interoperable concepts, products and services that combine new information and communication technologies (ICT) and social environments with the aim to improve and increase the quality of life for people in all stages of the life cycle"(Pieper, Antona, & Cortés, 2011).

1.2 Problem Statement

Ageing population brings many challenges not only to the elderly people but also to their caregivers. The following lists the major challenges and problems towards informal caregivers and current health system due to growth in ageing society:

- *Increase in age related diseases*: There is possibility of increase in age related incurable diseases such as Alzheimer's or Parkinson's diseases as a consequence of rise in elderly population.
- *Increase in health care costs*: "Population ageing is associated with higher health expenditure, partly due to the increase in the proportion of older persons, which have higher prevalence of morbidity and demand for health care than younger adults" (United Nations, 2013).
- *Shortage of professionals*: It is anticipated that there will be a shortage of professional care givers trained to work with ageing population. In fact, informal caregivers should take responsibility to work with elderly people for instance family members which in turn may results in emotional distress and physical health problems for caregivers.
- *Elderly people dependency*: Due to the increasing number of ageing population and age related diseases, elderly people will be unable to live independently in their preferred environment which will eventually gives challenges to health care system on how they could provide quality health care services to ageing population.

The above problems have raised the requirement for effective and efficient solution addressing the real user needs. However, not all users are ready to accept the system which is being designed and developed for them. Thus, acceptability of system is one of the major issues of AAL solutions. Moreover, Age related physical, perceptual and cognitive decline makes the task of developing efficient solutions even more challenging. Though family members or external caregivers are providing assistance to most of the elderly people, this will be difficult when there will be maximum ageing population and less number of health care professionals. In spite of focusing on design of technological solutions, it is better to address the need of people by providing integrated solution which can assure the usability, usefulness, privacy and security for elderly people.

1.3 Research Questions

The subsequent three research questions are applied to construct overall thesis topic. This paper is not going to provide complete answers to these questions but instead gives overall idea on how these questions can be addressed while developing Ambient Assisted Living technologies. State of art was determined through the first research question which is:

1. *What is the current state of research in Ambient Assisted Living (AAL) technologies?*

This question is answered by the literature review presented on this thesis paper, in which research until 2015 is considered. Furthermore, this question is also addressed in previous Introduction and problem statement section moderately. Before deciding on research methodology to answer other research questions, it was necessary to discover current research in AAL field. For this purpose, different online databases mainly Google scholar, ACM, IEEE and Springer were searched to find out related research papers. After that, the literature was evaluated qualitatively to answer the second research question which is as follows:

2. *What factors are influencing the acceptance of AAL technologies by elderly people?*

To answer this question, literature was evaluated in three different perspectives which are Technology acceptance model (TAM), Usability Engineering, and User

Involvement strategy. All of these three perspectives were intended to address acceptance of technology by elderly people. Moreover, Socio- emotional factors comes from research in AAL technologies were also considered to derive some important influencing factors which can affect to the acceptability of technology. After the factors were determined, following research question was posed to establish the impact of different derived factors on acceptability of AAL technology.

3. *What is the impact of influencing factors on Acceptance of AAL technologies?*

This question is answered on the basis of quantitative data collected through elderly people. For this point, quantitative methodology is applied to verify relationship between different influencing factors and to determine most impactful variables leading to acceptability of technology thus heading towards success of AAL technology. Different quantitative methods such as correlation and regression analysis are applied to get the overall result.

1.4 Thesis Organization

This thesis is divided into seven parts. Chapter two, Literature review section describes the current state of art in the field of ambient assisted living technology including currently running projects worldwide. Also, this section discusses the different perspectives of technology acceptance by elderly people. Chapter three, hypothetical model of assisted living technology presents original acceptance model derived from literature review. After that Chapter four, Research Methodology discusses on different research approaches and adopted approach for this thesis, research strategies, data collection and data analysis including results. Chapter five presents the overall outcome and discussion related to the result drawn from data analysis whereas Chapter six gives limitation and recommendation. Finally conclusion is driven in Chapter seven.

2 Literature Review

AAL technologies offer promising perspective on autonomous aging in place (Jaschinski, 2014). In this highly advanced technological era, Ambient Assisted Living has become one of the important research and development areas where usability and accessibility plays major role. Research are being carried out with the aim of developing accessible and usable solutions for elderly people to make their life independent and allow them to live in their preferred environment for longer period of time.

As the people aged over 60 are growing more quickly than the other age group, it causes high costs in medical and social care thus creating challenges to develop acceptable technological solutions or services. Developing full-fledged technology to support elderly living is not an easy task because they are less exposed to computers than young people and the requirements, priorities, needs and expectations of people aged 60 or more is difficult to address.

Even though the technologies which promises to provide higher quality of life to elderly people has been emerged in a fast pace, only little information is known about whether the elderly people are ready to accept these solutions or not. Some research hypothesized that the involvement of user from the beginning of development of technology helps to make the system more acceptable whereas some other thinks that usability factors plays the major role in technology acceptance.

So far, Most of the solutions are technology driven rather than user driven and less research has been conducted in user acceptance. There is yet no clear and unique evidence about what are the major constraints towards acceptance of AAL technological solutions. The subsequent sections of this literature tries to address these views by discussing on requirements of AAL services, the major projects carried out in the field of Ambient assisted Living and finally concludes by different perspectives on technology acceptance.

2.1 AAL Requirements and Services

Kleinberger, Becker, Ras, Holzinger and Müller (2007) mention three major requirements for ambient assisted living systems to fulfill its motive to address the need of handicapped and elderly people suffering from all kinds of disabilities such as gait changes, neurological alterations, visual acuity changes, vestibular compromise, spontaneous fractures, and falls, cardiac alteration with syncope, or sudden change in blood pressure. The first requirement is that; Assisted Living System must be ambient and unobtrusive meaning it must be responsive to the environment and behavior of people to reach a higher acceptance whereas second one is System should adopt themselves to changing personal situations or the capabilities of the individual and the environment to fulfill individual needs and final requirement is System has to provide their services in an accessible way to enhance usability.

Kleinberger et al. (2007) categorizes Home Care System as part of Ambient Assistance system into three domains as follows:

1) Emergency assistance services: emergency prediction, emergency detection, emergency prevention
2) Autonomy enhancement services: cooking assistance, cleaning assistance, eating assistance
3) Comfort services : home automation, safety, finding things, infotainment services

As opposed to which Nehmer, Becker, Karshmer and Lamm (2006) categorizes ambient assisted system into three domains and further categorizes it into two sub domains for each domain which is clearly shown in the table presented below:

Table 1. AAL requirements and services

	Indoor Assistance	**Outdoor Assistance**
Emergency assistance Services	Emergency prediction, emergency detection, emergency prevention	Emergency prediction, emergency detection, emergency prevention
Autonomy Enhancement Services	Cooking Assistance, Eating Assistance, drinking Assistance, cleaning Assistance etc.	Shopping assistance, travel assistance, banking assistance
Comfort Services	Logistic services, services for finding things, infotainment services	Transportation services, orientation services

Kleinberger et al. (2007) excluded Outdoor Assistance and call it **"Home Care System**" focusing on support for elderly and disabled people in their own homes and categorized it with three domains including indoor assistance services only. This paper not only focuses on acceptance of technology used for indoor assistance services but also used for outdoor assistance.

2.2. AAL projects and Related work

Robinson, Brittain, Lindsay, Jackson and Olivier (2009) shows that involving people with dementia in the different stages of participatory design can lead to the successful adaptation of proposed technological solutions and relevant to the needs of people. But unlikely Eisma et.al (2004) who carried out only one stage participatory design process i.e. in scoping stage to gather data on technological experiences of older people, Robinson et al. (2009) carried out three stage participatory design process by involving five focus groups with 43 participants in participatory design stage and

four meeting with two people in prototype development stage to prove that user-centered approach can actually address the need of target user group.

Eisma et.al (2004) claims that traditional methods of User-centered design should be adopted to effectively elicit requirements from older people so that developed system will be easily adopted by targeted user. Also Eisma et.al (2004) presents UTOPIA project (usable technology for older people- Inclusive and Appropriate) established by group of four Scottish Universities whose main focus was to develop effective methods for the early involvement of older people in the development of information technology related products and also on providing industry with tools to assist in the development of technical products to support older people.

The two main questions that were studied by Eisma et.al (2004) are relevant to main topic of this thesis paper. Those requirements are; how can we include older people most effectively in the development process? And what is different about older people and their relationship with technology? Eisma et.al (2004) found that to communicate most effectively with elderly people, research partnership should be formed. Contacting wide range of potential users, maintaining the relationship and eliciting information through qualitative approaches such as questionnaire, focus groups, workshops and interviews can be the medium of forming partnership.

Eisma et.al (2004) noted some hindrances such as inexperience with modern technologies, attitudes towards technology, learning and support problems and interface assumptions while eliciting information. And finally Eisma et.al (2004) concluded that use of technology declines with age and if the older people have positive attitude towards technology, the assisting technologies are more likely to be accepted. Similarly this paper also includes the fact that positive attitude of elderly people leads to the acceptance of technology developed for them.

The success of any technological products or services designed for elderly people depends on how usable the product or service is. From many years, researchers are focusing on user involvement in the design of technology. Some talk about involvement of user from the early development stage and some of them discusses on involvement after prototyping the system. An EU funded project SOPRANO (Service-oriented programmable smart environments) for older Europeans was set up in June,

2008 to develop an ambient assisted living system to improve the lives of frail and disabled older people (Sixsmith et.al, 2009).

Sixsmith et al. (2009) describes user driven approach within the development of SOPRANO project. It carried out extensive research by involving users at every stages of R&D process and followed qualitative approach involving 14 focus groups with more than 90 participants and individual interviews and proposed nine themes which are Social Isolation, Safety and security, forgetfulness, keeping healthy and active, community participation and contribution to local community, accessing information/keeping up to date, getting access to shops and services, quality management of care provision and mobility inside and outside the home. The overall feedback of user proved beneficial in developing architecture for SOPRANO prototype system and the user involvement helped technical designers to improve system components. Sixsmith et al. (2009) suggest that "*technology developers should listen to and act on the input from older people and their caregivers"*.

Queirós, Silva, Alvarelhão, Rocha and Teixeira (2013) carried out systematic literature review of 1048 articles and argue that integration and interoperability of existing technologies should be improved and user-centric developments should be promoted with the strong involvement of users concerning usability and accessibility issues thus giving user-centric idea in the development of AAL technologies. Queirós et al. (2013) found most of the literatures technology oriented rather than user oriented, most of them focusing on how technology can be embed in AAL context instead of proposing ways to involve users to make the system adaptable. He also noted that different AAL technologies came from different research groups lacking interoperability between them.

Queirós et al. (2013) also suggested to form research team comprised of professionals having different skills and backgrounds for instance health or social professionals and engineers by actively involving future users in all the stages of AAL development and evaluation processes. As Queirós et al. (2013) reported that user involvement in development, evaluation and validation of AAL system including usability and accessibility issues are not sufficiently explored; the motive of this thesis paper is to address these issues. The literature review conducted by Queirós et al. (2013)

emphasized the importance of universal access during the development of AAL technologies. Similarly, a systematic review of sixteen out of 2841 articles using existing technology acceptance model or framework was done by (Peek et al., 2014).

Peek et al. (2014) overviewed the factors influencing acceptance of electronic technology for ageing in place and pointed that the factors in pre-implementation stage such as high cost, privacy implications, usability, increased safety, perceived usefulness, desire to age in place etc affect the acceptance of technology by older people. He also reported that those factors also persist in post-implementation stage while the new factors also added. However, it lacks to figure out the factors in post-adoption stage which also determine whether the technology is acceptable by older people or not. Jaschinski (2014) filled this gap by studying adoption factors of AAL technologies when it's in use. Also, by relating pre-adoption and post adoption factors, Jaschinski (2014) intended to integrate it in technology adoption model. This paper also focuses on both the pre-adoption and post- adoption factors with different intention. It studies different perspectives to figure out different factors leading to the acceptance of technology and analyzes the relation and impact of each factor on the acceptance.

Living laboratory concept is another emerging research methodology which involves sensing, validating and refining complex technological solutions with real life contexts. One of the ideas of this methodology is to achieve involvement of users starting from the beginning of development phase to evaluation and validation phase of AAL system development (Krieg-Brückner, Röfer, Shi, & Gersdorf, 2010; Chiriac, Saurer, Stummer, Stummer, & Kunze, 2011; De Ruyter, Van Loenen, &Teeven, 2007; Panek, Rauhala, & Zagler, 2007; Panek & Zagler, 2008). Moreover, user studies were conducted regarding multimodal i.e. speech and gesture interaction between participants (elderly users) and the intelligent wheelchair (Anastasiou, Jian, & Zhekova, 2012) with the idea of navigating predefined destinations in a smart home environment.

Anastasiou, Jian, & Zhekova (2012) claim that with the more natural, user friendly, effective and efficient interaction, assistive environments became more suitable in the real world with its real users. Likewise the design and implementation of multi-

modal interactive guidance system (MIGSEP) for elderly to use in hospital environments was presented by (Jian et.al, 2011). MIGSEP as opposed to intelligent wheelchair combined touch, speech and visual channels in the interface of the system. Specifically Jian et.al (2011) concentrated on system aspects named effectiveness regarding task success by elderly, efficiency of executing tasks and user satisfaction regarding the overall system.

Meanwhile, Schwechat Living Lab for Ambient Assisted Living (AAL) technologies were established with the idea of co-operating with different stakeholders ranging from social service providers, local authorities, carers, companies to the end user of the system i.e. elderly people in order to invent, discuss, explore, implement and evaluate innovative technologies to support the elderly people (Bright & Coventry, 2013).This kind of living lab approach will help to accommodate the needs of actual users by involving them from the beginning of development of AAL technologies. Even though living lab methodology helps to represent the real context in which real users interact with the system improving the design and development of AAL technologies, it lacks the idea of user acceptance which is also the most essential part of ambient assisted living. Because, the development of technology is worthless if the real users deny accepting the system.

According to 2015 EU Ageing Report, people aged 65 or above relative to those aged 15-64 will almost doubled by 2060- rising from 87.5 million in 2010 to 152.6 million in 2060 whereas the number of older people aged 80 years and above will also have significant growth. This may be the reason that there are many projects organized in Europe funded by European Union. Bright and Coventry (2013) demonstrated the user inclusive requirements addressing psychological and socio-emotional needs of users in DALi(Devices for Assisted Living), EU funded multi-disciplinary project aimed at developing intelligent mobility aid for older people supporting navigation same as intelligent wheelchair described by (Anastasiou, Jian, & Zhekova, 2012).

Bright and Coventry (2013) claim that socio emotional and psychological costs such as self-consciousness, embarrassment, pride, fear of stigmatised and not wanting to admit a need should be addressed while designing the system which leads to product adoption. Bright and Coventry (2013) also state that only usability and usefulness factors are not enough to make the AAL technology more adoptive but it should also convey emotional

benefits and reduce socio emotional and psychological costs. To prove the claim, Bright and Coventry (2013) followed qualitative methodology including focus groups and interviews whose result showed that intelligent walker which is the aim of DALi project should be designed by considering the emotional and psychological factors to make it more acceptable.

Some of the recent EU projects working on home monitoring system are also the topic of research in AAL. One of the projects ADVENT (Panagiotakopoulos et.al, 2014) focuses on providing comfortable, safe and secure environment to support daily living of elderly people as well as allowing mobility and independency. Panagiotakopoulos et.al (2014) presents system architecture by analyzing user and system requirements and mentioned the challenges from ADVENT perspective. Smart Assist project (Schrader, Carlson, & Rothenpieler, 2010) also shares some common objective with ADVENT project which provides the socio-technical platform based on wireless sensors at home. The project uses the combination of wireless-in-house sensors and mobile sensors on smart phones to realize unobtrusive health monitoring. However ADVENT aims to use wider range of signals than Smart-Assist to acquire wider range of information to monitor user's status accurately.

Likewise another project ALLADIN (Haritou, Cuno, Glickman, Androulidakis, & Baboshin, 2011) also aims at providing home care system for monitoring elders suffering from dementia. In the corresponding system, elderly health status is evaluated by the information gathered from physiological parameters measurements by elders as well as feedback provided by autographic device and when necessary the alarm is produced. For the advancement of smart homes, the research and development innovation project which is partly funded by French company EDF was conducted (Marie, Daniel, &Eric, 2011). The objective of this project is to help elderly to live at home in a safe condition. As the part of project, daily activity habits or lifestyle at home for example fall, fainting restlessness with the help of mobility data collection and analysis is assessed by home monitoring system. As in the previous mentioned projects, sensor technology is used to gather mobility data for monitoring system.

Due to the rapid advancements in AAL technological solutions, user- centered development has become the need of today's development approach. User centric development refers to the close interaction between designers and users. Even most of the projects are following this approach, there are some challenges still unaddressed by many of them. Marie, Daniel, and Eric (2011) argues that technological and medical devices should not be imposed upon the elderly instead careful balance between technology and individual's agreement with the respective elderly should be maintained. Sun, De Florio, Gui, & Blondia (2009) points out some challenges of AAL solutions to be fully accepted by Elderly people. Those challenges were possible social isolation due to the over use of technology and the lack of communication between assisted people and outside world (Sun, De Florio, Gui, & Blondia, 2009).

Sun, De Florio, Gui and Blondia (2009) believes that to construct effective and efficient ambient assisted systems to help elderly people spend independent and quality life, both the technical and social perspectives should be considered. In addition (Sun, De Florio, Gui, & Blondia, 2009) also considers that human participation can help deal with the challenges because participation help explore the potential of assistive technologies. Goodman & Lundell (2005) also mentioned organizational challenges occurred during monitoring and interacting with elderly people in their home environments. User centric approaches can be failed when there are variation among users and if the involvement of users creates difficulties in research due to the difference in their needs and abilities [Newell, Gregor, Morgan, Pullin, & Macaulay, 2011; Astell et.al, 2009].

2.3. Models and Theories of Technology Acceptance

2.3.1 Innovation Diffusion Theory of Acceptance

Many Human Computer Interaction professionals are concerned about the determinants of acceptance of new technology to ensure that new design and implementation fits the user needs. According to Rogers (2010) who confers innovation diffusion theory, the acceptance of technology is determined by five characteristics:

- Relative Advantage: The extent to which a technology offers improvements over current available tools.

- Compatibility: The extent to which technology is consistent with social practices and norms among its uses
- Complexity: The extent to which technology is easy to use and easy to learn
- Trialability: The opportunity to try an innovation before committing to use it
- Observability: The extent to which the technologies outputs and its gains are clear to see

Whereas Shackel (1991), a Human Computer Interaction (HCI) researcher claims that there is the relationship between usability and acceptability of the system. He proposes the paradigm where he clearly states that the combination of utility, usability and likeability should be balanced in a trade-off against cost to make sure the system is acceptable. Usability is often related to definite qualities of user interface which are under the control of system designer, and HCI professionals focus more on ensuring usability through systematic usability evaluations to make sure that user can successively operate given technology effectively, efficiently and satisfactorily. The diagram below clearly shows that usability is the prerequisite requirement for acceptability. This may be the reason why usability engineers and HCI practitioners give more emphasis to usability issues and mention less about the acceptability.

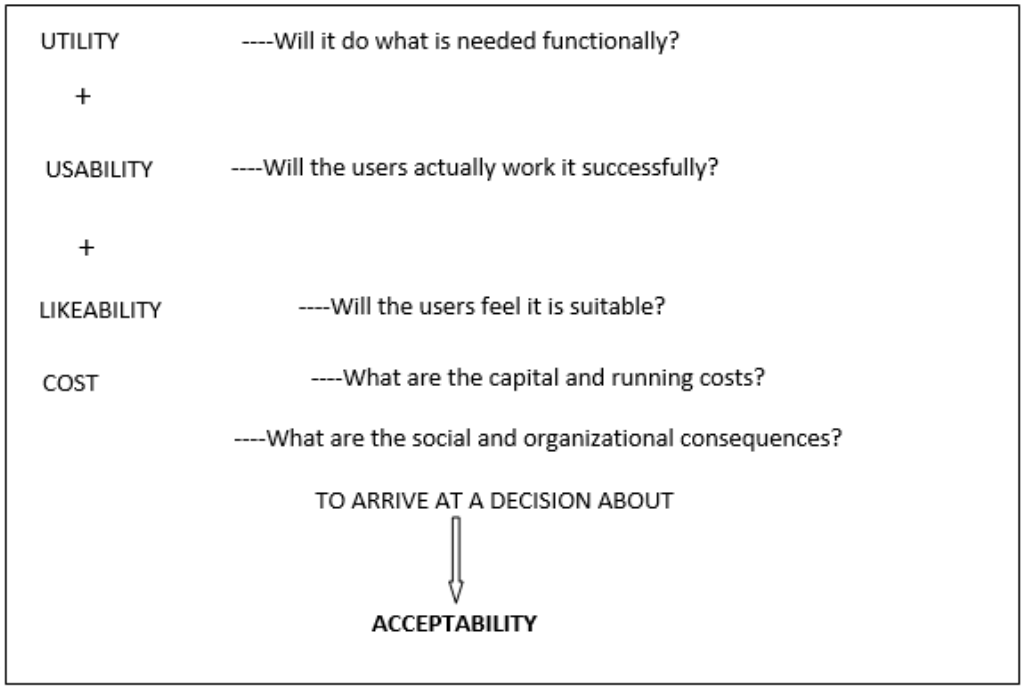


Figure 1. Relation between Acceptability and Usability by Shackel (1991)

The above factors can be linked to Rogers's five characteristics while demonstrating the idea of acceptability of the given system. Though the ability of user to operate system is the major factor resembling acceptance, it does not necessarily make it acceptable because many technological systems which are proved usable are never accepted by the user. Thus, when it comes to acceptability designers and implementers should take care of different perspectives.

2.3.2. Technology Acceptance Model

There are different models for the acceptance process of given Technological system for an instance TAM, TAM2, TAM3, Motivational model, theory of planned behavior but the most pioneering model for system acceptance is Technology acceptance Model (TAM). One of the major research questions of this thesis paper is to figure out factors which can influence the acceptance of ambient assisted living technologies by elderly people. Technology Acceptance Model (TAM) predicts user acceptance based on two factors named: perceived usefulness and perceived ease of use as shown in the figure below:

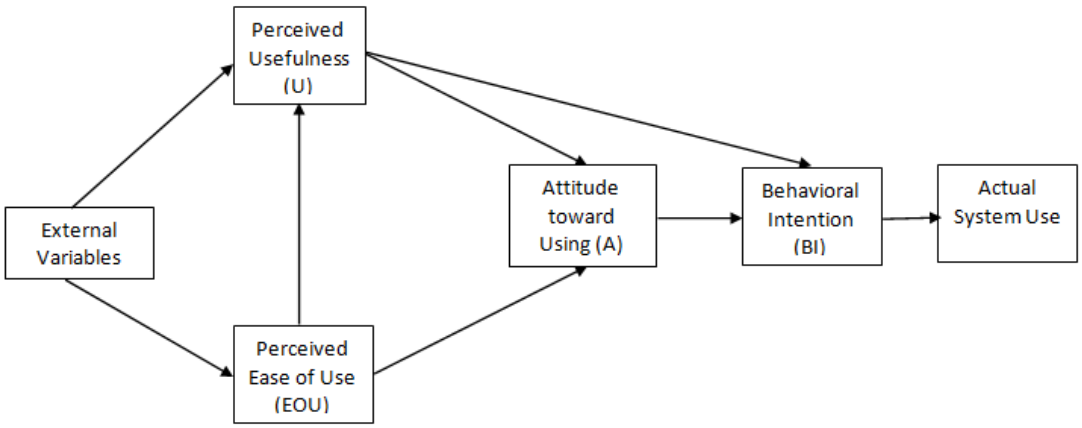


Figure 2. Technology Acceptance Model (Davis et al., 1989)

In the above figure Perceived usefulness is the extent to which user finds the system increasing his/her performance and Perceived Ease of Use is the extent to which user finds the system effortless (Dillon & Morris, 1996). Technological Acceptance Model (TAM) developed originally by Fred Davis in the year of 1986 was the pioneering concept to evaluate the system acceptance on different dimensions which was based

on theory of reasoned action or theory of planned behavior (Leitner, Mitrea, & Fercher, 2013).

As above figure shows, Both U and EOU factors impact the attitude of users (finding the system favorable or unfavorable) using the system. Likewise, Behavioral intension to use the system is the function of A and U which ultimately leads to the actual use. The aim of TCM is to foresee information system acceptance, ambient intelligence technology solution in this case and identify design problems before users actually use the system. TAM basically suggests that perceptions of users towards the system is formed very earlier even the system is not completely implemented. So, the above variables defined in the diagram plays very important role in the acceptance of the system.

TAM has been applied in wide range of applications. Results from several experiments with TAM shows that usefulness is the most important factor for system acceptance. However, TAM is useful only when users are exposed to the real system. It is appropriate in the implementation stage where designers can use it to determine how acceptable the implemented system is and how to improve the design to make it more acceptable rather than in the early design stage of system.

2.3.3. User Involvement Model

User Involvement model is generally based on the assumption that user involvement in the design process of information system leads to the increased system usage, increased user information satisfaction and increased system quality (Baroudi, Olson, & Ives, 1986). Baroudi, Olson and Ives (1986) presents two models for user involvement and its effect on system usage and user information satisfaction among which one is traditional model and another one is enhanced model of traditional one.

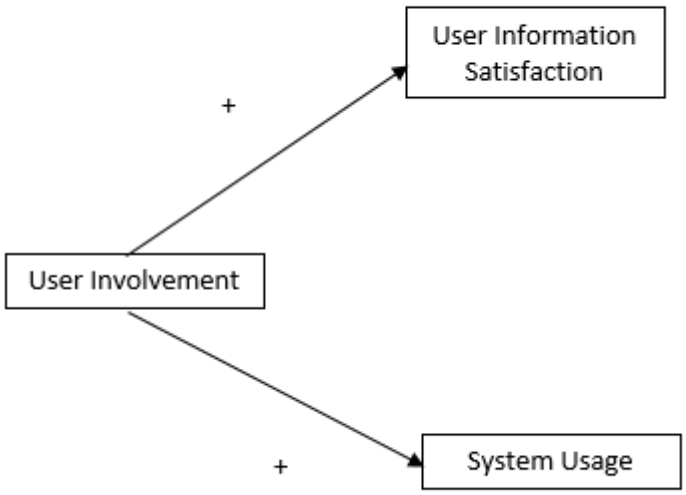
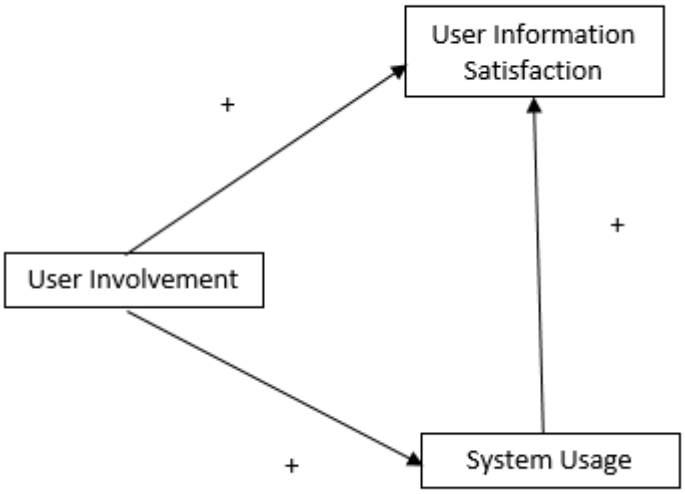


Figure 3. Traditional model of user involvement



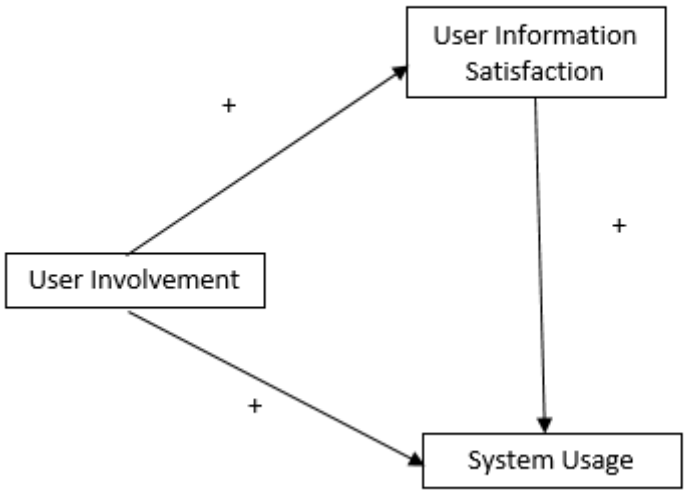


Figure 4. Enhanced model of traditional user Involvement

Traditional model hypothesizes that user involvement increases both system usage and user information satisfaction. The general idea behind this model is that if the users are involved in the design process, it will help users to better understand the system and better address their actual needs. Consequently they will be motivated to use the system and get satisfaction. Baroudi, Olson and Ives (1986) found no relationship between user involvement and system usage in three studies and in three studies he found mixed support. Similarly, regarding the user information satisfaction, he found significant relationship in five studies and no relationship in two studies.

Based on the results of traditional model (Baroudi, Olson & Ives, 1986) emerged two models with the relationship between user information satisfaction and system usage as shown in the figure. Model 1 in figure 2 hypothesizes that user involvement will results into both user information satisfaction and system usage. Meanwhile the more satisfied the user is, the more motivation they will get to use the system. Baroudi, Olson and Ives (1986) mentioned that user information satisfaction is an attitude of users towards the system while system usage is behavior.

This paper intends to merge the above three perspectives to discover different factors concerning acceptability of technology. The following chapter describes research methodology used for this thesis.

3 Hypothetical Model of AAL Technology Acceptance

Based on the literature review finding, hypothetical model for AAL technology acceptance is proposed which is shown in the figure below. This model is validated against the real experience of elderly people who use technology in daily basis to assist them.

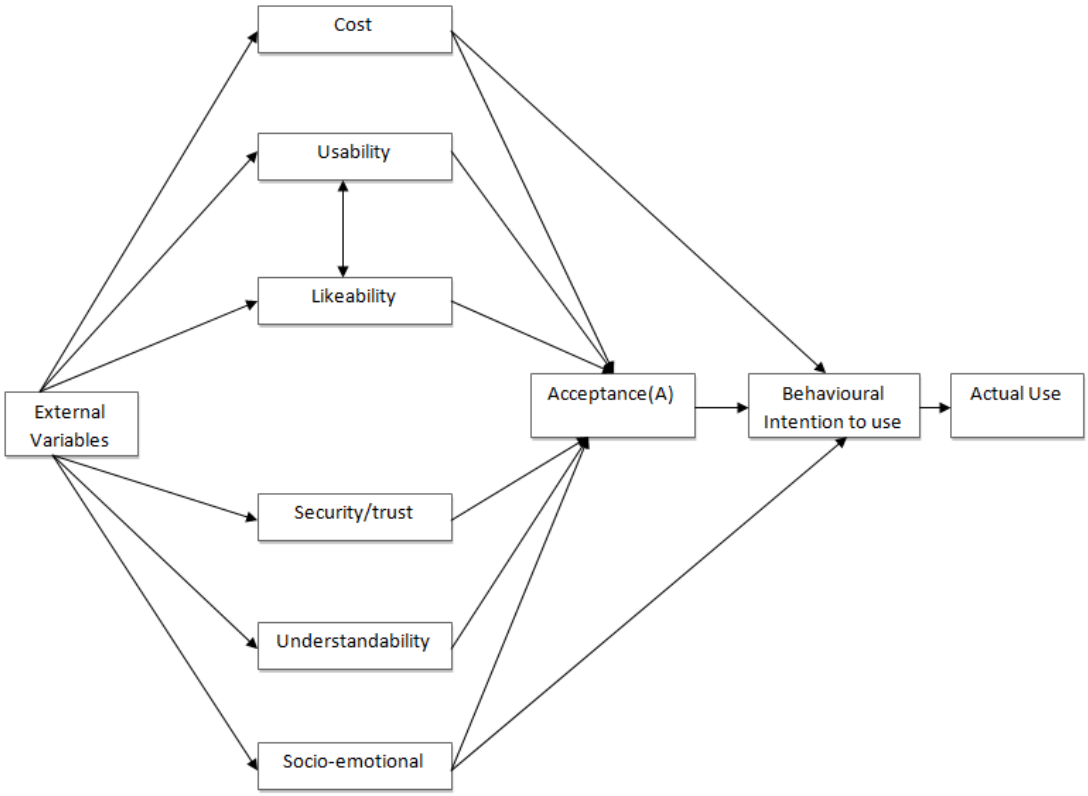


Figure 5. Hypothetical model of AAL technology acceptance

In the above figure, six major factors are presented which directly affects to the acceptance of technology which then impact on intention of elderly people to use it. It further determines the actual use. External variables in above figure mean demographic variables, educational background of elderly people as well as experience in using technology. Usability and Likeability has one to one relationship because most of the research underpinned the fact that; the more the people find technology efficient and useful, the more they like to use it and vice versa.

Also cost and socio-emotional factors can directly affect to the intention of elderly people using the technology. So the aim of this research is to prove null hypothesis wrong and the null hypothesis is: All the factors mentioned above have no effect in acceptance of technology. In other words,

H0 = Usability, Security/ trust, Socio-emotional, Likeability, Understandability and Cost has no effect on Acceptability of the technology by elderly people

H1 = Usability, Security/ trust, Socio-emotional, Likeability, Understandability and Cost has significant effect on Acceptability of the technology by elderly people

The above hypotheses are tested with T-test and F-test in Chapter 4 in analysis section.

4 Research Methodology

This section begins with research approach and is followed by research strategy utilize for the study. The main purpose of this thesis is to study major factors of acceptance of ambient assisted living technology intended to be used by elderly people. Moreover, it also aims at providing validation of hypothetical acceptance model for AAL solutions where major factors are evaluated through quantitative methods such as correlation and regression analysis. The finding of major factors is achieved by literature review done in the field of ambient assisted living as well as study from different perspectives of technology acceptance.

4.1 Research Approach

Broadly speaking, there are mainly two types of research approaches widely being used i.e. qualitative approach and quantitative approach. For this research, both approaches are used in different research phases which are clearly shown in the figure below:

Research Stages	Research Questions	Research Objectives	Research Methods
Problem Understanding	What is the current state of research in Ambient Assisted Living Technologies?	Figuring out what has been done in the field of AAL technologies?	Literature Review
Qualitative Research	What factors are influencing the acceptance of AAL technologies by older people?	Development of questionnaire including major factors leading to the acceptance of AAL technologies by older people	Literature review + Survey (Questionnaire)
Quantitative Research	What is the impact of each factor on Acceptance of AAL technologies?	Analysis of data collected through older people	Analytical Techniques

Figure 6. Research Overview

4.1.1 Qualitative Approach

"Qualitative approach to research is concerned with subjective assessment of attitudes, opinions and behavior" (Kothari, 2004). As being non-numerical, exploratory and descriptive approach, it aims to get the meaning, feeling and describe the variation in situation, attitudes and behavior. Qualitative data cannot be graphed and it is generally used to realize how people feel about certain circumstances or situations and why they feel so. For example, if one needs to explore why older population is growing too fast, then it falls into the qualitative category whereas if one wants to investigate how the population is growing then it becomes quantitative research. So, it depends on what kind of data one aims to get defies choosing the right approach. Qualitative approach is more appropriate in exploring the nature of certain phenomenon, problem or issue without quantifying which also offers flexibility in all facet of research process (Research Methodology, n.d.). Usually focus group interviews, depth interviews and projective techniques are used for carrying out qualitative research.

4.1.2. Quantitative Approach

Quantitative approach "*involves the generation of data in quantitative form which can be subjected to rigorous quantitative analysis in a formal and rigid fashion*" (Kothari, 2004). This is numerical and non-descriptive approach which applies statistics and mathematics to evaluate the evidence. It is suitable to establish extent of a problem or situation by quantifying the variation (Research Methodology, n.d.). Quantitative research embarks with the data collection based on some hypothesis which is further evaluated by applying statistical methods. The mostly used method in quantitative research is survey where sample of population is studied to determine the characteristics and comparing collected data to draw the conclusion.

4.1.3. Adopted Approach

The main intention of this study is to investigate aspects of AAL technology acceptance by elderly people. In the beginning, where the factors were determined, it used qualitative research approach and after that it used Quantitative research approach to quantify each factors leading to the acceptance of AAL technology. The

objective of this approach for this thesis is to determine relationship between different factors of acceptance and variation among them utilizing statistical methods such as correlation analysis and regression analysis. Based on the analyzed data, this paper aims at validating the acceptance model of AAL technology specified in Chapter 3.

4.2 Research Strategy

Research strategy is a plan of action which allows conducting research systematically and gives direction towards research efforts (UNC Asheville, 2013). Selecting proper research strategy helps reach to the goal of research very efficiently. Thus, research strategy is not just a plan but a long term plan which needs to be done very carefully to carry out research. Different research strategies can be adopted depending on research approaches which are described below:

4.2.1. Quantitative Research Strategies

According to Creswell, J. W. (2013), there are mainly two research strategies associated with Quantitative approach.

1) Experiments and Quasi-experiments

Experiments are the process or operation usually conducted in controlled environment to discover unknown fact, to test the hypothesis or to demonstrate known fact. There are mainly three different types of experiments which are Randomized, Quazi and Natural.

2) Surveys

Surveys include questionnaires or structured interviews for data collection which generalizes sample to a population (Creswell, J. W., 2013). Cross-sectional and longitudinal studies fall into the category of surveys.

4.2.2. Qualitative Research Strategies

According to Creswell, J. W. (2013), there are mainly five research strategies associated with Qualitative approach.

1) Ethnographies

It emphasizes the study of entire culture which can range from geographic location, ethnicity to group or organization, business or any defined group. Ethnography is tremendously large area of different variety of methods which studies any cultural group in natural setting over an extended period of time by collecting observational data (Creswell, J. W., 2013).

2) Grounded Theory

It tries to draw general abstract theory of process, action or interaction grounded in the observation of participants in the study (Creswell, J. W., 2013). This is a complex iterative process starts with generative questions followed by several stages of data collection and modification.

3) Case studies

It intends to collect comprehensive information using varieties of data collection methodologies and discover in-depth facts about activity, process, event or program (Creswell, J. W., 2013).

4) Phenomenological Research

It is sometimes considered as philosophical research that attempts to find human experiences regarding phenomenon of study (Creswell, J. W., 2013).

5) Narrative Research

It deals with the study of lives of individuals to get the stories about their lives which then retold by researcher in a descriptive chronology (Creswell, J. W., 2013).

4.2.3. Adopted Research Strategy

The research strategy that I adopted for this research is survey as I chose Quantitative research approach.

In general the research strategy depends on research questions. The main research question of my study is "*What is the impact of different factors on the acceptance of*

assisted living technologies by elderly people?" So, the most appropriate strategy I found is survey to collect quantitative data on different factors to relate it with acceptance. When the thesis question is answering what question, the most suitable strategy is survey or experiments.

I firstly adopted qualitative research strategy specially histories to determine current state of art in Assisted living technologies and also to designate important factors affecting the use of assisted living technologies by elderly people. I then followed quantitative approach to figure out important factors for the acceptance of technology.

4.3. Research Methods

After determining correct research strategy for my study, I applied survey research method of quantitative approach to uncover most influencing factors in the acceptance of ambient assisted living technologies. Sampling procedure is explained in first subsection which is then followed by Questionnaire which is designed using closed- ended questions having likert scale of 5. Additionally, this section provides data collection and data analysis which has the major impact on answering my research questions and to reach the goal of my thesis.

4.3.1. Sampling

Among different sampling techniques available; for example simple random sampling, Stratified sampling and systematic sampling, I applied stratified sampling method because the specific group of elderly people is needed to answer the research questions. Sampling size was 10 due to the lack of time and resources and also because participants should be elderly citizens to conduct this study. A survey was conducted in 23-05-2015 and 24-05-2015 in a lab environment of University of Eastern Finland.

The samples were selected on the basis of their knowledge and use of IT in their day to day lives. Survey was conducted individually rather than in a group to make them comfortable. Participants were first given Informed consent to ensure them that; their information is anonymous and will not be revealed without their permission. After

that they answered to the questionnaire in no time limit. Most of the participants were well educated and was using technology in their day to day lives such as automatic timers, smart phones, I-pad, and computers and so on. This information was crucial to make sure the participants understand the questionnaire and answered it in a most efficient way. The quality and effectiveness of this survey was limited because of the small sample size.

Participant profiles tabulated in table 2 provide the detail profiles of ten elderly citizens of Joensuu, who volunteered to participate in this study. Five out of ten participants were male and remaining five was female. The participant's ages' ranged from 60-80 years and they had no physical and cognitive disability. Even though the participants were not from IT background, they all were experienced of using technology in their daily lives. Eight participants had more than 10 years experience of using technology in daily basis whereas two participants had 1-10 years of experience. They were using technology for both entertainment purposes as well as for assistance purposes like online shopping, navigation, as automatic timer, communication with family members, assistance while shopping and so on.

Table 2. Participant profiles

Participants	Gender/ Age	Technology Experience	Educational Background(IT)	Physical/Cognitive Disability	Purpose of Using Technology
P1	F/68	10 years+	N/Basic school	N	Assist/Entertain.
P2	F/75	1-5 year	N/Basic school	N	Assist/Entertain
P3	F/79	10 years+	N/Vocational	N	Assist/Entertain
P4	F/76	10 years+	N/Middle school	N	Assist/Entertain
P5	M/73	10 years+	N/Graduation	N	Assist/Entertain
P6	M/74	10 years+	N/Vocational	N	Assist/Entertain
P7	M/62	10 years+	N/Graduation	N	Assist/Entertain
P8	M/66	10 years+	N/Post Graduation	N	Assist/Entertain
P9	M/75	10 years+	N/Basic school	N	Assist/Entertain
P10	F/70	5-10 years	N/graduation	N	Assist/Entertain

4.3.2. Questionnaire

Offline questionnaire was chosen among different survey methods to conduct data collection because of the uniqueness of sample. Questionnaire consisted of close ended questions with likert scale data. In addition, some open ended questions such as background information of elderly people and comments on their views towards

acceptance of technology was also gathered during the data collection. Questionnaire was formed on the basis of different factors analyzed through different perspectives as mentioned in literature review section. To present likert scale data efficiently, I assigned point values to each response i.e.

Strongly Agree = 1 point

Agree = 2 points

Neutral = 3 points

Disagree = 4 points

Strongly Disagree = 5 points

The questions were devised on the basis of research question and aim of the research. Informed consent was given along with the questionnaire describing background information of the survey, rights of the participants and purpose of the research. The questions were divided into sections with different factors of technology acceptance and questions were chosen in a way to give easy understanding to the elderly people. As all the participants for this study were Finnish, Questionnaire was prepared both in English and Finnish. The detail view of Questionnaire is given in appendix section of this paper. This survey was used to explore participant's attitude towards the use of assisted living technologies.

4.3.3. Data Collection

The response of the survey was collected in 23-05-2015 and 24-05-2015. The collected data were first structured in Microsoft Excel spreadsheet where the data sets were prepared according to the measured values of different factors gathered during the survey. The data were organized in different columns with the following measure factors:

1) Ease of Use

This factor contains four questions having likert scale to analyze the extent to which elderly people find technology easy to use and effortless.

2) Security/ Trust

This factor contains five questions having likert scale to analyze the extent to which elderly people feel secure while using technology and trust it.

3) Efficiency / Usefulness

This factor contains five questions having likert scale to analyze the extent to which elderly people thinks the technology makes them productive, useful and efficient.

4) Cost

This factor contains two questions having likert scale to analyze the extent to which cost is a decidable factor for elderly people to use technology in their daily lives.

5) Likeability

This factor contains only one question having likert scale to analyze the extent to which elderly people like to use technology for carrying out daily tasks.

6) Socio- emotional factors

This factor contains four questions having likert scale to analyze the extent to which elderly people thinks social and emotional factors affect the use of technology.

7) Understandability

This factor contains three questions having likert scale to analyze the extent to which elderly people quickly adopt and understand the use of technology.

8) Ease of Learning

This factor contains five questions having likert scale to analyze the extent to which how quickly elderly people learn to use the technology.

The sample size was 10 so I further categorized above 8 groups of factor into 6 i.e. Usability, Security/trust, Socio-emotional, Likeability, Understandability and Cost where usability factor comprises Ease of use, efficiency/Usefulness and Ease of learning.

For the analysis purpose, acceptance factor, the outcome of survey is considered as dependent variable and rest of the six variables are considered independent.

4.3.4. Data Analysis

Data analysis is never ended procedure which not only answers the research questions but also provides the way to collect data in future. Different data analysis procedures helps testing the hypothesis formed in the beginning of research. With the help of different data analysis procedures, one can convert data into information and discover relationship between different variables (IGNOU, 2005). Quantitative data analysis usually comprises of statistical measures to describe the quantitative data.

The source of quantitative data for this study is questionnaire. Before doing detail analysis of data in R, one of the statistical computational environments, the survey data were first processed in Microsoft Excel. Generally, three forms of statistical methods namely descriptive statistics, correlation statistics and inferential statistics are applied to analyze quantitative data. I utilized all three methods to fulfill the goal of my study which is described in detail in the following section.

4.3.4.1. Analysis using Descriptive statistics

The questionnaire was formed with different categories and in different categories there were different number of questions. I mainly used Central tendency as part of the descriptive statistics to analyze the collected data:

1) Central Tendency

Mean Median and Mode falls into the category of central tendency methods. For this study, I used mean to calculate the average response for each categories whose result is shown in the table below where factors are represented in columns and responses are recorded in rows for each participant. The responses are represented with ordinal data values ranging from 1 to 5 where 1 is strongly agree and 5 is strongly disagree.

Participants	Usability	Security/trust	Socio-emotional	Likeability	Understandability	Cost	Acceptance	Gender
1	2	3	4	2	2	5	3	0
2	2	2	3	2	3	3	2	0
3	2	2	3	1	3	4	2	0
4	2	2	3	1	4	4	2	0
5	2	3	4	1	4	3	2	1
6	2	4	4	1	3	4	3	1
7	3	2	3	3	4	3	3	0
8	2	3	3	1	3	3	2	1
9	3	3	3	3	3	2	3	1
10	2	3	3	2	2	3	2	1

Figure 7. Data set processed in Excel

I used distribution/ frequency mechanisms to show how the responses for each category were distributed in strongly agree to strongly disagree scale the results of which are presented in results section.

4.3.4.2. Analysis using Correlation statistics

To answer the main research question, I used following correlation statistical methods.

1) Correlation coefficient

The correlation coefficient is a measure of strength of linear relationship among two variables for the specific equation and is the number between -1 and +1. In statistics, it is designated by symbol r and sometimes referred to as r-value. The sign of r determines the direction of relationship between two variables let's say X and Y.

The magnitude of r specifies how strong the relationship between variable X and Y is. If r ≈1, there is strong positive linear relationship between X and Y. More specifically, when X increases, Y also increases. Unlikely, if r≈0, there is no linear relationship between X and Y which means Y does not have tendency to increase or decrease when X increases. However, if r ≈ -1, there is strong negative linear relationship between X and Y which means when X increases Y decreases and vice-versa. So, the correlation coefficient is the value $-1 \leq r \leq 1$. The closer the value is to 0, the weaker the relation is and the closer the value is to 1 or -1, the strong the relationship is in between X and Y.

There are parametric and non-parametric methods of correlation coefficients. Pearson correlation coefficient is parametric method of correlation coefficient which is

usually suitable when analyzing continuous data and spearman and Kendall are non-parametric methods suitable to analyze ordinal data. The data collected for this thesis is of type ordinal but as it can be considered as continuous data, I applied both parametric and non-parametric correlation coefficient methods to ensure if different methods give different results. The results of correlation coefficient analysis are presented in results section.

4.3.4.3. Analysis using inferential statistics

Multiple regression and ANOVA test is applied as part of inferential statistics methods which are described in detail in following section:

1) Multiple Regression

Multiple regression is an extension of the simple linear regression which shows degree to which multiple independent variables affect the change in dependent variable. It is used to predict the variable based on two or more variables. The variable to predict is called dependent or criterion variable and the variables use to predict dependent variable is called independent or predictor variables. It is useful when analyzing if one variable predicts another.

In this paper, the motive of using multiple regression technique is to determine the overall fit (goodness of fit) of the hypothetical model presented in chapter three and the relative association of independent variables on the acceptance of AAL technologies. In this case, dependent variable is acceptance and independent variables are different factors of acceptance i.e. Usability, Security/trust, Socio-emotional, Likeability, Understandability and Cost.

The initial linear model of multiple regression according to hypothetical model presented in chapter 3 is:

$$\text{Acceptance} = \beta_0 + \beta_1.\text{Usability} + \beta_2.\text{Security/trust} + \beta_3.\text{Socio-emotional} + \beta_4.\text{Likeability} + \beta_5.\text{Understandability} + \beta_6.\text{Cost} + \varepsilon$$

Where, β_0 is the intercept, $\beta_{1->}$ β_6 are slopes or coefficients which depict the size of the effect that the independent variables are having on dependent variable. In other

words, slopes measure how much dependent variable changes for each unit of change in independent variable and ε is the unobserved error or disturbance term. It's assumed that the errors follow normal distribution.

1) Analysis of Variance (ANOVA)

ANOVA tests if the means of two or more populations are equal (What is anova, 2015). The aim of using ANOVA for this study is to check which independent variable has bigger impact on acceptance compared to other independent variables. ANOVA is based on the approach of using variances to determine whether the means are different. It evaluates the importance of one or more factors by the comparison of response variable means at different factor levels. The null hypothesis states that all factor level means are equal while the alternative hypothesis states that at least one is different (What is anova, 2015).

The Anova test was performed to assess whether there was significant difference between the means of six independent groups of factors.

The results of both inferential statistics are given in Results section.

5 RESULTS AND DISCUSSIONS

5.1. Descriptive Statistics

The results of analysis through descriptive statistics are shown in frequency chart and individual pie charts below:

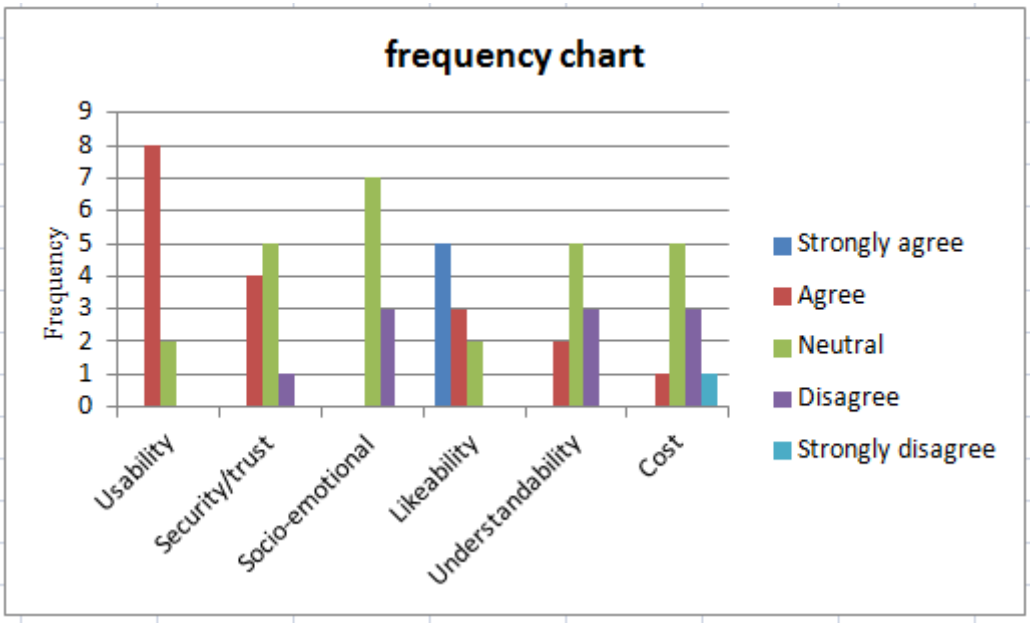
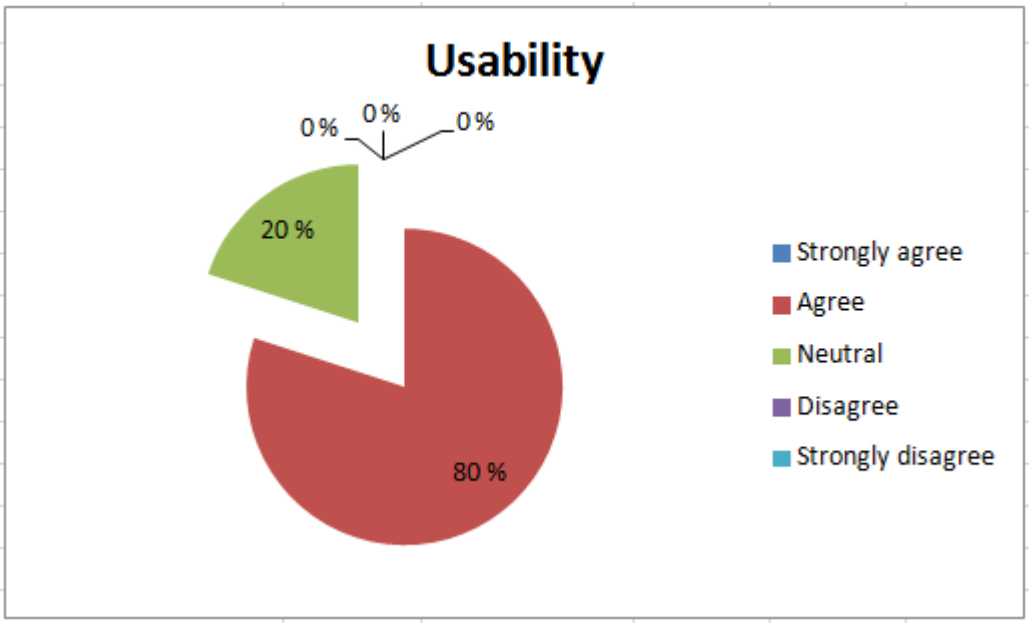


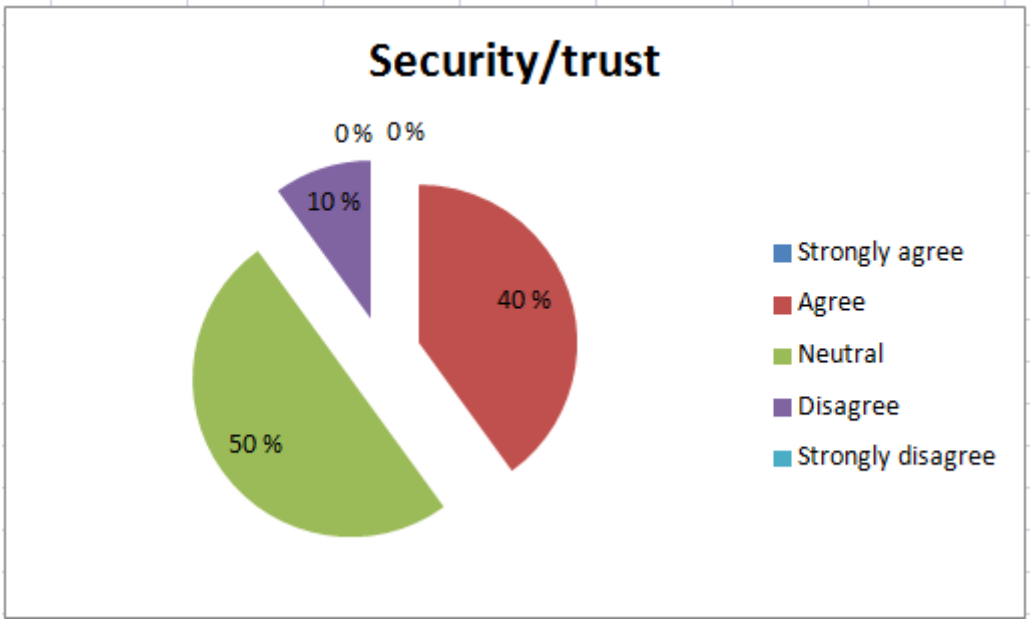
Figure 8. Distribution of acceptance factors by likert scale

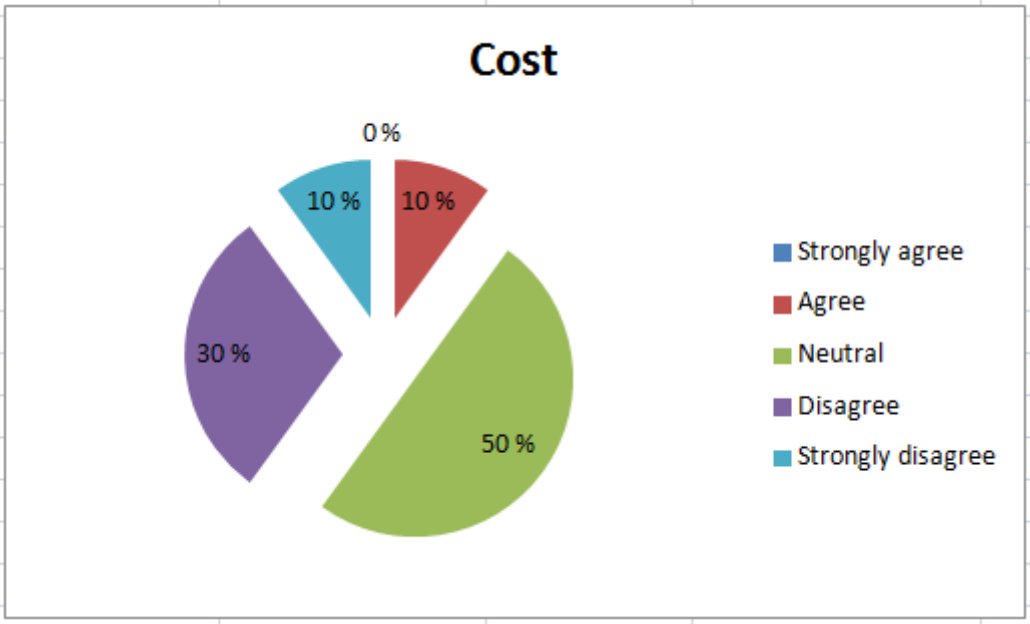
Evident in bar chart above is the distributions of sample frequency according to the factors of technology acceptance by five factors ranging from strongly agree to strongly disagree. The figure shows that only factor named likeability has strongly agree label which means reason behind acceptance of current technologies that elderly people are using ranging from smart phones to automatic timers is likeability.

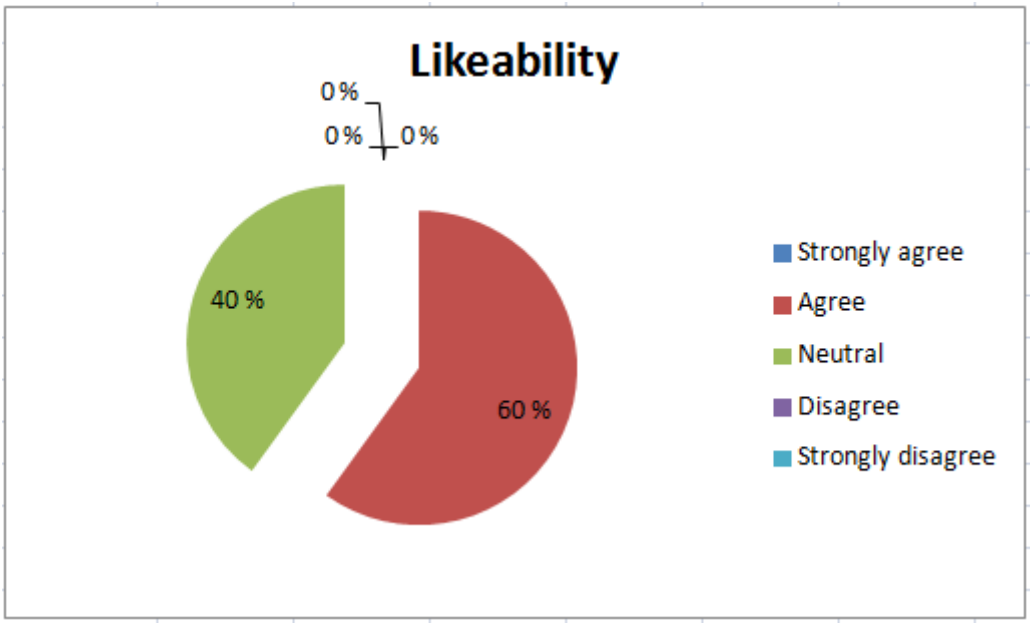
Moreover, the factors named Usability, Security/trust and Likeability have high frequency of Agree label. Elderly people think that these factors are affecting to their attitude towards using the technology. At the same time, there is no factor other than likeability for which elderly people strongly agree on. Meanwhile socio-emotional factor have little or no effect on acceptability of technology as no one agree on this factor affecting their acceptance of technology.

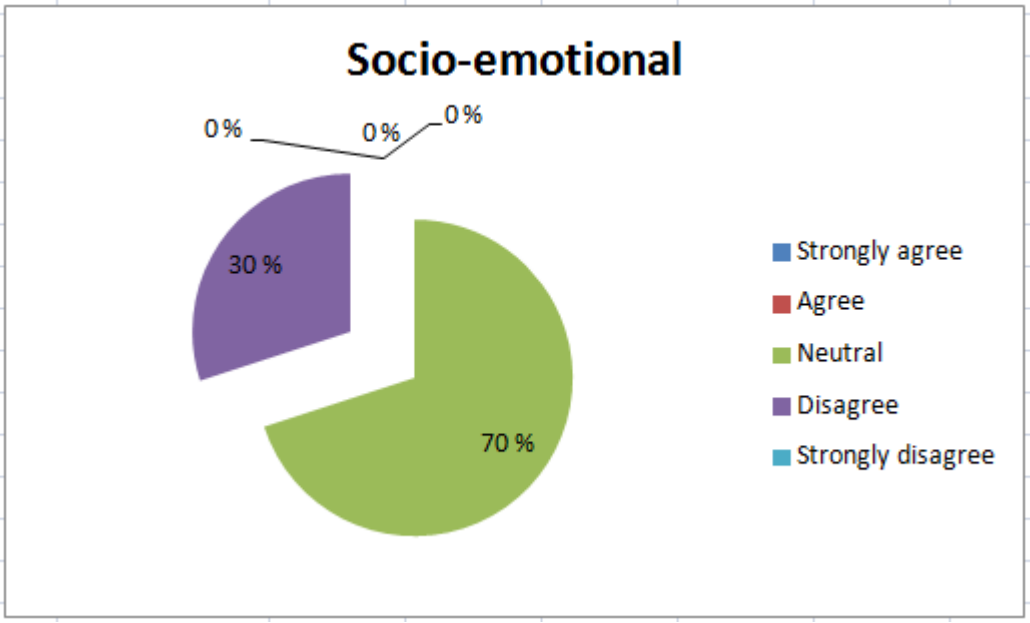
However, factors having agree scale such as Usability, Security/trust, understandability and cost gives positive feedback on how these factors can impact their use of technology. Unlikely, socio-emotional factor has no agree label so it does not have influence on the technology acceptance by elderly people according to the above bar chart. Since the chart gives variability of different factors on likert scale, Likeability factor seems to dominate other factors in strongly agree likert scale. The detailed figure about proportion of people responses on each factors are given in the pie charts below.

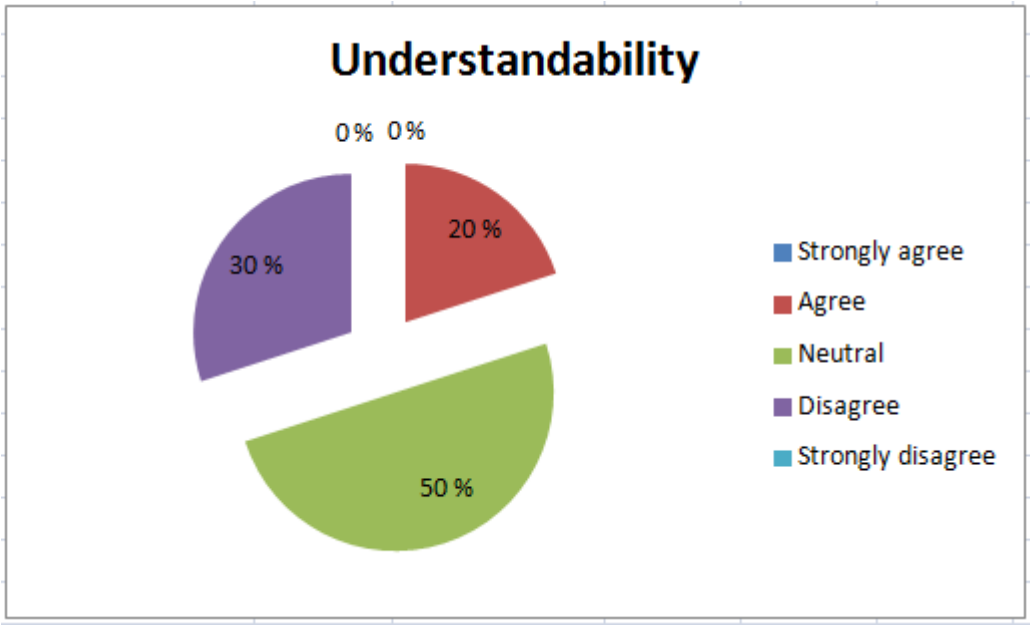





Cost
0 %
10 %
10 %
30 %
50 %
Strongly agree
Agree
Neutral
Disagree
Strongly disagree


Likeability
0 %
0 %
0 %
40 %
60 %
Strongly agree
Agree
Neutral
Disagree
Strongly disagree


Socio-emotional
0 %
0 %
0 %
30 %
70 %
Strongly agree
Agree
Neutral
Disagree
Strongly disagree


Understandability
0 %
0 %
20 %
30 %
50 %
Strongly agree
Agree
Neutral
Disagree
Strongly disagree

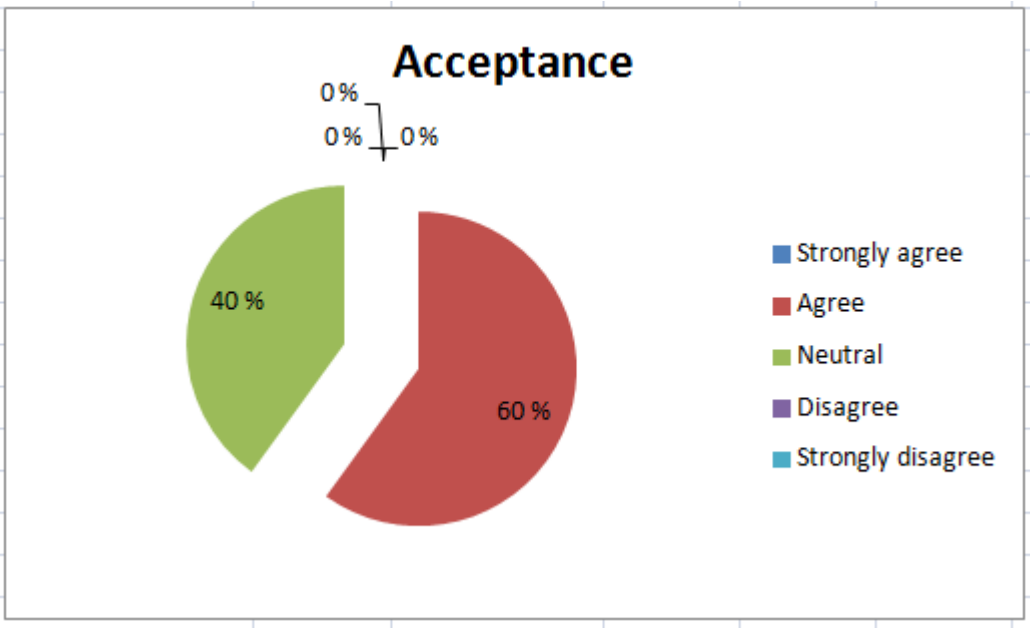


Figure 9. Individual frequency charts for technology factors

It's clear from the information given in the pie chart for Usability distribution that 80% people agree on usability factor affecting their acceptance to current technologies that they are using, whereas 20% people neither agree nor disagree on whether the technology is effortless, easy to use and efficient or not.

The evidence from the above pie chart for security and trust shows that 40% people aware about the security factor of technology acceptance in a sense that they don't want to be interrupted or irritated while using the technology and want to feel secure. Whereas 10% people do not care about the security factor and 50% people neither agree nor disagree on the fact that security can affect acceptance of technology.

It's also clear from the pie chart for cost that only 10% people thinks that cost makes the difference if they want to adopt new technologies to assist them in their daily tasks. But the figure also suggests that 30% people disagrees and 10 % people strongly disagrees about the fact that if technology is costly, their motivation decreases to use technological solutions which is opposite to our hypothesis that cost can be a stronger influencer towards the acceptance of technology.

It's quite obvious that Likeability strongly influence the acceptance of technology by elderly people. 50% people strongly agree on some of technological solutions, they

are using are likely to help assist in their daily life and help in maintaining independence thus affecting the acceptance. Also, 30% people agree about the fact and 20 % people are neutral in this case.

Surprisingly, the pie chart for socio-emotional factors such as feeling weak and embarrassed while using assistive technology in front of people shows completely reverse idea compared to what previous researches on socio emotional factors suggested. 30% people disagree on the fact that social factors could affect the utilization of existing technological solutions such as intelligent wheelchair for navigation purposes. Whereas 70% people neither agree nor disagree and some of them said it depends on the situation. But, not a single percentage agrees that emotional and social factors can affect to the use of technology.

The evidence from the above pie chart for understandability gives some idea about how the technological solutions designed for elderly people should be. The figure shows 20% people easily adapt to the technology that they are using and they got less training before the use of it. But at the same time 30% people disagrees about the fact that technological solutions were easy to get familiar with in the beginning and 50% people were neutral about this fact. So, considering this figure the technology should be designed in a way that people can get familiar with it in less period of time. At the same time the interface should be as simple as possible to use and enough training should be provided before they could adapt to it.

Finally, the evidence from the above pie chart for measured factor acceptance shows that not a single percentage of people strongly agree on acceptance of current technologies whereas 60% people agrees that the technology is worth accepted to carry out their daily tasks and 40% are neutral in this case.

So, from the above analysis, it can be easily predict that socio- emotional factor has less important role in the acceptance of technological solutions by elderly people. After that cost has also less influence on the adaptability of technology.

5.2. Correlation-coefficient analysis

This section gives the result from Correlation coefficient analysis as coefficient matrix where we can see the correlation among different factors of acceptance and then discussion about the results.

Table 3. Correlation coefficient Matrix

Factors	Statistical methods	Usability	Security/ Trust	Socio-emotional	Likeability	Understandability	Cost	Acceptance
Usability	Pearson correlation	1	-.15	-.32	.83	.28	-.56	.61
	Spearman	1	-.14	-.32	.75	.28	-.56	.61
	Kendall	1	-.13	-.32	.71	.26	-.53	.61
Security/trust	Pearson correlation	-.15	1	.64	-.17	-.37	.03	.38
	Spearman	-.14	1	.62	-.14	-.41	-.02	.35
	Kendall	-.13	1	.60	-.13	-.36	-.03	.34
Socio-emotional	Pearson correlation	-.32	.64	1	-.30	-.09	.49	.35
	Spearman	-.32	.62	1	-.28	-.08	.45	.35
	Kendall	-.32	.60	1	-.27	-.07	.42	.35
Likeability	Pearson correlation	.83	-.17	-.30	1	-.12	-.44	.57
	Spearman	.75	-.14	-.28	1	-.20	-.46	.54
	Kendall	.71	-.13	-.27	1	-.19	-.41	.51
Understand ability	Pearson correlation	.28	-.37	-.09	-.12	1	-.25	-.11
	Spearman	.28	-.41	-.08	-.20	1	-.17	-.11
	Kendall	.26	-.36	-.07	-.19	1	-.15	-.10
Cost	Pearson correlation	-.56	.03	.49	-.44	-.25	1	.10
	Spearman	-.56	-.02	.45	-.46	-.17	1	.07
Acceptance	Pearson correlation	.61	.38	.35	.57	-.11	.10	1
	spearman	.61	.35	.35	.54	-.11	.07	1
	Kendall	.61	.34	.35	.51	-.10	.07	1

The result in above table demonstrates that; there is very little difference between each correlation methods where all the factors have almost similar correlation with each other in each method. For interpretation, it has been hypothesized that the values between 0 and 0.1 has little or no relationship whereas 0.1 and 0.5 has noticeable relationship. Moreover, values between 0.5 and 0.9 have strong relationship and value nearly close to 1 indicates that the variable measures exactly the same thing instead with different scales.

The correlations between usability and likeability is much higher than average with 0.83. This suggests that the more usable the technical product or solution is, the more possibly elderly people like it and vice versa. For another factors Usability and cost, there is negative correlation with value -0.56 which suggests that when cost is low, elderly people may find the technology usable and vice versa. Nevertheless there is correlation between usability and cost factor. Furthermore Usability and Acceptance has positive correlation with 0.61 which implies that the more usable the technical product is; the more possibility of its acceptance by elderly people. Similarly Likeability and Acceptance has positive strong correlation with value 0.57 which suggest that when elderly people like the technological solution, they are ready to accept it.

It's also clear from the correlation matrix that there is positive correlation between security/trust and socio-emotional factors with value 0.64 which mean the more secure the elderly people will feel the more chances of being not affected by socio-emotional factors such as fear to use technology in front of society, feeling of domination and so on. Also, the noticeable correlation was found between security and acceptability with value 0.3 as well as between cost and likeability with value -.46.

The values which are significant at 0.05 significance level explains that the possibility of wrong assumption about rejecting null hypothesis is less than 5%. So in this study, correlations are significantly different from zero and we can reject the null hypothesis for factors having correlations not significant at given significance level.

5.3. Inferential Statistics

This section first describes the multiple linear regression method and then discusses the enhanced form of regression which is ANOVA test.

Table 4. Output of summary (lm (formula = Acceptance ~ Usability + Security/trust + Cost + Likeability + Socio-emotional + Understandability))

	Estimate	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	-2.93836	0.77260	-3.803	0.0319*
Usability	0.87671	0.49606	1.767	0.1753
Security/trust	0.44521	0.22946	1.940	0.1477
Cost	0.42466	0.13234	3.209	0.0490*
Likeability	0.26027	0.26219	0.993	0.3940
Socio-emotional	0.01370	0.29444	0.047	0.9658
Understandability	0.08904	0.20741	0.429	0.6967

Signif. codes : 0 ‘ ***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1788 on 3 degrees of freedom

Multiple R-Squared: 0.96, Adjusted R-squared: 0.8801

F-statistic: 12.01 on 6 and 3 DF, p-value: 0.03329

Linear model given in previous chapter for multiple regression is analyzed in R (statistical computing environment) whose output is shown in the table above. The p-value for each row in above table tests the null hypothesis of coefficient is equal to zero or there is no effect of predictor on criterion variable. A low p-value (<0.05) indicates that null hypothesis can be rejected. The predictor variable which has the

low p-value is likely to be significant in the model which means changes in corresponding predictor value is correlated with the changes in criterion value. On the other hand, the independent variable having high p-value has minimum or no connection with dependent variable.

In the above table, only cost has the p value of 0.04 which is less than alpha level 0.05. It means cost is statistically significant in the model of acceptance and it should be included with higher priority in the model.

However, p-value for socio-emotional factor is significantly greater than the values of other variables and also the effect size is too low i.e. 0.013 on dependent variable, acceptance. This behavior implies that it is better to exclude this factor from the regression model. Seeing that the observations are quite less for this research, it's hard to conclude which factors to keep and which to remove. But, from the result above, socio emotional and understandability factor has larger p-value (>0.05) and low effect size so can be considered as less influencing variables. Moreover, even though the effect size of usability (0.87) is greater than the effect size of other variables, the output shows no significant relation of usability in the model. This may be because some independent variables have no correlation with each other and still in the regression model. This suggests that, model can still be improved.

It is always useful to evaluate how well the model fits the data. There are various ways to do it. Analyzing R-squared is one option which measures the squared correlation of dependent variable values with the values that the model would predict. R-squared is coefficient of multiple determinations for multiple regression and it measures how closely the data fits into the regression line. Commonly the higher the R-squared the better the model fits the data. It is always in between 0 and 100%. As the R-squared value for above model is 96% we can say that the model fits the data well and the model is effective. But R-squared cannot always verify whether the model is efficient. So, to assess the validity of the model, residual plots are generated.

The figure below shows the residual vs. fitted plots along with Normal Q-Q plot.

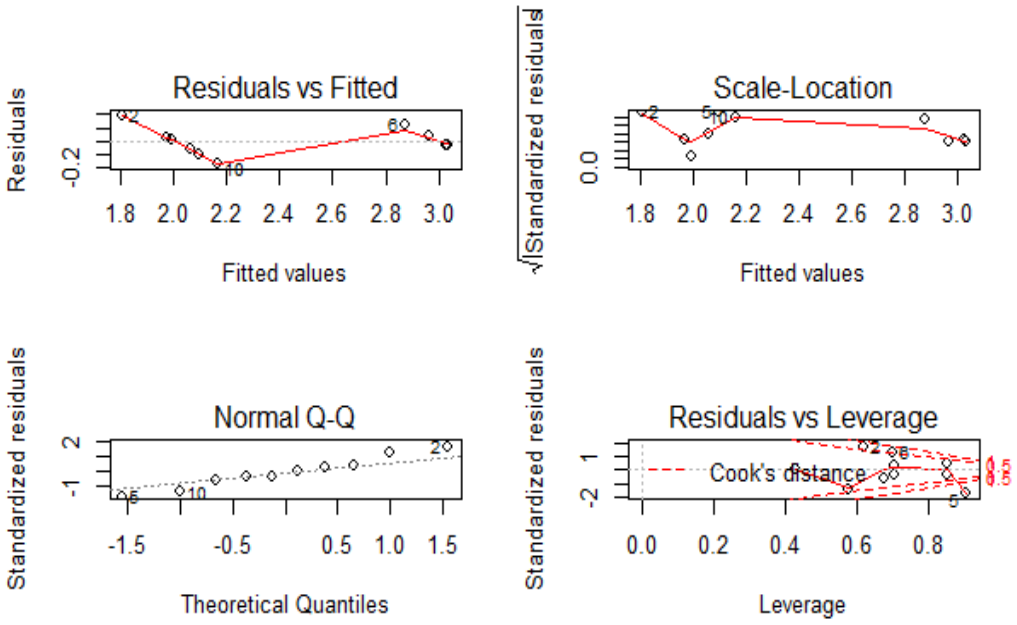


Figure 10. Residual plotting

Residual vs. fitted plot in above figure shows the prediction from model in x-axis named fitted values and accuracy of the prediction in y-axis named residuals. Residual is the difference between observed and predicted value which is the part of dependent variable and is the best estimate of the error term from the regression model. As we can see; most of the data points are near to the regression line and variability of residuals are not changing over the range of dependent variable. But, while looking more closely, regression line is systematically over and under the data points showing some bias along the curve and the data is not as random as it should be. It clearly indicates that, even though the R-squared is high, model does not perfectly fit the data and can be improved.

However, by taking into consideration the low data sample, residual vs. fitted plot shows some randomness and is partially fitting the data so it's the indicator for improving the current model. One of the assumptions of regression analysis is residuals are normally distributed (Frost Jim, 2014) .The normal Q-Q plot depicts that residuals comes from normal distribution because data points are lining up almost linearly on the line of identity. Moreover, a scale location plot in above figure is also similar

to residual vs. fitted plot which uses square root of standardized residuals. Unlike the residual vs. fitted plot, it shows some randomness of the data which is the indication that model fits the data. So, the result of above regression analysis seems logical and model seems to fit the data partially. The correctness of multiple regression model is further tested by the F-test in ANOVA table which is explained in next section.

The output of Anova test is shown in the table below for the model initially proposed.

Table 5. ANOVA table with input anova (lm (formula = Acceptance ~ Usability + Security/trust + Cost + Likeability + Socio-emotional + Understandability))

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
Usability	1	0.90000	0.90000	28.1571	0.01307*
Security/trust	1	0.56250	0.56250	17.5982	0.02471*
Cost	1	0.77979	0.77979	24.3964	0.01592*
Likeability	1	0.04767	0.04767	1.4913	0.30923
Socio-emotional	1	0.00826	0.00826	0.2583	0.64628
Understandability	1	0.00589	0.00589	0.1843	0.69667

Residuals

Signif. codes: 0 ‘ ***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The above table dictates that; there is significant difference of mean between Usability (p value of 0.01307), Security/ trust (p value of 0.02471) and Cost (p-value of 0.01592) but no significant difference related to mean scores of Likeability, Socio-emotional and Understandability factors. It suggests that; the inclusion of usability, security/trust and cost in the model of acceptance is reasonable. While comparing F-values it seems that Usability has the highest value of 28.15 which makes it significant in the model with less p-value of 0.01307. After that, Cost has the next higher F-

value of 24.39 and security/trust with 17.59 which also makes these factors impactful to the acceptance. Unlikely, Understandability with lowest F-value, 0.1843, Socio-emotional with subsequent low F-value, 0.25 and Likeability with F-value of 1.49 makes it less significant in the linear model described in multiple regression.

5.4. Alternative Model

Based on the results of multiple regression and ANOVA test, I formulated alternative model by excluding some independent factors which seems to have less influence on the dependent variable. The alternative model is:

$$\text{Acceptance} = \beta_0 + \beta_1.\text{Usability} + \beta_2.\text{Security/trust} + \beta_3.\text{Cost} + \varepsilon$$

The summary of output for the above model is given in the table below:

Table 6. Output of lm (formula = Acceptance ~ Usability + Security/trust + Cost)

	Estimate	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	-3.86380	0.81607	-4.735	0.003209**
Usability	1.32616	0.15711	8.441	0.000151***
Security/trust	0.40143	0.08121	4.943	0.002595**
Cost	0.42294	0.07765	5.447	0.001592**

Signif. codes : 0 ‘ ***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1621 on 6 degrees of freedom

Multiple R-Squared: 0.9343, Adjusted R-squared: 0.9014

F-statistic: 28.44 on 3 and 6 DF, p-value: 0.0006052

The output from above table with (p = 0.0006052) clearly depicts that the null hypothesis of independent variables Usability, Security/trust and Cost collectively have no effect on acceptance can be rejected. The results also confirm that the three variables have significant control to each other affecting dependent variable acceptance.

Additionally R-Squared value of 93% indicates that the model is effective in describing acceptance factor. As the main research question of this paper is to determine important factors for acceptance of technology by elderly people, usability, security and cost seems to be the major variables.

The usability factor with highest effect size 1.32 shows that; if usability increases by 1 unit then the acceptance will increased by 1.3 unit. Also, the p –value of usability is significant with significance level 0.001 which makes usability the most effective factor for the acceptance of technology by elderly people. Subsequently, cost has second highest effect size with value 0.42 and security/trust has third highest effect size with value 0.40. For cost and security/trust, the p-values i.e. 0.001 and 0.002 are significant at the significance level 0.01 which makes them second and third most influencing factors for acceptance.

Moreover, a partial F-Test is performed to compare alternative and hypothetical model to test whether the subsequent independent variables other than above three have effect on dependent variable or not. I performed partial F-Test by fitting both the hypothetical and alternative models separately and subsequently evaluating them by using anova function. The result of anova function is shown below:

Analysis of Variance Table

Model 1: Acceptance ~ Usability + Security/trust + Cost

Model 2: Acceptance ~ Usability+ Security/trust + Cost + Likeability + Understandability + Socio-emotional

Res.Df	RSS	DF	Sum of Sq	F	Pr (>F)
1 6	0.15771				
2 3	0.09589	3	0.061816	0.6446	0.6365

Figure 11. Output of anova (model1, model2)

The output demonstrates that the null hypothesis ($\beta 4 = \beta 5 = \beta 6 = 0$) cannot be rejected because p-value is equal to 0.6365 at 5% significance level. Finally, it becomes evident that the independent variables Likeability, Understandability and Socio-emotional do not provide significant information to the acceptance variable while the Usability, Security/trust and Cost is taken into consideration.

5.5. Final Result

This section is planned with reference to the research questions presented in this paper. The literature review section provides the answer for first and second research questions. To answer the third research question, data were gathered from elderly people as described in data collection and analyzed by using different statistical methods as presented in data analysis. Though the detail result is already presented in above sections, the brief summary of overall result for third research question is as below:

Q. What is the impact of influencing factors on Acceptance of AAL technologies?

To address the need of elderly people, highly automated and intelligent systems have been developed with the purpose to help them perform all activities independently. But, if the elderly people for whom the system is designed deny its usage, then the development of such high tech solutions will be useless. So, this particular piece of information has raised the importance of acceptance of assistive technologies in recent years. As more researches are being carried out in the field of Ambient assisted living system, it is worth to explore the relationship between different influencing variables for acceptance of AAL technology and the impact of each of them on acceptance. The variables that were studied in this thesis are usability, security/trust, cost, likeability, understandability and socio-emotional.

In the beginning, it was hypothesized that the socio emotional factors such as feeling of dependency, pride, embarrassment can affect the use of assistive technology by elderly people. But, the result showed completely opposite viewpoint that this factor has very little to do with their acceptance of technology. This is supported by the

analysis result where correlation coefficient (r) was found 0.3 between socio-emotional factor and acceptance which is very less. Also, the exclusion of socio-emotional factor in alternative model supports this fact.

Similarly, analyzing cost factor also gave different point of view than it was thought in the beginning of research. It was envisioned that when the cost of product or service is less, the people are more likely to use it and accept it. But, the analysis shows positive correlation of cost factor with acceptance which means; even when the cost is high, people are ready to accept it. It was also apparently clear from the collected data that elderly people does not care much about the cost of technologies if it really meant to help them carrying out their daily tasks.

Meanwhile, highest level of correlation was found between usability and likeability. This correlation makes proper sense because, if the product/service is effective and efficient, elderly people like to use it more. Similarly, usability and acceptance were found to be positively correlated. Additionally, regression analysis and analysis of variances results that usability, security/trust and cost are the determining factors which can influence in the acceptance of technology by elderly people.

6 CONCLUSIONS

This study has covered the ambient assisted living research along with acceptance of AAL technology by elderly people. Based on literature review findings and the analysis of questionnaire survey, following things can be derived.

Acceptance of Assisted living technology by elderly people is vital as it positively influence their attitude towards using technology in daily lives. The EU funded projects such as UTOPIA, SOPRANO, MIGSEP, ADVENT and ALLADIN were aimed at developing ambient assisted living systems to improve the lives of elderly people specially frail and disabled. Moreover, living laboratory concept for example schwechat living lab was emerged to develop highly effective assisted living solutions by co-operating with different stakeholders, local authorities, carers and end users. It was intended to invent and discuss innovative technologies to support active ageing in place. Alongside, different research and projects on AAL is still on progress whose goal is to improve the quality of life of vastly growing elderly population.

The data collected through the offline questionnaire was processed in statistical computing environments, Microsoft excel 2010 and R. It was then evaluated against the hypothetical model of acceptance where usability, security/trust, cost, socio-emotional, understandability and likeability were the major factors which was supposed to affect in the attitude of elderly people towards accepting the technology. The analysis results in detail were presented in earlier chapters.

The result demonstrated a high degree of correlation among some factors like acceptance and usability whereas the correlation was extremely low among some factors like acceptance and socio-emotional. This can lead us to the conclusion that the participants were very confident about the effect of efficiency and effectiveness of technological solutions to its acceptance whereas they perceived social discomfort while using technology as very minor obstacle on deciding acceptance.

Similarly, the findings from inferential statistics i.e. multiple regression analysis and anova suggested that the inclusion of usability, security/trust and cost can improve the effectiveness of acceptance model. In contrary, the use of socio-emotional factor, understandability and likeability in acceptance model can degrade the overall model efficacy as they have very less influence in acceptance.

In conclusion, there is high potential of assisted living technologies to address the need of elderly people which allow them to live and work independently. However, in order to increase the acceptance level of current available technologies, a lot of things need to be improved. As the elderly participants suggested during my study, the attention should be given to ease of use functionality and also to the training beforehand so that they can use the technological solutions independently which are designed for them. There is still a lot of space for the research in acceptance of AAL technology because this study was just a small part of it and lots of potential issues are still need to be addressed.

7 LIMITATIONS AND RECOMMENDATIONS

The general rule of thumb to carry out quantitative data analysis is minimum 10-15 observations but to generate accurate results with inferential statistics, we need more sample data. Due to the lack of time and special group of participants' i.e. elderly people group, only 10 sample data were collected for this research. With the small observation, it was difficult to determine how well the multiple regression model matches the data or whether the non-linear model would be more reliable for the data points that I collected instead of linear model. So, the small sample size is the main limitation of this thesis.

Nevertheless, from the above results it is likely to produce some recommendations for the designers and implementers of software engineering discipline. Besides the fact of how costly the product is or how secure the product is, the deciding factor for acceptance is how easy to use the product or service is. So, the most important recommendation for them is to focus on usability factor of technological product or services designed for them. According to my findings, it is also recommended that; the more controllable the product is the more efficient it becomes to be handled by elderly people. Moreover, use of voice and gesture can also improve the interaction of devices with the elderly people. For instance, if user finds technological devices or system friendlier then their willingness to use it becomes higher.

Comments as qualitative data were also gathered during the time of data collection where the topic was; *how the technology should be to make it more acceptable?* In response, almost all participants pointed out the term "easy to use" product/service. From their responses, it can be concluded that the first and foremost factor for the acceptance is usability of the product/service. Also, they mentioned about training before using the product or services designed for them. Some of the participants think that if enough training is supplied before using the technical solutions for example special kind of smart phones, assistive location aware devices, smart wheel-

chairs, assistive robotics and so on, then the acceptance level could be much more higher than it is in the present context.

In addition, one of the participants believed that the technology should be more environment friendly, logical to use as well as simple so that layman can also use it. Another point that one of them mentioned was; there should be awareness programs on currently available technologies at the early stage for elderly people so that they could know what kind of systems are available in the market which is beneficial for them. Similarly, one of them also pointed out that; some of the technologies are still unreachable to many people which can be the hindrance for its usage in their day to day lives.

One of the participants argued that; he has not seen the technology as simple and as clean as it should be. I think these feedbacks should be taken into consideration by people who are responsible for designing, developing, implementing and delivery of technological system/services. Nevertheless, I found the participants very enthusiastic about using the technology in their daily lives as supportive means. It indicates that the importance of Assistive living technology and services cannot be ignored.

References

[Aarts & Wichert, 2009] Aarts, E., & Wichert, R. (2009). *Ambient intelligence* (pp. 244-249). Springer Berlin Heidelberg.

[Active Assisted Living Programme, 2015] Our Projects. (2015). In *Active Assisted Living Programme.* Retrieved from http://www.aal-europe.eu/our-projects/

[Anastasiou, Jian, & Zhekova, 2012] Anastasiou, D., Jian, C., & Zhekova, D. (2012, July). Speech and gesture interaction in an Ambient assisted living lab. In *Proceedings of the 1st Workshop on Speech and Multimodal Interaction in Assistive Environments* (pp. 18-27). Association for Computational Linguistics.

[Astell et.al, 2009] Astell, A., Alm, N., Gowans, G., Ellis, M., Dye, R., & Vaughan, P. (2009). Involving older people with dementia and their carers in designing computer based support systems: some methodological considerations. *Universal Access in the Information Society*, *8*(1), 49-58.

[Astell et.al, 2009] Astell, A., Alm, N., Gowans, G., Ellis, M., Dye, R., & Vaughan, P. (2009). Involving older people with dementia and their carers in designing computer based support systems: some methodological considerations. *Universal Access in the Information Society*, *8*(1), 49-58.

[Baroudi, Olson, & Ives, 1986] Baroudi, J. J., Olson, M. H., & Ives, B. (1986). An empirical study of the impact of user involvement on system usage and information satisfaction. *Communications of the ACM*, *29*(3), 232-238.

[Bright & Coventry, 2013] Bright, A. K., & Coventry, L. (2013, May). Assistive technology for older adults: psychological and socio-emotional design requirements. In *Proceedings of the 6th International Conference on PErvasive Technologies Related to Assistive Environments* (p. 9). ACM.

[Chiriac, Saurer, Stummer, Stummer, & Kunze, 2011] Chiriac, S., Saurer, B. R., Stummer, G., & Kunze, C. (2011, May). Introducing a low-cost ambient monitoring system for activity recognition. In *Pervasive Computing Technologies*

for Healthcare (PervasiveHealth), 2011 5th International Conference on (pp. 340-345). IEEE.

[Creswell, J.W., 2013] Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

[Data preparation and analysis, n.d.] Data preparation and analysis. (n.d.). Retrieved from http://www.uniteforsight.org/research-methodology/module5

[De Ruyter, Van Loenen, &Teeven, 2007] De Ruyter, B., Van Loenen, E., & Teeven, V. (2007). User centered research in experiencelab. In *Ambient Intelligence* (pp. 305-313). Springer Berlin Heidelberg.

[DESA, 2013] United Nations, DESA, (2013). *World Population Ageing* [PDF file]. New York: United Nations Publications. Retrieved from http://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2013.pdf.

[Dillon & Morris, 1996] Dillon, A., & Morris, M. G. (1996). User acceptance of new information technology: theories and models. *Annual review of information science and technology*.

[Eisma et.al, 2004] Eisma, R., Dickinson, A., Goodman, J., Syme, A., Tiwari, L., & Newell, A. F. (2004). Early user involvement in the development of information technology-related products for older people. *Universal Access in the Information Society, 3*(2), 131-140.

[Frost Jim, 2014] Frost Jim. (2014, October). How important are normal residuals in regression analysis data (literally) [Blog post]. Retrieved from http://blog.minitab.com/blog/adventures-in-statistics/how-important-are-normal-residuals-in-regression-analysis

[Goodman & Lundell, 2005] Goodman, J., & Lundell, J. (2005). HCI and the older population. *Interacting with Computers, 17*(6), 613-620.

[Haritou, Cuno, Glickman, Androulidakis, & Baboshin, 2011] Haritou, M., Cuno, S., Glickman, Y., Androulidakis, A. and Baboshin, A. (2011). ALLADIN: A home

care system for the efficient monitoring of elderly people with dementia. *Proceedings of the AAL Forum 2011*, Lecce, 51-58.

[Hocking Daniel, 2011] Hocking Daniel. (2011, July). Model validation: Interpreting residual plots (literally) [Blog post]. Retrieved from http://www.r-bloggers.com/model-validation-interpreting-residual-plots/

[IGNOU, 2005] IGNOU. (2005). Data analysis procedures. Retrieved from http://www.celt.mmu.ac.uk/researchmethods/Modules/Data_analysis/

[Interpreting residual plots to improve your regression, n.d.] Interpreting residual plots to improve your regression. (n.d.). Retrieved from http://docs.statwing.com/interpreting-residual-plots-to-improve-your-regression/#hetero-header

[James Hall, 2010] James Hall. (2010). Quantitative approaches to research design and data analysis [pdf]. Retrieved from http://www.academia.edu/1705556/Quantitative_approaches_to_research_design_and_data_analysis

[Jaschinski, 2014] Jaschinski, C. (2014, September). Ambient assisted living: towards a model of technology adoption and use among elderly users. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication* (pp. 319-324). ACM.

[Jian et.al, 2011] Jian, C., Sasse, N., von Steinbüchel-Rheinwall, N., Schafmeister, F., Shi, H., Rachuy, C., & Schmidt, H. (2011, May). Towards effective, efficient and elderly-friendly multimodal interaction. In *Proceedings of the 4th International Conference on PErvasive Technologies Related to Assistive Environments* (p. 45). ACM.

[Johnson, R. B. and Onwuegbuzie, A. J., 2004] Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational researcher*, *33*(7), 14-26.

[King B. William, n.d.] King B. William. (n.d.). Independent samples t Test. Retrieved from http://ww2.coastal.edu/kingw/statistics/R-tutorials/independent-t.html

[Kleinberger, Becker, Ras, Holzinger, & Müller, 2007] Kleinberger, T., Becker, M., Ras, E., Holzinger, A., & Müller, P. (2007). Ambient intelligence in assisted living: enable elderly people to handle future interfaces. In *Universal access in human-computer interaction. Ambient interaction* (pp. 103-112). Springer Berlin Heidelberg.

[Kothari, 2004] Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.

[Krieg-Brückner, Röfer, Shi, & Gersdorf, 2010] Krieg-Brückner, B., Röfer, T., Shi, H., & Gersdorf, B. (2010). Mobility assistance in the Bremen Ambient Assisted Living Lab. *GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry*, *23*(2), 121.

[Leitner, Mitrea, & Fercher, 2013] Leitner, G., Mitrea, O., & Fercher, A. J. (2013). Towards an Acceptance Model for AAL. In *Human Factors in Computing and Informatics* (pp. 672-679). Springer Berlin Heidelberg.

[Linear Regression, 2011] Linear Regression. (2011, Apr). Retrieved from http://www.stat.berkeley.edu/~spector/s133/Lr0.html

[Marie, Daniel, &Eric, 2011] Marie, C., Daniel, E., & Eric, C. (2011, May). Elderly daily activity habits or lifestyle in their natural environments. In *Proceedings of the 4th International Conference on PErvasive Technologies Related to Assistive Environments* (p. 26). ACM.

[Nehmer, Becker, Karshmer, & Lamm, 2006] Nehmer, J., Becker, M., Karshmer, A., & Lamm, R. (2006, May). Living assistance systems: an ambient intelligence approach. In *Proceedings of the 28th international conference on Software engineering* (pp. 43-50). ACM.

[Newell, Gregor, Morgan, Pullin, & Macaulay, 2011] Newell, A. F., Gregor, P., Morgan, M., Pullin, G., & Macaulay, C. (2011). User-sensitive inclusive design. *Universal Access in the Information Society*, *10*(3), 235-243.

[Oppermann & Rasher, 1997] Oppermann, R., & Rasher, R. (1997). Adaptability and adaptivity in learning systems. *Knowledge transfer*, *2*, 173-179.

[Panagiotakopoulos et.al, 2014] Panagiotakopoulos, T., Antonopoulos, C., Koutalieris, G., Kalantzis, p., Theodoropoulos, C., Koumanakos, G., Kameas, A., Voros, N., Koubias,S. (2014, May). ADVENT: A system architecture for advanced monitoring of elders with chronic conditions. In *Proceedings of the 4th International Conference on PErvasive Technologies Related to Assistive Environments* (p.9). ACM.

[Panek & Zagler, 2008] Panek, P., & Zagler, W. L. (2008). *A living lab for ambient assisted living in the municipality of Schwechat* (pp. 1008-1015). Springer Berlin Heidelberg.

[Panek, Rauhala, & Zagler, 2007] Panek, P., Rauhala, M., & Zagler, W. L. (2007). *Towards a living lab for old people and their carers as co-creators of ambient assisted living (aal) technologies and applications*. na.

[Peek et.al, nd]Peek, S. T. M., Wouters, E. J. M., van Hoof, J., Luijkx, K. G., Boeije, H. R., & Vrijhoef, H. J. M. Factors influencing acceptance of technology for aging in place: a systematic review: a systematic review. *International Journal of Medical Informatics*, *83*(4), 235-248.

[Pieper, Antona, & Cortés, 2011] Pieper, M., Antona, M., & Cortés, U. (2011). Ambient Assisted Living. *ERCIM News*. Retrieved from http://www.ics.forth.gr/files/publications/antona/2011/Pieper_et_al.pdf.

[Powell Taylor Ellen, n.d.] Powell Taylor Ellen.(n.d.). Retrieved from http://learningstore.uwex.edu/assets/pdfs/g3658-6.pdf

[Quantitative design and analysis, 2012] Quantitative design and analysis [pdf]. (2012). Retrieved from http://www.kennesaw.edu/assessment/forms/Quantitativemethods.pdf

[Quantitative Research, n.d.] Quantitative Research. (n.d.). Retrieved from https://koppa.jyu.fi/avoimet/hum/menetelmapolkuja/en/methodmap/strategies/quantitative-research

[Queirós, Silva, Alvarelhão, Rocha, & Teixeira, 2013] Queirós, A., Silva, A., Alvarelhão, J., Rocha, N. P., & Teixeira, A. (2013). Usability, accessibility and ambient-assisted living: A systematic literature review. *Universal Access in the Information Society*, 1-10.

[Research Methodology, n.d.] Research Methodology [pdf]. (n.d.). Retrieved from http://www.ihmgwalior.net/pdf/research_methodology.pdf

[Robinson, Brittain, Lindsay, Jackson, & Olivier, 2009] Robinson, L., Brittain, K., Lindsay, S., Jackson, D., & Olivier, P. (2009). Keeping In Touch Everyday (KITE) project: developing assistive technologies with people with dementia and their carers to promote independence. *International Psychogeriatrics*, *21*(03), 494-502.

[Rogers, 2010] Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.

[Savitri Abeyasekera, n.d.] Savitri Abeyasekera. (n.d.). Quantitative analysis approaches to qualitative data: why, when and how [pdf]. Retrieved from http://www.reading.ac.uk/ssc/resources/Docs/Quantitative_analysis_approaches_to_qualitative_data.pdf

[Schrader, Carlson, & Rothenpieler, 2010] Schrader, A., Carlson, D., & Rothenpieler, P. (2010). SmartAssist-Wireless Sensor Networks for Unobtrusive Health Monitoring. In *Proceedings of the 5th Behaviour Monitoring and Interpretation Workshop at the 33rd German Conference on Artificial Intelligence (KI-2010)*.

[Shackel, 1991] Shackel, B. (1991). Usability-context, framework, definition, design and evaluation. *Human factors for informatics usability*, 21-37.

[Sixsmith et.al, 2009] Sixsmith, A., Meuller, S., Lull, F., Klein, M., Bierhoff, I., Delaney, S., & Savage, R. (2009). SOPRANO–an ambient assisted living system for supporting older people at home. In *Ambient Assistive Health and*

Wellness Management in the Heart of the City (pp. 233-236). Springer Berlin Heidelberg.

[Sun, De Florio, Gui, & Blondia, 2009] Sun, H., De Florio, V., Gui, N., & Blondia, C. (2009, April). Promises and challenges of ambient assisted living systems. In *Information Technology: New Generations, 2009. ITNG'09. Sixth International Conference on* (pp. 1201-1207). Ieee.

[Trochim M.K.William, 2006] Trochim M.K.William. (2006). Qualitative Approaches. Retrieved from http://www.socialresearchmethods.net/kb/qualapp.php

[UNC Asheville, 2013] UNC Asheville. (2013). Developing a library research strategy. Retrieved from http://library.unca.edu/lr/resstrat.html

[United States general accounting office, 1992] United States general accounting office. (1992, May). Quantitative data analysis: An Introduction (Publication No. GAO/PEMD-10.1.11). Retrieved from http://www.gao.gov/special.pubs/pe10111.pdf

[Venkatesh, 2013] Venkatesh, V. (2013). Unified Theory of Acceptance and Use of Technology (UTAUT). *online], http://www. vvenkatesh. com/it/organizations/theoretical models. asp*.

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

[Wesley, 2013] Wesley. (2013). Some common approaches for analyzing Likert scales and other categorical data (literally) [Blog post]. Retrieved from http://www.r-bloggers.com/some-common-approaches-for-analyzing-likert-scales-and-other-categorical-data/

[What is anova, 2015] What is anova? (2015). Retrieved from http://support.minitab.com/en-us/minitab/17/topic-library/modeling-statistics/anova/basics/what-is-anova/

APPENDICES

Appendix 1: Questionnaire in Finnish

"Kysely ikäihmisten teknologiankyyttöhalukkuudesta ja -hyväksynnästä"

Kyselyssä sanalla teknologia viitataan järjestelmään, joka auttaa vanhuksia itsenäisessä elämisessä. Esimerkiksi: GPS-laitteet, erilaiset kannettavat laitteet sykkeen ja verenpaineen mittaamiseen, kaatumisen ilmaisimet, älykkäät pyörätuolit esim. navigoinnin avuksi tai hätäapu hälythimet ja lääkkerdenkäytönmuistutus.

Henkilökohtaiset tiedot

Nimi *

Sukupuoli *

☐ Mies

☐ Nainen

Ikä *

Koulutus

☐ Taivastaava

☐ Lukio

☐ Ammattikoulu

☐ Ammattikorkeakoulu

☐ Yliopisto

☐ Muu

Koulutuksellinen tausta

☐ Tietotekniikka tai muu siihen liittyvä ala

☐ Muu

Käytätkö mitään apuvälinettä fyysisen toiminnan tukena?

☐ Kyllä

☐ Ei

Onko sinulla diaknosortu henkisiä terveyteen liittyurä ongelmia?

☐ Kyllä

☐ Ei

Tutkimukseen liittyvät erikoistiedot

1. **Käytätkö teknologiaa esimerkiksi tietokonetta tai apulaitetta päivittäin?**

☐ Kyllä

☐ Ei

2. **Minkälaista teknologiaa normaalisti käytät?**

3. **Kuinka kauan olet käyttänyt teknologiaa?**

☐ Vähemmän kuin vuoden

☐ 1-5 vuotta

☐ 5-10 vuotta

☐ Enemmän kuin 10 vuotta

☐ En lainkaan

4. **Mitä käyttötarkoitusta varten käytät teknologiaa?**

☐ Päivittäisten askareiden avuksi

☐ Huviksi

☐ Molempia

☐ Muu

Käytön helppous

5. **Minusta teknologia on yksinkertaista ja helppoa käyttää.**

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

6. **Teknologian käyttö on minusta vaivatonta.**

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

7. **Pystyn käyttämään teknologiaa ilman ohjeita.**

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

8. **Jos teen virheitä, pystyn toipumaan niistä nopeasti.**

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Hyväksyntä

9. **Olen tyytyväinen teknologioihin, joita käytän päivittäin.**

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

10. **Haluan suositella teknologian käyttöä muille ikäisilleni ihmisille.**

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

11. Teknologia toimii sillä tavalla kuin haluan sen toimivan.

	1	2	3	4	5	
Täysinsamaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

12. Teknologiaa on hauska käyttää.

	1	2	3	4	5	
Täysinsamaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

13. Haluan lisää erilaisia teknologioita päivittäiseen elämääni.

	1	2	3	4	5	
Täysinsamaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Turvallisuus

14. Tunnen oloni turvalliseksi, jos teknologia esim. mittaa tai seuraa minua jatkuvasti.

	1	2	3	4	5	
Täysinsamaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

15. Luotan teknologioihin.

	1	2	3	4	5	
Täysinsamaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

16. Tunnen oloni keskeytetyksi tai ärsyntyneeksi, jos jokin teknologia esim. muistuttaa minua jatkuvasti lääkkeistä tai siitä mitä minun pitäisi tehdä.

	1	2	3	4	5	
Täysinsamaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

17. Olen tietoinen teknologioista, jotka voivat auttaa minua päivittäisissä askareissani.

	1	2	3	4	5	
Täysinsamaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

18. Teknologian käytöllä on vaikutuksia sosiaaliseen elämääni.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Tehokkuus/hyödyllisyys

19. Teknologian käyttö parantaa tavoitteiden saavuttamista.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

20. Teknologia auttaa minua päivittäisissä askareissani.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

21. Teknologia tekee sen mitä odotan sen tekevän.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

22. Teknologian käyttö säästää aikaa ja auttaa minua tekemään askareeni nopeammin.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

23. Teknologian käyttö antaa minulle enemmän elämän hallintaa (hallinnan tunnetta).

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Kustannus

24. Teknologioiden hinta on minulle ratkaiseva tekijä niiden käyttämiseksi.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

25. Käytän teknologiaa päivittäin enemmän pakosta kuin halusta.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Miellyttävyys

26. Minusta teknologian käyttö on järkevää helpottaakseni päivittäisiä askareita.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Sosiaaliset ja emotionaaliset tekijät

27. Minua hävettää käyttää teknologiaa muiden ihmisten läsnäollessa.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

28. Haluan apua teknologioista, jos tunnen oloni heikoksi tai apävarmaksi.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

29. Pelkään teknologian eristävän minut ystävistäni ja yhteiskunnasta.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

30. Olen tietoinen teknologian mahdollisuuksista.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Ymmärrettävyys

31. Sain koulutusta tai apua teknologian käyttöön ennen sen käyttöä.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

32. Kesti pitkään oppia teknologioiden käyttö.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

33. Mukaudun helposti teknologioiden käyttöön.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

Oppimisen helppous

34. Teknologian käyttöönotto oli minulle nopeaa.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

35. Vaikka en käyttäisi teknologiaa päivittäin, pystyn helposti jatkamaan sen käyttöä.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

36. Opin nopeasti teknologian käyttöön tarvittavat taidot.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

37. Teknologian käyttö pitää minut aktiivisena.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

38. Kokonaiskuva teknologian päivittäisestä käytöstä on minulle positiivinen.

	1	2	3	4	5	
Täysin samaa mieltä	○	○	○	○	○	**Täysin eri mieltä**

39. Kommentteja siitä millaista teknologian pitäisi olla, että se olisi hyväksytympää?

KIITOS PALJON!!!!

Appendix 2: Questionnaire in English

"Assessment of Technology Acceptance by Elderly People"

In the questionnaire the term technology means the system which assist elderly people to allow independent living. For example: simple GPS tracker, wearable devices to test heart rate and blood pressure, fall detector systems, intelligent wheelchair helping in navigation, emergency monitoring and medication systems.

Personal Information

Name*

Gender*

☐ Male

☐ Female

Age*

Qualification

☐ School

☐ Diploma

☐ Graduation

☐ Post Graduation

☐ Vocational

☐ Other

Educational Background

☐ Computer or related Field

☐ Other

Do you have any physical disability?

☐ Kyllä

☐ Ei

Do you have any cognitive disability?

☐ Kyllä

☐ Ei

Specific Information related to study

1. **Do you use technology in your daily life?**

☐ Yes

☐ No

2. **What kind of technology you normally use?**

3. **For how long you have been using technology?**

☐ Less than a year

☐ 1-5 year

☐ 5-10 year

☐ More than 10 year

☐ Never

4. **For what purpose you are using technology?**

☐ To help you in your daily tasks

☐ For Entertainment

☐ Both of the above

☐ Other

Ease of Use

5. **I find the technology simple and easy to use.**

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

6. **I find using technology effortless.**

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

7. **I can use technology without written instructions.**

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

8. **If I commit some mistakes when using technology/system, I can recover from it fast.**

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

Acceptance

9. **I am satisfied when using technology in my daily life.**

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

10. **I want to recommend the use of technology to other people of my age.**

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

11. **The technology works in the same way as I wanted it to work**

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

12. The technology is fun to use.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

13. I want to have more of these kinds of technologies in my daily life.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

Security

14. I feel secure if some technology for example sensors observe me continuously.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

15. I trust the technology.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

16. I feel interrupted or irritated if some technology for example mobile phone reminds me what I should do, what medication I should take frequently.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

17. I am aware of technologies that may help me in my daily life.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

18. The use of technology will affect in my social life.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

Efficiency/ Usefulness

19. The use of technology makes me more productive than not using it.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

20. The technology is useful to assist in my daily tasks.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

21. The technology does what I expect it to do.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

22. Usage of technology saves my time and helps accomplish my tasks faster.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

23. Usage of technology gives me more control over my tasks.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

Cost

24. The cost makes the difference to me if i want to use some technology to assist me

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

25. I use technology in my daily basis more of necessity than desire

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

Likeability

26. I think the technology is good to carry out daily tasks.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

Socio-emotional factors

27. I feel embarrassed if I have to use technology such as intelligent wheelchair in front of other people.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

28. I want to be assisted with technology if I will feel weak.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

29. I have fear that if I use technology to assist me, it makes me feel different among my friends and society.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	Strongly disagree

30. I am aware about the use of technology.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	Strongly disagree

Understandability

31. I got training or assistance before using the technology.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	Strongly disagree

32. It took long time for me to get familiar with the technology.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	Strongly disagree

33. I easily adapt to the technology.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	Strongly disagree

Ease of Learning

34. I quickly learnt how to use technology in the beginning.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

35. Even I do not use technology for a while I can easily remember how to use it.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

36. I quickly became skillful on using the technology.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

37. The use of technology is keeping me active.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

38. The overall perception of using technology in my daily life is good.

	1	2	3	4	5	
Strongly Agree	○	○	○	○	○	**Strongly disagree**

39. Any comments on how the technology should be to make it more acceptable?

THANK YOU!!!!