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# Exploring tangible interaction: Alternative interfaces for assisting elderly users

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# Abstract

The use of tangible user interfaces in assisting elderly users is still a fairly unexplored domain. While the current research provides some solutions to this domain, the research are still limited. The elderly population is growing, as a result of increased living standard and better health services. This causes a high demand of nursing homes, which will cause more elderly people to be living in their own homes. This thesis investigates how tangible user interfaces (TUI) can make things easier compared to the elderly people's current living situation. Domain-knowledge of common age impairments and details of TUIs have been collected through literature review, to propose a framework for designing TUIs for elderly people, based on previous frameworks on TUIs and common age impairments discovered.

Further domain-knowledge has been collected through focus groups, interviews, workshops and observations. Four prototypes featuring TUIs and designed to compensate for some challenges of aging have been developed. This includes T-Radio; a radio controlled by tangible blocks, Payless; an alternative way to pay for food and beverages in a canteen using only a RFID key card, Natural Charge; seven different wireless chargers to investigate the best configuration, and LightUp; a light bulb that changes the color intensity depending on environmental temperature.

The prototypes were taken through a formative usability test with experts from the HCI community, revealing some problems of the prototypes before a few modifications were done. Then summative usability tests with elderly participants were conducted at two different research sites; a local care home and a senior center. The results were analyzed using the proposed framework and led to three problem areas that were investigated, before the implications for design were presented. The results show that there are great potential in TUIs to compensate for age impairments and make things easier than today.

**Keywords:** *tangible user interface, design, elderly users, welfare technology, framework, prototyping, usability testing*

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# List of acronyms and abbreviations

| | |
|---|---|
| TUI | Tangible user interface |
| GUI | Graphical user interface |
| ISO | International Organization for Standardization |
| HCI | Human–computer interaction |
| RFID | Radio-frequency identification |
| NFC | Near field communication |
| BLE | Bluetooth low energy |

# Chapter 1

# Introduction

## 1.1 Motivation

Today an increasingly number of elderly is need of health care. Due to high birth rates after WW'II and decreasing birth rates the last decades, the population of elderly is very high and still growing. Better living standards and health services, contribute to a higher life expectancy (Brunborg 2004). With such high numbers of elderly compared to the younger population, a few problems occur. One of these problems is a high demand for nursing homes, which because of limited capacity, is reserved for those most in need of special care. Therefore an increasing number of elderly live in their own homes or sheltered housing (Otnes 2011). This raises a few issues: How can the elderly prolong their stay in their own homes without compromising the care, before moving to a nursing home?These issues give room for many technological solutions for elderly people's welfare. We need to find new solutions that are helpful for enabling people to live longer in their own homes.

Today's technology offers many solutions to make things easier than before, the problem is that they are not so user-friendly. By making a physical interface, something familiar to people born before the computer era, hopefully more people may be able to utilize today's technology. The main idea is to look at how technology can assist the elderly in some of their everyday tasks.

When creating a system designed for elderly users, we need to take into consideration the effects of aging. This is typically reduced vision, fine motor movement and cognitive functions, which will be further explained in chapter 3. These reduced functions may make it harder to operate traditional graphical user interfaces on a computer, using a standard mouse and keyboard. Reduced vision make it harder to see the text on the screen if the font size is too small, fine motor movement make it harder to hit the intended objects with the mouse, and reduced cognitive functions makes the whole system harder to process. This opens up for a different type of user interface based on the use of physical artifacts; a tangible user interface (TUI), which is an interface where the user interacts with digital information through the use of artifacts in the physical environment. With a tangible user interface, known artifacts can be used as a part of the interface and there are more possibilities to adapt the user interface to a specific user.

## 1.2 Research question

The purpose of this thesis is to design and investigate new solutions to assist elderly people in their everyday life. This thesis focuses on the use of tangible user interfaces and how this type of interface is suitable for elderly people, considering the challenges of aging. The research question of this thesis is:

> How can the use of modern technology with tangible user interface assist senior citizens living situation?

This is a broad research question with many potential answers. In this thesis, the research question will be answered through four objectives. The objectives are to (1) identify design requirements and challenges in designing for elderly users, (2) develop prototypes using tangible user interfaces, (3) demonstrate how tangible user interfaces can compensate for the challenges of aging, and (4) find design implications of tangible user interface for elderly users.

In addition, I will look thoroughly on how the prototypes compensate for age related challenges, how the participants understand the interaction, and to what degree they were able to comprehend the information presented by the prototypes, which lays the foundation for the analysis.

## 1.3 Research context

This master thesis is a part of a larger ongoing project: A3 - "Autonomy and Automation in an Information Society for All". The project aims to improve and simplify systems that are part of public services, to the benefit of all citizens. The project explores three areas of public services in which automation is used: 1) the semi-automatic tax, 2) patient information seen through the lens of patient privacy, and 3) welfare technology in health care. This master thesis falls under area number 3 - welfare technology in health care.

## 1.4 Chapter overview

**Chapter 2 - Background** gives an introduction to commercially available products relevant to TUIs and elderly, in addition related work where relevant findings are listed in a table.

**Chapter 3 - The aging population - an overview of the most common age impairments** looks at the aging body. It goes through the most common challenges of aging to better understand who to design for.

**Chapter 4 - Tangible user interface and its suitability for elderly users** gives a more thorough description of what TUIs are and how previous framework of TUIs considers age impairments. This chapter ends with proposing a framework for designing TUIs for elderly users.

**Chapter 5 - Methods** looks at the philosophical approach, design process and research context, in addition to the methods used: focus groups, semi-structured interviews contextual interview, observation, workshops, prototyping and usability testing.

**Chapter 6 - T-Radio** presents the T-Radio prototype, how it was made, results from usability tests and analysis of results.

**Chapter 7 - Payless** presents the Payless prototype, how it was made, results from usability tests and analysis of results.

**Chapter 8 - Natural Charge** presents the Natural Charge prototype, what it consist of, how it was tested and analysis of results.

**Chapter 9 - LightUp** presents the LightUp prototype, how it was made, results from usability tests and analysis of results.

**Chapter 10 - Analysis** analyzes the results from the prototypes on different themes before presenting the findings.

**Chapter 11 - Discussion** discusses the findings, frameworks, how the prototypes worked in compensating for age impairments, the suitability of TUIs, and the validity of the results.

**Chapter 12 - Conclusions and future work** concludes this thesis by giving a summary of the work and contribution presented, in addition to presenting design implication and exploring possibilities for future work.

# Chapter 2

# Background

This chapter presents and discusses related work, and a few consumer products. Relevant findings from related work are structured into a table. The background work further extends to Chapter 3 and 4 by presenting theory on elderly people and tangible use interfaces.

## 2.1 Existing consumer welfare products

A few welfare products recently have become available on the consumer market in the last years, fitting the description of tangible user interfaces. Philips has created both a medication dispensing service [1] to help elderly to take their pills, and Lifeline [2], a safety solution that provides automatic fall detection, localization and access to 24/7 emergency response center. A similar solution is provided by Mobilehelp [3], consists of a device with a button that you can press anywhere to summon emergency help. Telikin [4] is a touchscreen computer that focuses on giving an easy-to-use interface that is user friendly for elderly users. Another system called Presto [5] give users the ability to receive e-mail without a computer, by directly printing out the e-mail. Other systems like BeClose [6], GrandCare [7] and Lively [8] use sensors to monitor the activity and health of elderly users. The systems offer secure web pages that can be used by family and caregivers to monitor the elderly. GrandCare provides the elderly with a large touchscreen for social communication, instructions and reminders. Lively on the other hand, provides the elderly with a safety

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[1] `http://www.managemypills.com/`

[2] `http://www.lifelinesys.com/`

[3] `http://www.mobilehelp.com/`

[4] `http://www.telikin.com/`

[5] `http://www.presto.com/`

[6] `http://www.beclose.com/`

[7] `https://www.grandcare.com/`

[8] `http://www.mylively.com`

watch where they can receive medication reminders and get emergency response. It can also count steps and detect falls.

## 2.2 Related work

This section gives an overview of related work that is most relevant for this thesis. The papers presented in this section were found on the digital libraries of ACM (Association of Computer Machinery) [9], Springer Link [10], IEEE Xplore [11], ScienceDirect [12], Informa Healthcare [13] and Cambridge Journals [14] The papers were found either through search on Google Scholar [15] or recommended by supervisors.

### 2.2.1 Presentation of related works

Tangible technologies introduce new ways of interaction by mapping digital information to physical objects. This can for example be used in system designed for learning, Karime et al. (2009) presents a system that enables children to learn more about physical objects by pointing a magic stick to it, where a computer will show more information of the physical object. This system was designed by exploiting the simplicity of tangible user interfaces.

In a paper by Spreicer (2011), it is suggested that tangible user interfaces can be used to increase the acceptance of technology by the elderly. The paper presents an interesting model for technology acceptance by older adults. Findings from research conducted with the model indicate that the elderly are willing to use modern technologies, but are challenged by a low degree of “ease of use”. A prototype for sending e-mail or SMS with predefined content was developed and findings show that it is possible to use tangible technologies to create systems that are easy to learn and is suitable for elderly without prior computer knowledge. This paper and a paper by Ijsselsteijn et al. (2007) both lists some age related impairments that must be taken into consideration when designing simple interfaces for elderly. This includes visual and auditory declines, physical limitations and decline in cognitive functions. The current generation of seniors have also not been exposed to the same level of technology as the younger population, thus a focus on simplicity is important. These papers also present some interesting design opportunities more focused

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[9] `http://dl.acm.org/`

[10] `http://link.springer.com/`

[11] `http://ieeexplore.ieee.org`

[12] `http://www.sciencedirect.com/`

[13] `http://informahealthcare.com/`

[14] `http://journals.cambridge.org/`

[15] `http://scholar.google.no/`

on the elderly's leisure time, where other papers are often more focused on assisting personal care.

When designing new systems it is important that the intended users actually are willing to use such systems. McCreadie et al. (2005) has looked at the acceptability of assistive technology for older people with assistive technologies installed in their homes, this included technologies for communication, safety and alarms. Although not all the technologies worked properly, the positive comments far outweighed the negative comments of assistive technologies. Assistive technology is popular as it allows the elderly to regain their independence. To increase acceptability, systems can be designed to look like something old and familiar; this will also give a better understanding of how the system works. Veldhoven et al. (2008) created an interactive messaging and reminder display for elderly; this was designed to look like an old bulletin board to increase acceptability. Another system created by Nilsson et al. (2003), was made to let users listen to old news and music. This was designed to look like an old radio and gained good acceptance by the elderly.

Along with independence, privacy is also important, Goodman et al. (2005) has identified key areas of concern in the design of technology for older people, including ethics. Ethics should always be a concern when designing user interfaces, but especially when designing for vulnerable people like the elderly. Users of any design should not depend blindly on the system, especially if they think the system is wrong, neither should they ignore it. Assistive technologies for elderly should be of assistance and not life-depending.

Tangible user interfaces is a relatively new form of interface, but there have been some interesting applications aimed at older users, Häikiö et al. (2007) have developed a meal delivering service for elderly using NFC technology. This enabled the elderly to order their meal for the next day by holding their phone over the specific meal they wanted from a menu with hidden NFC tags. Similar NFC tags were also used by the driver to ensure that all the meals were delivered. It is a good example of how new technology can help the elderly. Another system created by Criel et al. (2011) lets the elderly program their own smart house behavior using NFC cards, and when they were programmed, they could place the card on a magnetic board to activate the desired smart house behavior. The programming seemed a little bit hard for most elderly, but the system enabled the elderly to be in control of their own environment. They could for example program the smart house to turn on a light above the trashcan at specific time to remind the elder to take out the garbage, or it could be programmed to turn on the TV on a specific channel at a specific time to remind the elderly person to watch their favorite TV show.

In a paper by Guía et al. (2013), they have developed games for cognitive rehabilitation. The games are designed for older adults, with a special focus on helping Alzheimer patients. The paper presents NFC as an emerging technology. These last three papers emphasize the usefulness of NFC as a viable technology to be used with tangible user interfaces and elderly. Other papers have also focused on cognitive rehabilitation, Jung et al. (2013), Marques et al. (2011) and Gamberini et al. (2009) reports from research where they all created tangible tabletop interfaces to train and preserve cognitive functions.

Another related paper (Cho et al. 2013) discusses design principles and how tangible user interfaces can be suitable for elderly. Design principles for elderly and key properties of tangible user interfaces were put together. Based on this, a framework was formed, highly relevant for this thesis, covering both elderly and tangible user interfaces.

### 2.2.2 Findings from related work

The related work is divided into three categories:

1. Tangible interaction

2. Interaction with elderly

3. Simple interaction

I have categorized relevant papers, as shown in Figure 2.1. Table 2.1 shows more detailed information about each paper, and points of interest for this thesis.

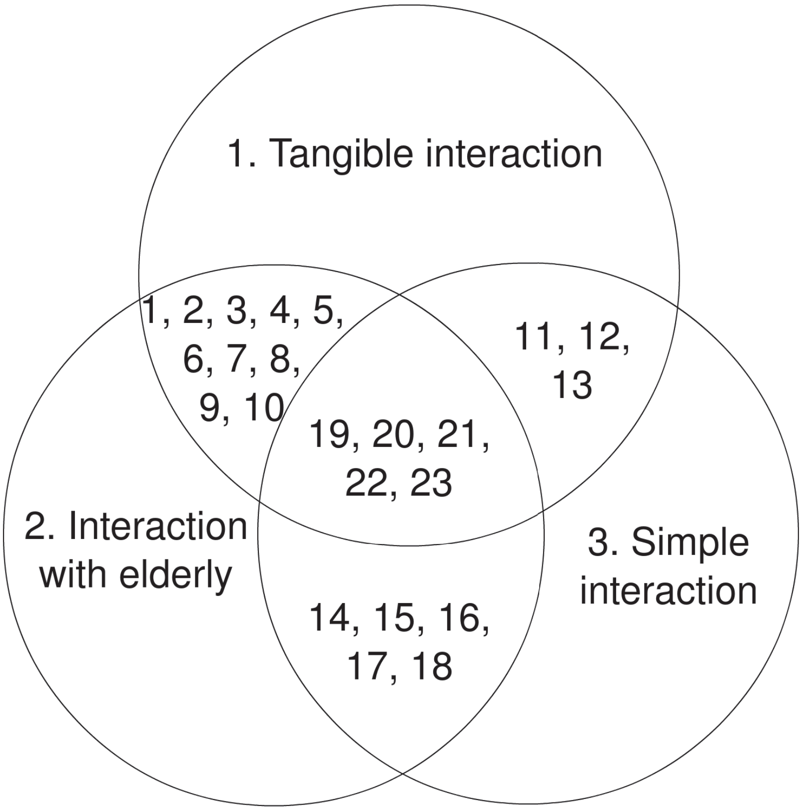

Figure 2.1: Venn diagram of related work

Table 2.1: Overview of related work and findings

| # | Source | Focus | Relevant methods | Relevant findings | Category |
|---|---|---|---|---|---|
| 1 | Nilsson et al. 2003 | TUI for elderly using old design | Cultural probes, workshops, user testing | Acceptability | 1, 2 |
| 2 | Marques et al. 2011 | Reduce obstacles that elderly face by using a multi-touch tabletop system | Low-fidelity prototyping, User testing | Tangible objects to promote gross motor skill stimulation | 1, 2 |
| 3 | Spreicer 2011 | Tangible interfaces for higher technological acceptance | Prototyping, workshops | Ease of use and learning for increased assistance | 1, 2 |
| 4 | Jung et al. 2013 | Cognitive rehabilitation system using tangible tabletop interface | Heuristic evaluation, prototyping | Tangible tabletop interfaces based activity daily living tasks for cognitive training. | 1, 2 |

| # | Source | Focus | Relevant methods | Relevant findings | Category |
|---|---|---|---|---|---|
| 5 | Wu et al. 2012 | Tangible social-media application for elderly | Prototyping, usability testing, focus groups, interviews | Customization services | 1, 2 |
| 6 | Sax et al. 2009 | Monitoring of elderly to ensure their health | Semi-structured interviews, usability testing | Influential dimensions on the user interface | 1, 2 |
| 7 | Al Mahmud et al. 2008 | Tabletop game experience for elderly users | Observation, test sessions, questionnaire, interviews, prototyping | Immersive interface | 1, 2 |
| 8 | Häikiö et al. 2007 | Touch based user interface for elderly | Interviews, observation, self-report diary, user testing | Suitability of touch-based user interface for elderly | 1, 2 |
| 9 | Veldhoven et al. 2008 | Design and usability of an interactive bulletin board | Interviews, observations, prototyping, user testing | Familiar interaction principles contribute to usability | 1, 2 |
| 10 | Gamberini et al. 2009 | Tabletop games to preserve cognitive functions | Prototyping, usability testing, questionnaires | Level of acceptability | 1, 2 |
| 11 | Sharlin et al. 2004 | Examines the relationship between humans and physical objects | Analyzing TUIs | Three spatial heuristics | 1, 3 |
| 12 | McNerney 2001 | Physical programming language using building-blocks | Prototyping, user testing, feedback from others observations | Flexible technology, tangible programing, affordance | 1, 3 |
| 13 | Karime et al. 2009 | Help children learn about new objects using TUI | Prototyping, user testing | System architecture | 1, 3 |
| 14 | Falck et al. 2007 | Wireless medical body sensors | Prototyping | Body-coupled communication | 2, 3 |
| 15 | Ijsselsteijn et al. 2007 | Digital game design for elderly users | Literature review | Design opportunities / Age related changes on design | 2, 3 |

| # | Source | Focus | Relevant methods | Relevant findings | Category |
|---|---|---|---|---|---|
| 16 | Goodman et al. 2005 | HCI,and the older population | Literature review, model of the acceptability of assistive technology | Technology design process for older people | 2, 3 |
| 17 | McCreadie et al. 2005 | Acceptability of assistive technology to older people | Interviews, tests of assistive technology | Model of the acceptability of assistive technology | 2, 3 |
| 18 | Warpenius et al. 2014 | Mobile user interface for elderly care | Surveys, interviews | Identifying system features | 2, 3 |
| 19 | Cho et al. 2013 | Design principles of user interface for elderly | Literature review | Framework of user interfaces for elderly | 1, 2, 3 |
| 20 | Rice et al. 2008 | Interfaces for digital interactive television for older adults | Prototyping, user testing, scenarios | Alternative methods of data gathering | 1, 2, 3 |
| 21 | Criel et al. 2011 | Let,elderly create personalized user behavior for their environment using TUI | Cultural probes, interviews, survey | Implications for design | 1, 2, 3 |
| 22 | Guía et al. 2013 | Cognitive rehabilitation using tangible computer games | System development | Proposed system | 1, 2, 3 |
| 23 | Mannapperuma 2010 | Home-based communication solution for elderly | Observation, interviews, test sessions | Key design principles | 1, 2, 3 |

## Chapter 3

# The aging population - an overview of the most common age impairments

### 3.1 What is old?

Freund et al. (1999) defines old as persons in the age between 70 and 84, and defines persons with an age of 85 or older as very old. United Nations (2013) has agreed that 60+ years may be usually denoted as old age and those 80 years and older is referred as the "oldest old". World Health Organization (2014) has however in a study in Africa, set the beginning of old age as 50, but states that most developed world countries has accepted the age of 65 years or older as a definition of elderly or older person. Hawthorn (2000) looks at old age in the context of interface design and operates with old age as the age of 45 and over, as from this age the effects of age becomes noticeable. In another paper by Orimo et al. (2006) it is suggested to change the definition of elderly, which conventionally is defined as 65 years or older. Where those from 65 to 74 years are referred to as "early elderly", and those 75 and older is referred to as "late elderly". Orimo et al. (2006) argues that because the physical activity of healthy elderly, the functional dependence in elderly patients with diabetes mellitus and the cerebral arteries have been more youthful in the later years, the definition of elderly should be changed to 75 years. In this thesis we will use the more conventional definition of old age as 65 years and older.

### 3.2 Age impairments

Some say age is just a number and that may be, but there are physical changes that come with age. Many notice some changes as early in their 40s or 50s. This is natural and is not necessary of much consequence, but the changes will continue and accelerate as the years go by. The vision will get more blurry, it becomes harder to read small text and the hearing will decline. These are the first and most noticeable changes, but there other functions that also decline and we will look further into these. Not every person is alike, but everyone experiences some changes.

### 3.2.1 Visual impairment

The diminishing capability of the eye to focus on near objects is caused by presbyopia, a condition that is commonly associated with age. The lens in the eye stiffens and thus makes it harder to focus on near objects. It is normal to notice this impairment in the late 40s and is increasingly getting worse as the person ages. The near point focus is about 10 cm at age 20, and increasingly moves the point of focus to about 100 cm at age 70 (Sun et al. 1988). This condition can easily be corrected with reading glasses, lenses or laser surgery.

Older people struggle more to see in dark environments, this is because the pupil becomes smaller and thus less light is able to enter the eye. More light is therefore needed for an elderly person to be able see sharply. Under normal conditions, a 40-year-old person needs twice the amount of light compared to a 20-year-old person, and at age 60, three times as much light is required. Elderly is also more sensitive to glare (F. Huppert 2003).

A higher contrast is necessary for the elderly to easier distinguish between different surfaces. To compensate for this, it would be best to use a high contrast (50:1) on-screen and in print. It is for example easy to read black text on a white background. Warm colors are good, and it is important that colors used in front are distinct from the background color. It is preferable to use matte surfaces, rather than glossy surfaces to minimize glare. To take into account the need for more illumination, it is better to have multiple indirect low intensity sources of light rather than direct light. Visual presentation of information should consist of large text, at least a font size of point 12 or larger, and big and clear buttons. Decorative backgrounds should be avoided, as should non-relevant information, rapid motion, flickering or flashing lights (Farage et al. 2012; F. Huppert 2003).

### 3.2.2 Hearing loss

A research by Davis et al. (1991) shows that it is normal for a person under the age of 55 to experience a hearing loss of 2.5 dB per decade. For those over 55 years of age, the hearing loss accelerates to 8.5 dB per decade. The deterioration in hearing is most aggressive in the high-pitched tones (2-8 kHz) and men are most vulnerable (Pedersen et al. 1989), therefore it is easier for elderly to listen to low pitched tones.

According to Farage et al. (2012) sound signals for elderly should be at least 60 decibel (dB). Compared to conversational speech which is at 50 dB. The sound should be at a high volume, with background noise turned to a minimum. It is preferable to avoid high frequencies and rather use frequencies in the range of 500-2000 Hz. Alarm sounds should not exceed 2000 Hz. It is easier to listen to a lower-pitched male voice than a high-pitched female voice, and a male voice would therefore be preferred if a system is using auditory speech.

When important information is provided through sound (e.g. doorbell), the signal can be reinforced by buzzing or flashing lights. It is also important that verbal information should be delivered at a slower pace to make it easier to recognize the words and understand the information. Hearing impairments worsen when there is background noise, because of a reduced ability to mask and ignore irrelevant sounds. Ambient sounds should therefore be minimized to avoid auditory disorientation (F. Huppert 2003).

### 3.2.3 Cognitive changes

Declines in *fluid intelligence* are a normal age impairment, which refers to the processing and reasoning components of intelligence and the natural ability to learn something new (S. Czaja et al. 2007). Because of reduced processing efficiency, the working memory, which is the ability to keep information active while processing or using it, declines with age (Salthouse et al. 1991), e.g. to follow a step-by-step guide and remember what to do next. *Prospective memory*, which is the ability to remember to do something in the future, also declines with age. In a study where nearly 12000 participants over the age of 65 were asked to perform a test of their *prospective memory*, only 54 % succeeded with the task. The study showed that there was a strong connection between the completion of the task and age. The male gender, less education and lower social status increased the risk of prospective memory impairments (F. A. Huppert et al. 2000). Another ability that declines with age is the ability to select information in the environment, e.g. to attend to information on a web page.

Aging also causes a decline in *spatial cognition*, which is the ability to represent spatial relationships among objects, e.g. mentally manipulate a puzzle piece to determine if it will fit in a space. In a study by Iachini et al. (2008), 44 young people with a mean age of 25 and 44 older people with a mean age of 65 were asked to do different spatial tasks. Results show that some spatial abilities, such as the ability to mentally rotate visual images and to retrieve spatio-temporal sequences, declines with age. Elderly people also struggle more with multitasking (doing more than one thing at once), especially if the tasks are complex (Kramer et al. 1996).

The brain also consist of *crystallized intelligence*, which is knowledge acquired through education and experience. This intelligence remains stable or increases, therefore the *semantic memory*, which refers to the long-term memory of work knowledge (e.g. history and language), does not decline with age.

Generally, older adults struggle more to acquire new skills and may not ever reach the same performance in the execution of the skills compared with younger people(S. Czaja et al. 2007). *Attention* is the ability to focus on a specific task or an object in the environment while ignoring other things. This ability changes with age and older people are slower to move their *attention* from one thing to another (e.g. talking on the phone while listening to the radio) (F. Huppert 2003)(S. Czaja et al. 2007). The ability to focus on one thing does not change with age, but it is the ability to ignore interferences (e.g. noise or movement), that declines. Elderly also tend to interpret language more literally (Farage et al. 2012), e.g. humor that uses sarcasm or is ironic, can be confusing. Farage et al. (2012) comes up with four key points for presenting information to elderly. These are simplicity, intuitive logic, moderate pace and a minimum of non-relevant information.

#### Brain disorders

The likelihood of getting degenerative brain disorders such as Alzheimer and vascular dementia increases with age. About 20 % of adults aged over 80 in the United Kingdom have some form of dementia (F. Huppert 2003). In Norway, there is no nationwide research of how many who live with dementia, but the most common metrics estimates the number to be 70000 (Strand et al. 2014). It is estimated that approximately 60 % of those have Alzheimer (Qiu et al. 2007). Alzheimer is the most common type of dementia that negatively affects memory, thinking and behavior (Burns et al. 2009). It is not a disease caused by old age, but it is a progressive disease that worsens over time and become more apparent with increased age. At an early stage, the memory loss is mild, but at a late stage people with Alzheimer's lose the ability to carry on conversations and respond to the environment. Vascular dementia is less common and accounts for approximately 20 % of dementia cases (Qiu et al. 2007). It causes a decline in thinking skills, because of reduced blood flow to the brain. It becomes apparent after a major stroke and typical symptoms are confusion, disorientation, trouble speaking or understanding speech and vision loss Román et al.

(2002).

### 3.2.4 Physical abilities

Response time and accuracy of movement declines with age. An older persons movements and reflexes are typically slower than a younger persons. This also includes reaction to stimuli (Farage et al. 2012). Elderly people are also more sensitive to cold and the indoor temperature should therefore not drop below 18°C (Kercher et al. 2003). We have three types of receptors on our skin that help us to experience touch; pressure, pain and heat/cold. Many of these receptors die off as we age, making us less sensitive to touch. This loss in the sensitivity of touch reduces our ability to differentiate between shapes and texture by touch (F. Huppert 2003), e.g. two pressure points on the skin must be further apart for an older person to sense that there actually is two points of pressure.

#### Changes in muscles and joints

*Muscle strength* as for example handgrip and quadriceps (the large muscle group on the thigh) is at its peak at the age of 25 and declines more rapidly from age 50. At the age of 75 and over, the hand strength is less than half of the strength of younger adults (F. Huppert 2003). We also have *muscle power*, which is the combination of muscle strength and speed. Muscle power is used for example when we rise from a chair or climb stairs, and declines at an even faster rate than muscle strength. Another ability that declines is *flexibility*, which refers to having a sufficient range of movement, e.g. loss of range in the shoulder joint. This makes it harder to reach above the head, e.g. to get something from a high shelf, hang up the laundry or brush the hair. Women have in general, about two-third the physical abilities of men and have a poorer power-to-weight ratio (Bassey 1997). Therefore, they have a greater disadvantage when it comes to lifting, walking and stair climbing.

#### Gait

*Balance* also has a tendency to decline with age, and uses many sensor inputs to be able to speedily use precise motor reactions (Colledge 1997). If you trip, it requires rapid and powerful movements to restore your *balance*. These movements decline with age, causing a higher tendency for falls. Over 30 % of all people over the age of 65 fall each year and this increase with age (Blake et al. 1988). Falls cause both mortality and morbidity, and of all the falls that cause death, ¾ of these are among people 65 years or older. Repeated falls is a common reason as to why a formerly independent person has to seek help at a long-term care institution. There are many reasons for falls, e.g. visual impairments that makes it hard to see obstacles, but the most dominant risk factor for falls is muscle weakness (Rubenstein et al. 2006). Thus, many falls can be avoided with proper exercise. *Endurance*, referring to the ability to sustain a prolonged activity, declines with age. If your muscles do not get enough oxygen, you will experience fatigue and breathlessness, and you need to rest to get enough oxygen to the muscles. Aging causes a loss of *elasticity*, clearly noticeable in the skin, but it is also affecting the lungs and the way we walk. Loss of *elasticity* reduces the efficiency of walking, because of the loss of rebound energy (Bassey 1997). Joint stiffness and poor balance also cause severe limitations in walking. As we age, we will from the mid-adulthood start to lose height. The average height of someone in the age of 65-74 is 5 cm less than the average of someone in the age of 16-24. Other visible changes are that feet become broader and waistlines thicken.

#### Age-related health problems

All of this mentioned above has been normal age impairments; some people are also unlucky enough to get age-related health problems. One of the most common health problems, influencing physical capabilities, is *arthritis*. It causes pain and reduced movement in the joints, which limits the ability for firm grips and precise finger movements (F. Huppert 2003). Another disease that limits movement is Parkinson. Parkinson is a neurodegenerative brain disorder that progresses slowly and worsens with age. The first and most noticeable symptom is involuntary shaking of the hands, arms, legs, jaw, chin and lips. Other main symptoms include slowness of movement, stiffness of the arms and legs, and trouble with balance and falls (Jankovic 2008).

### 3.2.5 Anxiety towards technology

In a study by S. J. Czaja et al. (1998), older people saw themselves as having less control over computers than younger people did. They also had significantly less efficacy in completing computer tasks, but they also perceived computers as being more useful compared to younger people. Another study by Laguna et al. (1997), revealed that older subjects reported higher levels of computer *anxiety* than younger persons, and that the *anxiety* level was related to the decision time on the computer, when performing a test. Many elderly have reported that they are afraid of using new technological devices and that they are afraid to damage the device (Marquine Raymundo et al. 2014). Some are afraid when using the Internet, ATM's, computers, new devices and making mistakes. They are afraid of what consequences a mistake can have, e.g. to accidentally delete other peoples documents on a computer. Many reported they are afraid because of previous bad experience with technology. They often have a hard time understanding how to use a device and think it could be easier to use. Elderly may have a harder time using new technology, but it helps with practice. Chu et al. (2010) reported that participants who took a 5-week computer training program, showed a decrease in computer *anxiety* compared to participants who did not take the program.

## Chapter 4

# Tangible user interface and its suitability for elderly users

### 4.1 The user interface

In 1995 Fitzmaurice et al. (1995) introduced the concept of a Graspable User Interface, which enables some of the elements from a virtual user interface to take a physical form. Graspable User Interfaces was to allow a direct control of electronic or virtual objects through physical artifacts that worked as handles for control. These were essentially new input devices to manipulate virtual objects. A few years later, Ishii et al. (1997) introduced "Tangible Bits" as an attempt to bridge the gap between cyberspace and the physical environment. This was to be done by making digital information, referred to as "bits", tangible. They present three concepts of tangible bits. The first is "Interactive Surfaces", where architectural space such as walls and doors can be transformed into an interface between the physical and virtual world. The second concept is described as "Coupling of Bits and Atoms", where everyday graspable objects such as cards and books can have a seamless coupling to digital information. The third concept is "Ambient Media", where for example, sound, light, airflow and water movement can be used as background interfaces and represent information. More generally, tangible user interfaces (TUI) replaces the more traditional graphical user interface (GUI) with real physical objects you can interact with.

> "TUIs will augment the real physical world by coupling digital information to everyday physical objects and environments.”
> Ishii et al. (1997)

According to definition by Ishii (2008), all physical objects can potentially be a part of a digital user interface. For example if an object, which is a part of a TUI, is moved or put in a specific position, a digital signal will be sent from either the tangible object itself or from another device which senses the object. TUI can use physical objects that fit seamlessly into a user's physical environment, often not visible to a normal viewer's eye. The aim is to take advantage of the haptic interaction skills with the environment, and the key idea is to give digital information a physical form, and letting these physical forms serve as a representation and a control for the digital information. This will make it possible to manipulate the digital information with our hands and percept it with our senses (Ishii 2008).

### 4.1.1 Examples of tangible user interfaces

One of the simplest examples is the computer mouse where you move the mouse around with your hand and a pointer on the screen moves accordingly. It shows a clear relationship between the physical movement of the mouse and its digital representation on the screen. A classic example of a tangible user interface is the Marble Answering Machine by Durrell Bishop (1992). In this concept, a marble represents a message, you can hear this message by placing the marble in a designated bay for playback or you can place it in another bay to dial the caller's number. In more recent years several products have been launched on the consumer market, among these are Sifteo cubes [1]. Sifteo cubes are small intelligent cubes with a display on them, which are able to communicate and interact with each other depending on their position. They can respond to motion, touch on the display and can detect nearby cubes and act accordingly depending on the game you are playing. Another example is the Reactable [2] music system. It consists of a table where a set of pucks can be placed. The user can move, turn and connect the pucks to each other to change the music. When a puck is placed on the table, it is illuminated and you can see the interaction between the pucks, turning music into something visible.

## 4.2 Applying TUI in the context of elderly users

When designing user interfaces to be used by elderly people, we must consider their age and the effects of the aging body. Spreicer (2011) defines three dimensions for the definition of aging and its effects:

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[1] `https://www.sifteo.com/home`

[2] `http://www.reactable.com/`

1. The biological age; defined by loss of muscle mass, cataract or elevated blood pressure. The effects of this are reduced vision or fine motor movement, which make it more difficult to operate a mouse and keyboard, and reading text on a computer screen.

2. Cognitive aging; changes in human cognition and information processing. This makes it difficult to adapt to new problems without extensive prior learning.

3. The social age; determined by social relationships and societal norms and roles. Retirement and perhaps changes in the private domain can reduce the social interaction with other adults.

Spreicer (2011) also states that age-related physical or cognitive impairments may have an impact when operating traditional user interfaces. This prevents many elderly from using new technology and having access to information in the same way as the rest of the population. The limited access to digital information is often referred to as the digital divide. To help reduce this digital divide, age-related impairments must therefore be taken into account when designing user interfaces for elderly. Since a traditional user interface may be too complicated to use, a tangible user interface may be more suitable.

Jive[3] is a good example of a tangible user interface for elderly. It is a computer designed to make it easier for elderly to stay connected with friends and family. It doesn't require a mouse, and its controlled by placing tangible blocks in specific locations on the screen. Another example is to use NFC to call a specific person by holding the phone over a picture. Tangible user interfaces can also be used to ensure health and safety, e.g. an activity monitor can be used to measure and encourage activity to prevent deterioration of muscles, which then again can prevent falls. A tabletop computer can be used to improve cognition and encourage social activities (section 2.2.1). Pill reminders and fall detection can also be supported by a tangible user interface (section 2.1).

### 4.2.1 Framework by Cho et al. (2013)

A framework for tangible user interface with the elderly in focus, has been created in a paper by Cho et al. (2013). In this paper, a number of design principles from previous papers on tangible user interfaces have been reviewed, along with papers on design principles for elderly. This resulted in a framework divided in two dimensions; tangible interface properties and supportive interface properties.

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[3] `http://jive.benarent.co.uk/`

### Tangible Interface Properties

This dimension consists of six categories valid for all tangible user interfaces: manipulation, intuitiveness, representation, context awareness, spatial interaction and social interaction. *Manipulation* is the direct manipulation of objects that users can grab and feel. *Intuitiveness* means that there should be a natural way of manipulating the interface without the need of a manual or learning process. *Representation* refers to the meaningful representation of digital and physical objects. *Context awareness* is the sense of the surroundings, while *spatial interaction* refers to the ability to control and coordinate within the environment. *Social interaction* is the awareness of others in the environment and the interaction between them.

### Supportive interface properties

This dimension contains eight design implications when designing tangible user interfaces for elderly people. The first criteria is *digital literacy* which is to what degree a user is able to understand and utilize resources. The second criteria is *accessibility* and refers to how the design enables users to move freely in the system without assistance, while the criteria *physical and sensory support* refers to what degree users have independence and support for sensory impairments. A central criteria is *simplicity* where the information presented in the interface should be easy to understand. The system should provide a safe and secure environment: criteria *safe and security*. The last two criteria are *self control* and *stimulation* referring respectively to the ability the users have to control the system without assistance, and how the system promotes independent functioning through stimulation of cognitive abilities.

## 4.3 Framework for tangible user interface in the context of elderly users

While Cho et al. (2013) already has established a framework for tangible interaction and elderly users, our focus is primarily on the framework presented by Hornecker et al. (2006). It is a framework on tangible interaction consisting of four themes: Tangible manipulation, spatial interaction, embodied facilitation and expressive representation (Figure 4.1). The framework focuses on the user experience around tangible systems, and directs attention to the qualities of interaction and away from technical functions. In this section, I will look closely at this framework and its suitability for designing tangible user interfaces for elderly users.

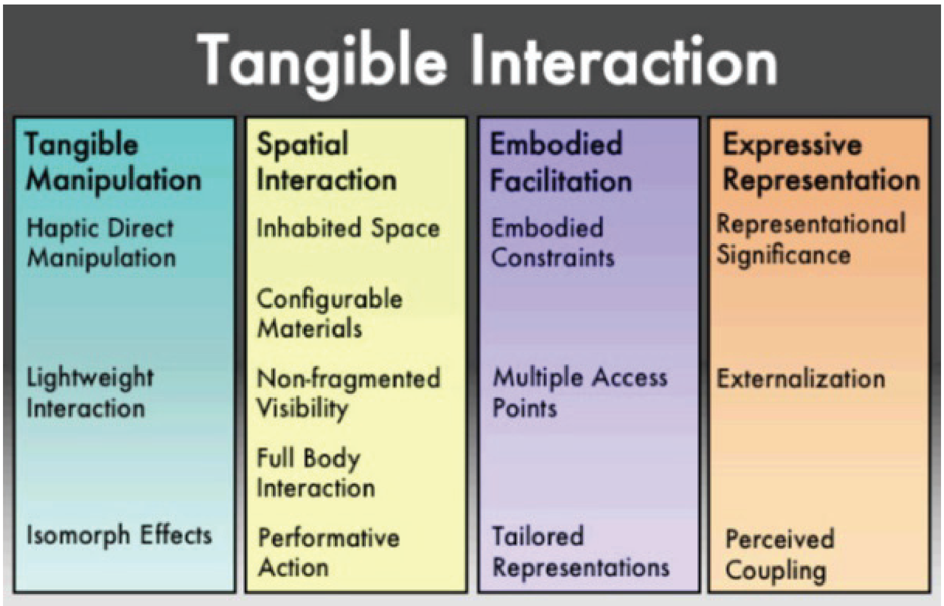


Figure 4.1: Overview of the framework for tangible interaction by Hornecker et al. (2006)

### 4.3.1 Tangible manipulation

Tangible manipulation refers to bodily interaction with physical objects.

**Lightweight interaction** gives the user feedback to every action that is performed and allows the user to proceed in small steps. It is important to let the users proceed in small steps, especially elderly, as they struggle more to select information in the environment. This involves their *attention*; the ability to focus on a specific task while ignoring other things. It is especially the ability to ignore irrelevant things that declines with age, for example to ignore non-relevant elements in an interface or sounds and movements in the environment (section 3.2.3). Elderly people may experience decline in *working memory*, the ability to keep information active while processing it. This, in addition to declines in response time and accuracy (section 3.2.4), can give elderly a sense of accomplishment by not being stuck on the same step for a long time by enabling them to proceed in small steps. Good feedback is essential for this sense of accomplishment. Sounds in the range of 500 to 2000 Hz (section 3.2.2) can give good feedback, depending on the interface. Considering these age impairments, *lightweight interaction* is a suitable category for designing tangible user interfaces for elderly.

**Isomorph effects** allow the user interface to be recognizable. For example, a new radio can be designed to look like an old and familiar radio, thus helping the user to understand what the device does and the relation between actions and their effects. The bulletin board designed to look like something old and familiar by Veldhoven et al. (2008) and the radio by Nilsson et al. (2003) are good examples of this. Some elderly people struggle to achieve new skills and with their *semantic memory* (the long term memory of work knowledge is in many cases more accessible than their short-term memory) (section 3.2.3). Isomorph effects can enable us to exploit the memory of old skills and help in making new interfaces easier to use. It can also reduce *anxiety* towards new technology (section 3.2.5) by presenting a system that looks and feels like something familiar, hopefully reducing fear of using the system and fear of damaging it.

**Haptic direct manipulation** allows the users to manipulate objects in the user interface (to grab, feel and move). Physical interaction can be easier to understand for those who have not grown up in the digital world. Direct manipulation can give a clearer image of the connection between physical interaction and the action that it triggers. In this category, the most prominent age impairments affected are declines in motor control and accuracy. At the age of 75+ the strength in the hand is less than half of younger adults, thus it is important that objects in the interface are light and easy to grip. The objects should be small enough to be held, but not too small that they cannot be seen by the user. Another relevant age impairment is declines in *spatial cognition*, the ability to mentally manipulate an object to see if it fits in a specific space (section 3.2.3). This can cause more trial and error if the system involves placing the objects in specific spaces. One needs accuracy and fine motor control to be able to place an object in a specifc way. An example of a system using haptic direct manipulation is the TanCu prototype by Spreicer (2011), used to send e-mail or SMS with predefined content. It uses physical cubes with different content on the sides of it. The first cube is used to choose recipient and the other cube is used to choose message content.

### 4.3.2 Spatial interaction

Spatial interaction refers to interaction by movement in space. It can for example rely on the movement of one's body in space, in relation to the positioning of some objects.

**Inhabited space** refers to if the space is a meaningful place, and if people and objects meet. None of the above-mentioned age impairments should be a problem in this category. It covers a lot of ground as long as there is a meaningful place, and there are systems covering this category that are not suitable for elderly, but it is hard to point out any age impairments directly involving this category, although physical abilities limits every activity (section 3.2.4). Declines in *muscle strength*, *muscle power* and *elasticity* can limit the ability to walk or the use of arms, while other age-related health problems like arthritis can make it hard to grab objects with the hands. An example of inhabited space is the system presented by Karime et al. (2009), where a magic stick is used to point at different objects. When an object is being pointed at, information about this object is shown on a screen. In this example, we use a stick and meet objects, and by helping us learn more about the object, it creates a meaningful place.

**Configurable materials** refers to meaningful re-arrangement or movement of materials in the environment. This includes both movement of objects and the body. This is a vast category and there are multiple age impairments that can complicate its use, depending on the system. Declines in motor control can make systems depending on movement harder to use. Declines in *muscle strength* in the hand can make it harder to grab small or big objects, and declines in quadriceps or other muscle groups related to the legs can make it harder to move around in the environment, thus it can be hard to use the interface if its relies on the movement of the body. Reduced range of movement caused by declines in *flexibility* can limit the user's ability to reach for high places (section 3.2.4). Declines in the *working memory* (section 3.2.3) can make a system that involves multiple steps that need to be followed complicated, and as mentioned under an earlier category, declines in *spatial cognition* can cause more trial and error if the system involves placing objects in a very specific order. One example of configurable materials is the system by Criel et al. (2011), where cards are placed on a magnetic board to activate smart house behavior, or removed to deactivate the behavior.

**Non-fragmented visibility** refers to a space's ability to allow everybody to see whats happening without fracturing the picture. Visual impairments can make it harder to see (section 3.2.1), but systems should compensate for this by reducing non-relevant information, have a good font size, have a high contrast to distinguish between elements and be well lit. It can also be harder to follow the visual reference with declines in the *working memory* (section 3.2.3). It can for example be easy to see what is happening, but hard to understand the context. The tabletop game mentioned in section 2.2.1 (Gamberini et al. 2009) is a good example of non-fragmented visibility. Everyone seated at the table can see what is happening on the interface.

**Full-body interaction** refers to large movements or the use of the whole body in the interaction with a user interface. This is significantly harder for elderly with motor declines, which makes this less relevant for designing user interfaces for elderly. Muscle weakness is the dominant factor for falls (Rubenstein et al. 2006), therefore full-body interaction may be relevant for interfaces designed to motivate exercise. Full body interaction is problematic for many elderly because of declines in *muscle power*, combining both speed and muscle strength. In addition, age impairments such as declines in *flexibility*, *balance*, *endurance* and *elasticity*, can cause limited reaching range, instability, lower stamina and reducing the effectiveness of walking (section 3.2.4).

**Performative action** refers to actions or movement used as a communicative effect to trigger another action. The most prominent age impairment would in this case be motor control. Actions that previously were easy to do can get harder with increased age because of declines in sensitivity and motor control (section 3.2.4), forcing the use of new actions. Examples of this includes BeClose, GrandCare and Lively which is mentioned in section 2.1. All of these systems use sensors to monitor the activity of the user, thus detecting the natural movement of the user.

### 4.3.3 Embodied facilitation

Embodied facilitation refers to how the configuration of material object and space can make the user interface easier to use.

**Embodied constraints** limits the allowed behaviors in the user interface, thus making it easier to use and limiting the possibility to make mistakes. *Anxiety* is a common problem among elderly people, where they often can be afraid of making mistakes when using interfaces not known to them, as mentioned in section 3.2.5. Ensuring elderly users that they cannot do anything wrong, will make them more confident and explore more of the interface.

**Multiple access points** can in this case give different persons access to user interfaces with different allowed behavior. For example, the elderly may have access to a simple user interface with only the basic functions available, thus also reducing the possibility to make mistakes, as also mentioned in the previous category. If a more advanced function is needed to configure the device, an administrator, or in this case a caretaker or family member, can have access to a more advanced user interface. For example, in systems like GrandCare as mentioned in section 2.1, elderly access the system through a large touch screen, while family members and caretakers can access the system through a web site. This is just one interpretation of this category, the intention as described by Hornecker et al. (2006) focuses on having multiple access points through the same interface to keep individuals of taking control. In the tabletop game by Gamberini et al. (2009), multiple participants have the opportunity to access the interface at the same time using their individual pen to interact with. In this example, the pens can be seen as access points, thus everybody with a pen can access the system.

**Tailored representations** allows the user interface to be tailored to a specific user group, which in this case is elderly. It should build on the users experience, connect with their skills and invite them into interaction. This is an important category for designing for elderly, as it allows us to make a user interface that considers different age impairments. It is not possible to make a user interface that is suitable for everyone. Not everyone get the same age impairments and there are many different levels of declines, in addition to coming from different backgrounds. The healthiest and those most exposed to modern technology of the elderly may want a more advanced interface, and can even get offended by being presented with a very simple interface. On the other hand, we have those who have experienced more severe age impairments and wants an interface that is as simples as possible. This does very much depend the degree of declines in motor control and cognitive functions, but also all other age impairments. There are a few examples mentioned in section 2.2.1. One example is the system presented by Guía et al. (2013) to help Alzheimer patients. A few other examples is the systems presented by Jung et al. (2013), Marques et al. (2011) and Gamberini et al. (2009) to preserve and train cognitive functions.

### 4.3.4 Expressive representation

Expressive representation focuses on how the digital functions and data is represented by physical interaction with objects.

**Representational significance** refers to the interrelation of physical and digital representations, and how users perceive them. It checks if the representations are meaningful and is of long-lasting importance, and if the physical and digital representations are of the same strength and importance. Strong physical representations are important for elderly users, and should be meaningful in a way that it is easy to understand and remember.

**Externalization** lets the user think and talk with or through objects that can be a reference to make it easier to remember how to interact with the user interface. This can aid recognition for elderly users, giving them props to act with to remember steps in the interface. This is especially relevant for those struggling with declines in *working memory* (section 3.2.3).

**Perceived coupling** gives a clear link between what you do in the user interface and what action is triggered, and give a *meaningful representation*. It is important that elderly users see that their physical interaction actually triggers a digital action, to help remember and understand what to do when using such interfaces.

## 4.4 Proposed framework

In this section I present a framework that I have based on the framework presented by Hornecker et al. (2006). I use this framework to categorize different concepts of aging, presented in chapter 3. The concepts of aging are sorted out on different categories of tangible interaction, as discussed in section 4.3, note that some concepts may involve multiple categories. A short description of the health challenge involved with the different concepts of aging is added, in addition to evaluation criteria, describing how the concepts can be evaluated. To further expand the framework, I include concepts from the framework presented by Cho et al. (2013).

The framework by Hornecker et al. (2006) and the framework by Cho et al. (2013) have a few similarities on the most central parts of tangible interaction, like for example *spatial interaction*, *tangible manipulation/manipulation* and *representation/perceived coupling*. Although Hornecker et al. (2006) describes their framework in much greater detail, Cho et al. (2013) have split their framework in two, where the second part is dedicated to elderly users. This part includes several criteria, e.g. *digital literacy*, *simplicity* and *physical and sensory support*, that I want to further empathize the importance of by giving some of them a place in the proposed framework below, see Table 4.1.

Not all of the concepts of aging are relevant for my prototypes that I describe in the later chapters. This includes *endurance*, as I do not have any prototypes requiring prolonged activity (appendix A.1). It also includes *elasticity* and *muscle power*, as no prototypes requires the participants to move around in the environment. *Crystallized intelligence* can be useful for exploiting the look of similar systems that the users know, to help them understand what it is and how it work, but this not used with the prototypes. Also the *accessibility* concept by Cho et al. (2013), is not relevant as it is more useful for understanding more complex systems.

A limitation of the framework is that it requires the reader to have read and understood the framework by Hornecker et al. (2006) to fully understand it. If I had dropped the part of the framework that included parts from Hornecker et al. (2006) it would still be useful, but it would be a more general framework relevant for all design of elderly. Thus the framework by Hornecker et al. (2006) is important in understanding how the different concepts of challenges by aging are relevant in the design of tangible user interfaces, which is the focus of this thesis.

Table 4.1: Framework

| **Hornecker et al. 2006** | **Concept** | **Health challenge** | **Evaluation criteria** |
|---|---|---|---|
| Configurable materials | Flexibility | Reduced range of movement | To what degree is the user able to move and place objects? |
| Configurable materials | Spatial cognition | Reduced ability to represent spatial relationships among objects | Is the user able to place the object in the right form? |
| Lightweight interaction | Fluid intelligence | Reduced capability of processing and reasoning | To what degree is the user able to understand and reason how the system works, and complete the task without further instructions? |
| Configurable materials | Accuracy | Reduced accuracy of movement | To what degree is the user able to accurately place objects? |
| Haptic direct manipulation, Configurable materials | Muscle strength | Declines in strength in different muscle groups | To what degree Is the user able to grab and move objects? |
| Embodied constraints | Anxiety | Afraid to try new things | To what degree is the user able to explore the system? |
| Lightweight interaction | Attention | Reduced ability to ignore interferences | To what degree is the user able to focus on the task? |
| Lightweight interaction | Intuitiveness (Cho et al. 2013) | Reduced fluid intelligence | To what degree is the user able to manipulate the system without a learning process? |
| Lightweight interaction | Digital literacy (Cho et al. 2013) | Reduced fluid intelligence | To what degree is the user able to understand how to interact with the interface? |
| Tailored representation | Simplicity (Cho et al. 2013) | Reduced fluid intelligence | To what degree is the user able to understand the information presented? |

| **Hornecker et al. 2006** | **Concept** | **Health challenge** | **Evaluation criteria** |
|---|---|---|---|
| Embodied constraints | Self control (Cho et al. 2013) | Reduced ability to control system without assistance | Is the user able to control the system? |
| Non-fragmented visibility | Physical and Sensory support (Cho et al. 2013) | Reduced sensory functions | Does the user hear or see what is happening on the interface? |

# Chapter 5

# Methods

In this chapter, I present the design process and the methods used to gather relevant data to help answer the research question, "How can the use of modern technology with tangible user interface assist senior citizens living situation?". First, I look at the philosophical approach and present the design process, before I give a brief description of the empirical context and participants. Then the different methods used for research and design are described.

## 5.1 My philosophical approach

"Philosophical assumptions or a theoretical paradigm about the nature of reality are crucial to understanding the overall perspective from which the study is designed and carried out." (Krauss 2005) Research paradigms is the basic belief system or worldview that guides the researcher in ontologically and epistemologically fundamental ways (Guba et al. 1994). In an interpretive research paradigm the researcher assumes that "knowledge of reality is gained only through social constructions such as language, consciousness, shared meanings, documents, tools, and other artifacts" (Klein et al. 1999). In this research, it is necessary to use qualitative methods providing subjective data to understand senior citizens living situations in order to create tangible user interfaces that can assist them. Scotland (2012) states that "reality is individually constructed; there are as many realities as individuals". All individuals have their own meanings that they assign to a phenomenon. I support this understanding of research, and it therefore lies within the interpretive paradigm.

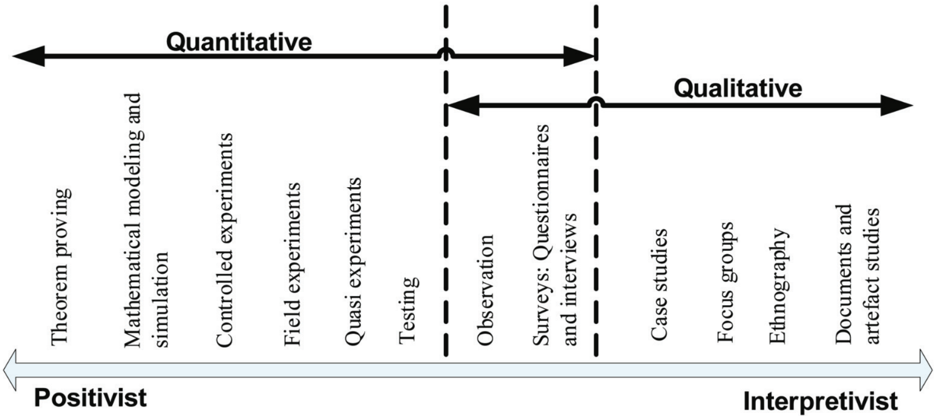


Figure 5.1: Research methods/strategies (De Villiers 2005)

Figure 5.1 shows how different research methods are divided on a positivist-interpretivist axis with an overlap in qualitative and quantitative research. As shown in the Figure, focus groups, ethnography and document studies belongs in the interpretive and qualitative end, while observation and interviews can provide both qualitative and quantitative data. All of these methods provide subjective data and are relevant in answering the research question, e.g. in understanding how elderly users do something, what they struggle with and what they think could be easier. In this study, I try to understand how modern technology with tangible user interface can help senior citizens, and it therefore includes usability testing. This will give different perspectives on how "users perceive and evaluate that system and what meanings the system has for them" (Kaplan et al. 2005). However, in Figure 5.1, testing is located in the quantitative and positivist end. Unlike interpretive researchers, positivists "assume that reality is objectively given and can be described by measurable properties which are independent of the observer (researcher) and his or her instruments" (Myers et al. 1997). Usability testing is a method that can provide qualitative data and quantitative data, in form of metrics that indicate usability.

There are purists that defy the mix of quantitative and qualitative data, while others encourage what they call mixed methods research. This is defined as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (Johnson et al. 2004). This research is more appropriately defined as a mixed methods research, rather than a pure qualitative or quantitative research, hence it lies within the interpretive paradigm with methodical elements from the positivist paradigm.

## 5.2 The design process

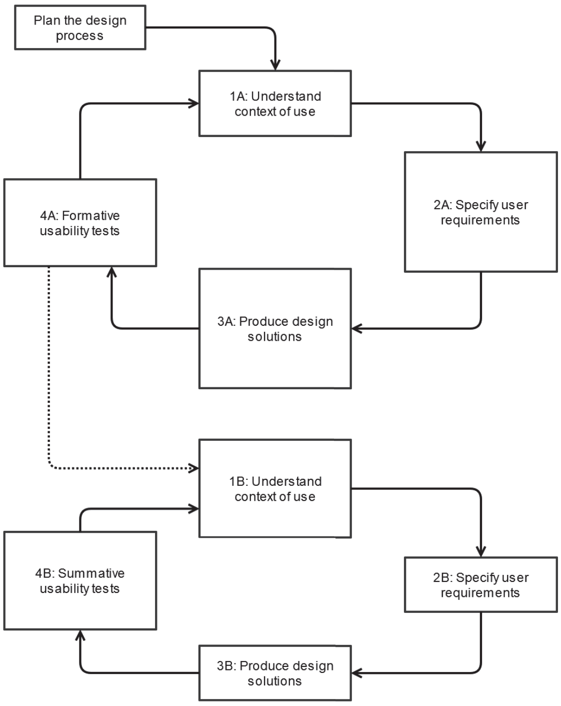


Figure 5.2: The design model. In this project, the dotted line is followed after one iteration in the first cycle.

The design process is based on the model for human-centered design for interactive system ISO 9241-210:2010, and the design model used in this thesis is shown in Figure 5.2. The process started with focus groups (section 5.5.1) to better understand how elderly people related to technology and general problems they faced. Then a thorough literature review (section 5.7.1) was conducted to better understand age impairments and characteristics of tangible user interfaces. Based on the preliminary data, four prototypes were created with a focus on tangibility, simplicity and ease of use. To identify high-level issues of the prototypes (e.g. design flaws that reduce usability), formative usability tests (section 5.6.2) was conducted with expert users (section 5.4.1), which also included semi-structured interviews (section 5.5.1) and observation (section 5.5.2). Figure 5.2 shows two parts or cycles, and this was the end of the first part before I moved to the second part (dotted lines), where only participants in the target group were involved. Workshops (section 5.7.2) focused on designing with elderly users and to let them try different technologies was conducted, before a conference paper (section 5.7.3) was written to help further thinking and development of the thesis. A contextual interview (section 5.5.1) was also conducted to give insight on how assistive technologies were used. A few improvements were done to the prototypes before the summative usability tests were conducted, including semi-structured interviews and observation. The numbers in Figure 5.2, e.g. "2A", correspond with the numbers shown in the Figure 5.3 (methods used in each phase). Primarily only one iteration was conducted in each part of the model, however this is an iterative model that allows us to move back to previous phases to make changes.

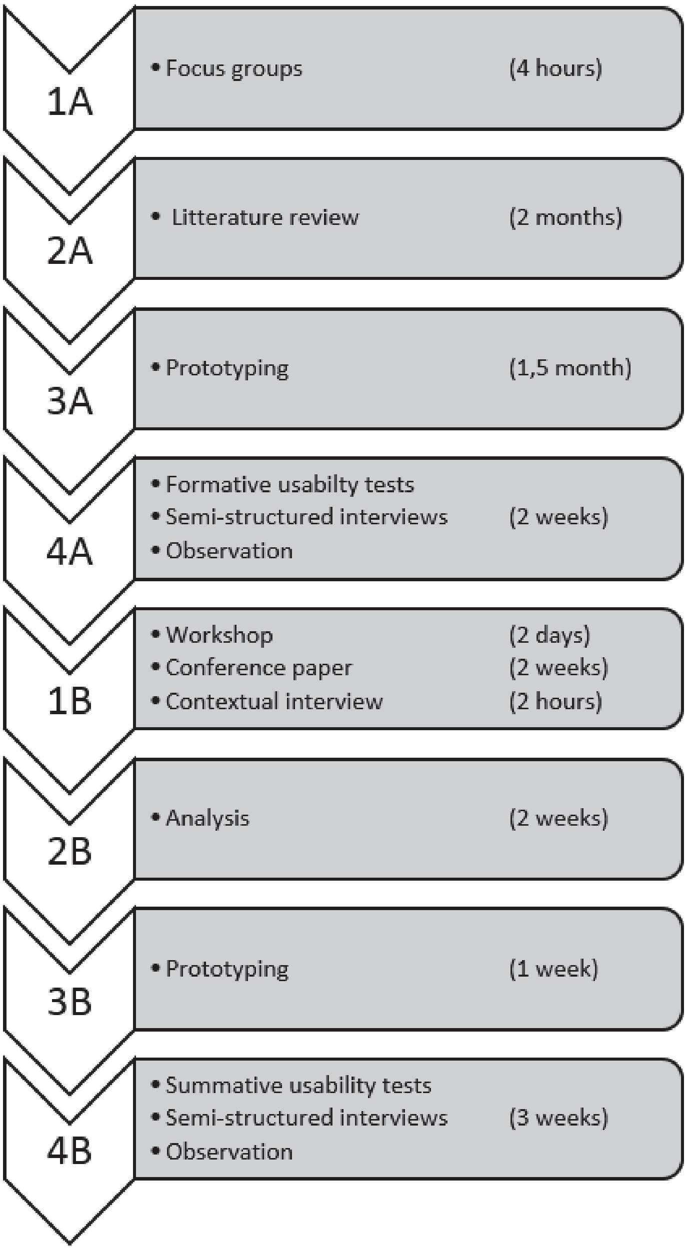


Figure 5.3: Timeline: An overview of activities conducted in the different phases of the design process

## 5.3 Context

This section describes two sites that have been used for research in this project.

### 5.3.1 Research context 1

Research context 1 is a local care home consisting of 91 individual apartments for elderly people, and is organized with a common reception, canteen and recreation room, see Figure 5.5(a). Outside of their apartments, the residents have immediate access to basic services such as hairdressing, foot therapist, gym and cinema, and they have a canteen where they are serving dinner every day. In addition to the canteen, there are several large recreation rooms and a rooftop terrace that the residents can use for social gatherings with neighbors. The local care home has many activities like different cultural events, a library, different hobby activities, religious and belief gatherings and many other events. Spacious modern fitness rooms facilitate physical activity. They serve free coffee each day at 17:00. This is a very important social routine for many the residents. Each Friday someone plays the piano and they can sing along in the canteen. Bingo each Tuesday is also very popular.

#### Residents

The local care home has residents over the age of 67 with greater needs of safety and activity, with an average of 84 years of age. The residents are healthy enough to not need a place at a nursing home, although many of them have some health challenges. They are given ordinary home services on an equal basis with others living in their own homes. Many of the residents are using wheelchairs or walkers to move about with, and some struggle with dementia and other illnesses. To provide extra safety, there is always a householder available to help.

#### Technology

The local care home aims to be a smart house, and each apartment is built to actively utilize technology in order to prolong the period elderly people can remain independent in their own homes before being admitted to a nursing home. Each individual apartment comes pre-installed with a set of new technologies, including automated lighting, heating and ventilation control (Figure 5.4(a)), stove guard, electrical sockets with timers, motion sensors in all rooms and video calling (Figure 5.4(a)). All the residents are offered a personal safety alarm, and all the apartments have automated leading light when it senses movement in the night. The doors to all apartments are featured with locks using radio-frequency identification (RFID), and are unlocked with a credit-card sized card containing a RFID chip. All apartments also have a customized Windows tablet (Figure 5.4(b)), where the residents can see the events program and what the canteen is serving for dinner. The tablet also features the ability to communicate with other residents and the ability to surf the Internet.


(a) (b)

Figure 5.4: 5.4(a) Ventilation control and video calling, and 5.4(b) preinstalled tablet

### 5.3.2 Research context 2

Research context 2 is a local senior center, which is an offer to all over the age of 60, see Figure 5.5(b). Unlike research context 1 (section 5.3.1), this is only a day center where people come to visit. The center has its own authorized podiatrist, hairdressers and they also help with skincare. They have a small library where you can loan books and a canteen where you can buy food. The canteen serves dinner for a small price two days in the week, it is also open other days but only serves sandwiches, pastries and beverages. The senior center is a gathering place where people come to talk and eat. They have training sessions a few times a week and every Friday some of the regular customers gather in the basement for a game of Bridge. The center does not have many employees and depends on volunteers to help.

(a) (b)

Figure 5.5: 5.5(a) Research context 1, photo by Vegard Dønnem Søyseth, 5.5(b) research context 2

### 5.3.3 Exploratory data gathering

To help understand context and get familiar at the research contexts, I have conducted focus groups (section 5.5.1), a contextual interview (section 5.5.1) and observation (section 5.5.2), which I will report some of the findings of in this section.

In the focus groups conducted at research context 2 (section 5.3.2) there were only a few that had used a computer, simply because they had not bothered to try, but it did not mean that they were not interested in trying. If they needed help with anything technological, they had a tendency to ask their sons or daughters for help. Some of the also said that they have a tendency to let their partners use mobile phones and internet, but that become a problem when the partner passes, e.g. one of them recently got his first mobile phone at the age of 82. From observations at both research context 1 (section 5.3.1) and 2 (section 5.3.2), I saw that many had Doro mobile phones which is made specifically for elderly people, however I had to help one of them to add a new number. There were also some that had iPhone and android phones, and one lady that had a small Nokia which she struggled to send a text message with, as the screen and buttons were very small. Another problem was that more and more of the local banks were disappearing, and they felt that were being forced to use online banking.

There was one couple that had one form of assistive technology, a light over the bed that turned on when it detected sounds, e.g. coughing. They also watch a lot of TV, but sometimes problems arises:

> "When I do not know what to do, I just push a few buttons"

There were a few that stood out in their technological use, as for example the 90 year old engineer that participated in the contextual interview (section 5.5.1) at research context 1 (section 5.3.1). He took a course in Windows 95 in 1998. Today he has his own Internet connection that he uses with a laptop running Windows 7, connected with an external monitor, mouse and keyboard. He also has a wireless printer in another room. Although he sometimes gets confused be all the running programs, he is an active user of e-mail and online banking. When he is alone, he uses wireless headphones to listen TV and music, but then he does not hear anything else. Therefore, he has a light under the TV that blinks when someone is at the door or if the phone rings. Other residents at research context 1 have asked him where he got the aids, e.g. light under the TV, which he got from Hjelpemiddelsentralen, a technical aids centre. It takes time and papers to get such aids, and there are many who would have benefited from such aids, but they do not bother because of the process of getting it.

In the usability tests, many liked to talk about the old days, what they have worked with and so on. For example, a 90-year-old civil engineer showed that he had no problem writing down the square root of 2 with 10 decimals. One of the participants had an interesting phrase:

> "I am senile and go to a senior center. It is up to you to judge whether I am demented."

## 5.4 Participants

The selection includes 52 participants. This consists of two user groups, experts as described in section 5.4.1 and elderly users as described in section 5.4.2, which is also the target group. Table 5.1 shows an overview of how the different user groups have participated in the project.

Table 5.1: Overview of participants

| **Group** | **N** | **Methods** |
|---|---|---|
| Experts | 15 | Usability testing, semi-structured interviews, observation |
| Elderly | 37 | Focus groups, workshop, semi-structured interviews, contextual interview, observation |

### 5.4.1 Expert users

I chose a sample of 14 participants to be taken through a formative usability test, although findings from a study by Virzi (1992) states that 80 % of usability problems are detected with four or five participants and that additional participants are less likely to reveal new information. According to this study, five participants should be sufficient, but in another study by Faulkner (2003), the risks of only using five participants are demonstrated. The study shows that five randomly selected participants can find 99 % of the problems, but another set of participants may only find 55 % of the problems. It is therefore safer to increase the sample size to 10 or 20 participants to ensure that most of the problems are found. The participants in our project were mainly people from the HCI community, studying design and interaction, a few studying programming and network and one participant from the electrical engineering community. The formative usability tests also included semi-structured interviews and observation of the tasks in the test. The age of the participants ranged from 24 to 40 years old. The tests were conducted in a controlled environment in a design laboratory at the Departments of Informatics. There were several reasons for involving expert users outside of the target group. Firstly, they are generally easier to recruit than elderly users, making them suitable to help identify important design flaws. Secondly, they have experience in design that may give helpful input in improving the design. Table 5.2 shows a sample of the participants involved, including age, gender and method.

Table 5.2: Sample of the expert participants

| User # | Age | Gender | Method |
|---|---|---|---|
| 1 | 24 | Female | Usability testing |
| 2 | 25 | Male | Usability testing |
| 3 | 23 | Female | Usability testing |
| 4 | 27 | Male | Usability testing |
| 5 | 40 | Male | Usability testing |

### 5.4.2 Elderly people

A sample of 25 participants from the age of 68 to 90 years old was taken through a summative usability test, including semi-structured interviews and observation. A few others were observed outside the test and one participated in a contextual interview. The participants were recruited from two different sites, a local care home and a senior center. Access to both sites was achieved through an email to the general managers. The participants were chosen by asking different persons to participate, without any special requirements other than being of old age. Nine participants were recruited at research context 1 and 16 participants were recruited at research context 2. The participants at research context 1 were in poorer health and harder to recruit than the participants from research context 2, which were mostly healthy. Out of nine participants from research context 1, 5 used walkers and one has had several strokes and used a wheelchair. One of them also had arthritis. Table 5.3 shows a sample of the elderly participants involved, including age, gender, challenges and methods.

Table 5.3: Sample of elderly participants

| User # | Age | Gender | Main challenge | Method | Site |
|---|---|---|---|---|---|
| 1 | 83 | Male | - | Focus groups | Research context 2 |
| 2 | 81 | Female | Mobility | Focus groups | Research context 2 |
| 3 | 85 | Female | Vision | Observation | Research context 2 |
| 4 | 77 | Male | Mobility (wheelchair) | Observation | Research context 1 |
| 5 | 90 | Male | Hearing | Usability testing, contextual interview | Research context 1 |
| 6 | 68 | Female | Arthritis, mobility | Usability testing | Research context 1 |
| 7 | 78 | Female | Mobility, coordination | Usability testing | Research context 1 |
| 8 | 90 | Male | Attention, Understanding technology | Usability testing | Research context 2 |
| 9 | 83 | Male | Vision | Usability testing | Research context 2 |
| 10 | 84 | Female | Anxiety | Usability testing | Research context 2 |

## 5.5 Data gathering

Research methods are important to build an understanding of the needs, practices, concerns, preferences, and attitudes of the people who might interact with a system (Lazar et al. 2010, p. 180). This section describes the research methods relevant for the interpretive paradigm that is used to collect data in this project.

### 5.5.1 Interview

Interviews can be divided into four main types: open-ended, structured, semi-structured and group interviews (Preece et al. 2002, p. 390). In this section, I will focus on semi-structured and group interviews to broaden the understanding of design and the mentality of elderly people, providing subjective data to be interpreted in regard of the chosen paradigm. I will also look at contextual interviews for a closer understanding of the elderly peoples living situation.

#### Semi-structured interviews

As a part of the usability tests, short semi-structured interviews were conducted in the formative and summative tests to help evaluate the design (Lazar et al. 2010, p. 192). The reason for choosing semi-structured interviews was to have a set of questions that could provide comparable data and still be able to deviate from these questions to provide a broader or deeper understanding. Veldhoven et al. (2008) and Mannapperuma (2010) both showed that a post-test interview can provide valuable information of how the users percept the design and how they experienced the usability of the prototype. Criel et al. (2011) also conducted a interview after the test which showed to what degree the users were able to grasp the concept and how they found the process of using their prototype. In our formative usability tests, the participants were asked more thoroughly questions about the design than in the summative evaluation. This was done to find flaws in the prototype, understand the users preferences and give better insight for further improvements of the design. In the summative usability tests, the participants were asked questions regarding the usability of the prototypes to better understand how they understood the concepts and how easy they were to interact with. This would also help to understand evaluation criteria's in the framework (section 4.4), regarding *fluid intelligence*, *anxiety*, *intuitiveness*, *simplicity* and other criteria not revealed from observation.

#### Group interviews

Group interviews or focus groups typically involve three to 10 people (Preece et al. 2002, p. 396). Although there are different opinions on the size of the focus group. Some suggest between eight and 12 people, while others suggest that five to seven people is more appropriate (Lazar et al. 2010, p. 192).

Wu et al. (2012) conducted a focus group study with multiple caregivers of elderly people, were elderly's habits of using computers were discussed. This is similar to what's done in this thesis, but the participants were elderly people. I conducted two focus group sessions with a total of eight participants in the initial exploration phase. This was done primarily to help choose a topic for further exploration in another school subject, INF5722 - "Experimental design of IT", but it was also done to understand context and requirements when designing for elderly users regarding this thesis. Another reason for choosing focus groups was to see if there were any disagreements that could possibly give a broader understanding of the topic, than it would from a group in total agreement with each other. The interviewees were asked about their use of technology, what they struggled with and what they thought could be better. The result is relevant for understanding some evaluation criteria in the framework (section 4.4), regarding *fluid intelligence*, *anxiety* and *digital literacy*.

#### Contextual interviews

A contextual interview is a combination of observation, discussion and reconstruction of past events. It has four main principles: context, partnership, interpretation and focus (Preece et al. 2002, p. 298). This means that the interview should be conducted in a relevant context, e.g. home or workplace, and the interviewer and interviewee should collaborate to understand the work. Observations must be interpreted and the interview should be kept relevant for the design being developed. The interviewer can ask the interviewee to demonstrate how they solve a problem, rather than explaining how they do it (Lazar et al. 2010, p. 191).

Observations were conducted at the research sites where the context is senior center or local care home, similar to the contextual observation by Wu et al. (2012) where the elderly's daily activities was observed at an elderly home, that is however covered by section 5.5.2. I conducted one contextual interview at an apartment at research site 1, where the use of technology was the topic of the interview. This was done to help understand the use of technology at home and how they can make their daily life easier. This help to understand *fluid intelligence*, *anxiety*, *accessibility*, *self control*, and *physical and sensory support*, from the framework (section 4.4).

### 5.5.2 Observation

Observation is a research method that involves watching and listening to people. Observing users interacting with technology, objects or just the way they move can give us a large amount of information about them. It can, e.g. tell you something about what they do, the context in which they do it, how well technology supports them and what other support that is needed. Observation can be used in a laboratory setting or in the field, the natural environment which a product is used (Preece et al. 2002, p. 359). In usability testing, observation is used to understand what challenges the users are having with a product (Lazar et al. 2010, p. 228). Observation can be useful at any time during product development, e.g. it can be useful early in the design process to help understand the user's needs.

Observations were primarily conducted in conjunction with usability testing. Häikiö et al. (2007) showed that observations during test sessions could provide valuable information of how the users adopt the technology, how they learned to use it, and what kind of problems they had. This is also evident in observations by Marques et al. (2011) where they observed how older adults interacted with a tabletop prototype. Rice et al. (2008) used observations to find noticeable differences between what the users said they preferred compared to what they actually could do. Observations is also useful when not used in usability testing, e.g. Al Mahmud et al. (2008) used observations to understand how elderly people behaved when playing card games. In this thesis, I used observations to understand problems and how easy the prototypes were to use during usability testing. However, observations were also conducted during focus groups and by just being at the research sites watching how elderly people moved around and interacted with technology. Observations can help to understand some evaluation criteria in the framework (section 4.4), regarding *flexibility*, *spatial cognition*, *accuracy*, *muscle strength and power*, *attention*, *accessibility* and *self control*.

## 5.6 Design methods

I have used some methods to help design, evaluate and test our solutions.

### 5.6.1 Prototyping

A prototype can be anything from a paper-based outline of system to a complex piece of software. It allow users to interact with an envisioned product, let them try it in a realistic setting and explore imagined uses (Preece et al. 2002, p. 240-241). I differentiate between two types of prototypes, low- and high-fidelity prototypes. In this thesis, only high-fidelity prototypes have been used, which uses materials to be expected in a finished product and features a working system (Preece et al. 2002, p. 245). The reason for this is that it was important to know that it was possible to make a working system with the envisioned features, as it would be easier to understand and interact with by elderly participants.

During this study, I have developed three prototypes, in addition to a fourth consisting of different commercially available products. The prototypes are more thoroughly described in chapter 6, 7, 8 and 9. All of the prototypes have been taken through formative and summative evaluations. The prototypes aim to be very simple to use and compensate for most of the health challenges described in the framework (section 4.4).

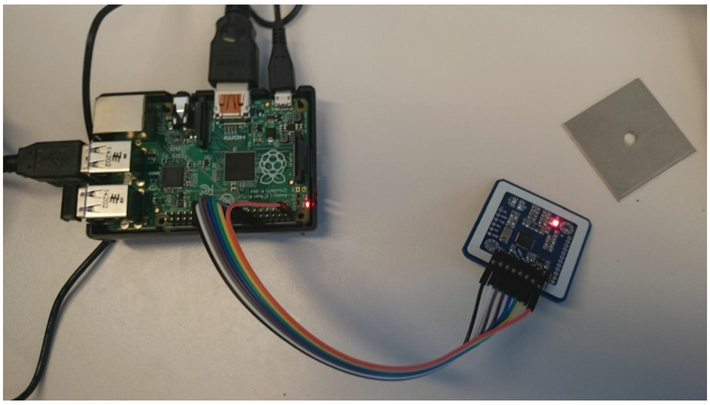


Figure 5.6: Prototyping

### 5.6.2 Usability testing

A part of the design process is to see if a prototype actually is a solution to a problem and to find out if it is easy to use; To do this I use usability testing, a technique used to evaluate a product by testing it on users. According to Dumas et al. (2007), a valid usability test has the following six characteristics: (1) the focus in on usability, (2) the participants are end users or potential end users, (3) there is a product or system to evaluate, (4) the participants perform tasks while thinking out loud, (5) the data are recorded and analyzed and (6) the results of the test are communicated to appropriate audiences.

In my tests of the prototypes, it was useful and necessary to conduct both a formative and a summative usability test, to be able to fix any flaws the prototype might have. Sax et al. (2009) conducted usability tests that showed that their basic concept was successful, but that there was some usability issues that should be fixed in the next prototype, which emphasizes the importance of usability testing. Gamberini et al. (2009) conducted usability tests with target users and with experts, which is what I have done in this thesis. I conducted the formative usability tests with expert users, which is not in line with one of the characteristics of usability testing, as these participants are not end users or potential end users. The reason for not using potential end users in the formative evaluation is that the target group is elderly users, which are more difficult to recruit. However, Lazar et al. (2010, p. 256) states that expert-based testing can be useful to find the most obvious interface flaws, but that these test should always come before user-based tests. The formative tests were therefore done with users outside of the target group, and included exploratory and assessments tests. The goal of these tests were to help to find out what is good and bad design, and to identify high-level issues and be able to correct some of these issues before conducting tests with the potential users, as shown in Figure 5.7(a), see test plan in appendix B. The tests aim at finding usability problems rather than to evaluate the overall usability of the product (Dumas et al. 2007). Veldhoven et al. (2008) states that low acceptability of new technology by elderly users might be partially caused by usability problems, which reinforces our reason for testing with expert users first.

(a) Formative test

(b) Summative test

Figure 5.7: 5.7(a) Formative usability test, 5.7(b) summative usability test

The formative usability tests in this project were conducted using a high-fidelity prototype. Summative usability tests were conducted using improved high-fidelity prototypes based on the feedback from the first tests. While the formative usability tests involved qualitative data consistent with the interpretive paradigm, the summative usability tests also involved quantitative data, see test plan in appendix B. This is testing, which is a known method in the positivist paradigm. I conducted the summative tests with potential end user to find out how usable the product was, as shown in Figure 5.7(b). This included validation or verification tests where the goal of these tests were to evaluate usability metrics, e.g. time on task and mistakes, and use these quantitative data to check if the products meets the usability requirements (Dumas et al. 2007). Comparison tests were done on one of the prototypes in both the formative and the summative tests. Usability tests help us understand how age impairments limit a person's ability to interact with the prototypes and if the prototypes compensate for these problems. The tests help us understand all of the evaluation criteria presented in the framework (section 4.4), although some terms like *endurance*, *elasticity* and *muscle power* are less relevant for some prototypes as these require physical movement of the body.

## 5.7 Other methods

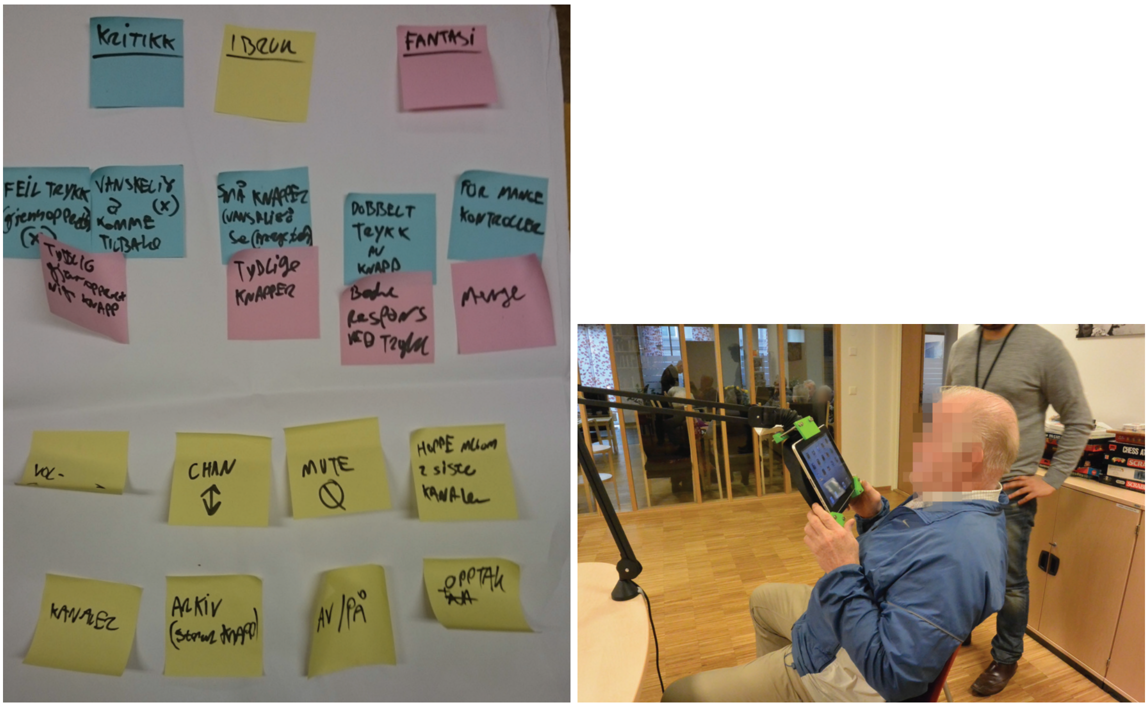
This section describes methods used in a supportive way, but requires less description either because they take a small part in this project or because the method is generally well understood.

### 5.7.1 Literature review

Literature review is an essential feature of any academic project (Webster et al. 2002). It is used to review prior and relevant work to create a foundation for further research. This was used to give an overview of related work in chapter 2. It was also used to better understand age impairments in chapter 3, and to understand what tangible interaction is in chapter 4.

### 5.7.2 Workshop

Future workshops are used for participatory and organizational development (Löwgren et al. 2004, ch. 4.2). When doing a future workshop the users want to clarify the common problems in a current situation, visionate about the future and discuss how to realize these visions. Two small workshops with one participant each time have been conducted. The first one was in conjunction with a school subject, INF5722 - "Experimental design of IT" at research context 2, where the functionality and the look of remote controls were explored. The second workshop was done in collaboration with my supervisor at research context 1, where new technologies were explored in conjunction with an elderly participant. The participant tried different technologies in collaboration with us, e.g. Google glass, Lumo posture corrector, moveable arm for tablets, and wireless charging of a tablet. A pneumatic hand dynamometer was also used to measure grip strength.



(a)

(b)

Figure 5.8: 5.8(a) Results from workshop at research context 2, 5.8(b) workshop at research context 1

### 5.7.3 Conference paper

In collaboration with my supervisor, a conference paper for the 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) was written. This was written based on prototypes created and results from the formative usability tests. In the paper, the different prototypes are categorized within the theme of spatial interaction from the framework by Hornecker et al. (2006), with the goal of discussing how we can explore the spatiality of tangible interaction during prototyping. The different categories of spatial interaction proved to be useful metrics in analyzing the results from the usability tests. A few of the challenges discussed involve the compensation for age impairments, and finding the right configuration when there is a high level of subjectivity in the preferences of the spatial reconfiguration. The writing of the paper helped to further improvements of the thesis, and it resulted in texts that could be used directly in this thesis. The full paper can be read in appendix C.

## 5.8 Data processing

All data was collected in a collection sheet, this included notes from observations, participant's thoughts when thinking aloud and answers to questions asked. At the end of each session, the handwritten data was transferred into a document file on a computer. No person identifying information was in this document and it was stored only with a participant number. The data from all the participants were put together and sorted out on each prototype. The data was then further sorted on different parts of the prototype, dividing the data into different categories to give a better overview. Quantitative data gathered from the tests were put in tables.

## 5.9 Ethical considerations

The research project was reported to the Data Protection Official for Research (Personvernombudet for forskning). All participants were asked to read and sign an informed consent, this was to help them understand the aim of this study and to get their permission to take pictures, see appendix B. There was no need to collect personal data, but pictures of participants testing the prototypes were preferred. Pictures that show people's faces are considered person identifiable information, and were censored. Pictures and test sheets were only stored with a participant number. A sheet connecting participant names to participant numbers were kept in a safe place.

# Chapter 6

# T-Radio

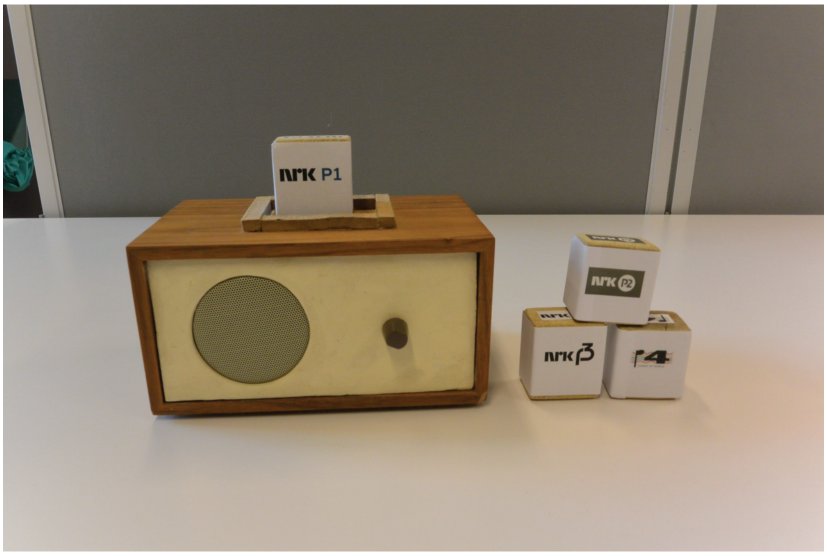


Figure 6.1: Final prototype of T-Radio

## 6.1 The prototype

### 6.1.1 Idea

The goal was to make a radio that can be controlled by tangible blocks. The desired functionality is to have multiple blocks, each representing a radio channel. When a block is placed on a marked area on top of the radio, the radio channel represented by the block starts playing. When the block is removed from the radio, the playback of the radio channel stops. The design idea is to simplify the required interaction from elderly people who want to listen to the radio by removing small buttons and difficult frequency sliders, see Figure 6.1.

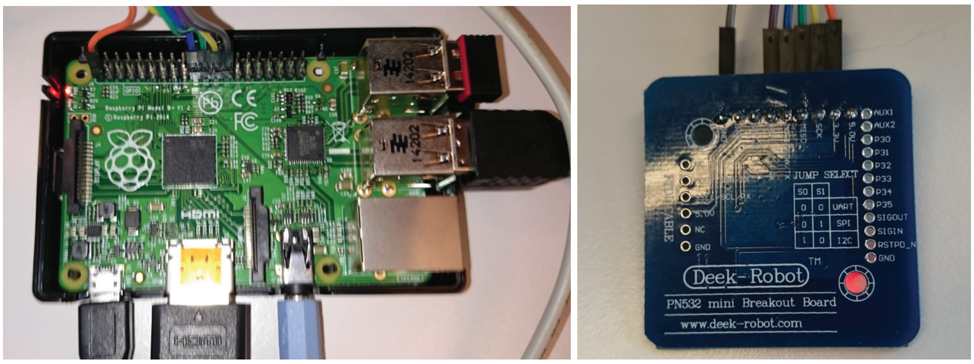
### Purpose

The purpose of the T-Radio is to show an example of how a roughly finished product can make things easier for elderly people by introducing new interactions by using a tangible user interface.

### 6.1.2 Technology

To achieve the desired functionality, a NFC reader accompanied by multiple NFC tags is used. The reader is placed near the top of the radio and the NFC tags are under the blocks. NFC has the ability to check if a tag is present on the reader and is therefore suitable for this prototype. To create this radio I used the following components:

- Raspberry Pi Model B+[1]
- Micro-SD memory card
- Wifi USB dongle
- PN532 RFID/NFC card reader
- NFC tags
- Small amplifier
- Loudspeaker
- Building materials to create a box



(a) (b)

Figure 6.2: 6.2(a) Raspberry Pi, 6.2(b) PN532 RFID/NFC reader.

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[1] `http://www.raspberrypi.org/products/model-b-plus/`

### 6.1.3 First Prototype

The first prototype that I created used Java as the programming language to get input from an Arduino with a NFC card reader (Figure 6.3(a)) using a suitable library [2] to ease the programming of the Arduino. Each NFC tag has a unique identification number (UID), and the UID of four different NFC tags were programmed in a Radio class in Java with different radio streams attached. When a NFC tag was held over the NFC card reader, the UID was read and a list was searched through to look for the matching UID. When a matching UID was found, a radio stream was played corresponding to the UID. The stream was played through Music Player Daemon (MPD) [3] controlled by by JavaMPD library [4]. The problem with this prototype was that is was not possible to keep the NFC tag over the reader while the radio channel was playing, because the stream would just reset and eventually the NFC reader would stop reading. Several attempts were made to try to get the desired function to work; The function being to play a radio stream as long as the NFC tag is present on the reader, and to stop playing when the NFC tag is removed. This did not work because of limitations in the Arduino library of the NFC card reader.

### 6.1.4 Second Prototype

The second prototype that I created, used a Raspberry Pi with a NFC card reader directly connected to its General Purpose Input Output (GPIO) pins. To control the NFC reader, a library called libNFC [5] was used. This is a more established library that has been under development since 2009. This library has its own method to check if a NFC tag is present and therefore allowed for some code to be executed while the tag was present. Also in this prototype, Music Player Daemon (MPD) was used to play radio streams. The libNFC library is written in the programming language C and therefore the C library, libmpdclient [6] was used to control playback in MPD. This prototype worked by checking for any NFC tags near the NFC reader, if a tag was present, the UID of tag was read and a list was searched through to find a matching UID with a corresponding radio stream. Then a radio stream was played using MPD, and if the tag were removed, the playback of the radio stream would stop. This prototype used a radio box from another project to be used as amplifier and loudspeaker, while the Raspberry Pi was lying behind the box, and the NFC reader was placed on top of

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[2] `https://github.com/Seeed-Studio/PN532`

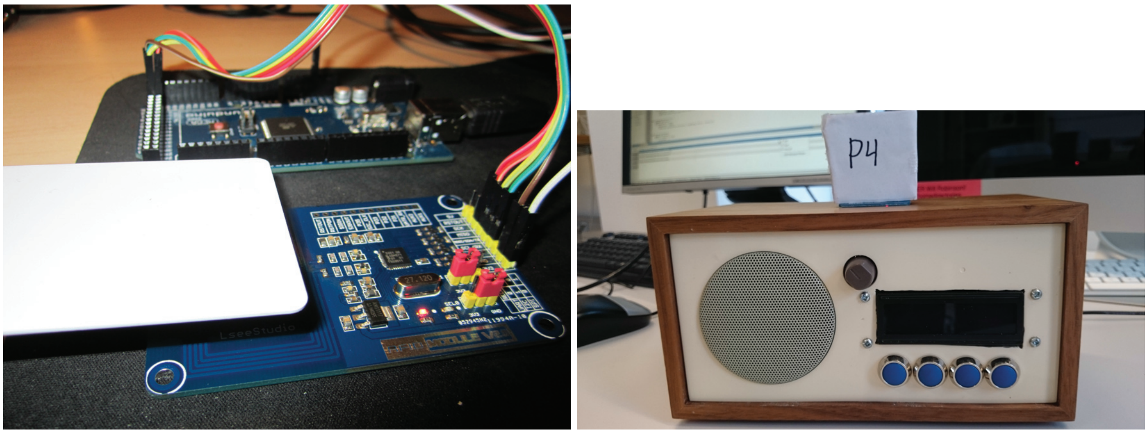
[3] `http://www.musicpd.org/`

[4] `https://github.com/billf5293/javampd`

[5] `https://bintray.com/nfc-tools/sources/libnfc`

[6] `https://github.com/cmende/libmpdclient`

box, as shown in Figure 6.3(b). Wooden blocks were created with textual writing of which radio channel it represented, and each block had a small NFC tag glued to the bottom. These NFC tags made it possible for the NFC reader to read which radio channel each block represented. This prototype was used in the formative usability tests.



(a) (b)

Figure 6.3: 6.3(a) the first prototype of T-Radio, 6.3(b) the second prototype of T-Radio.

### 6.1.5 Changes after usability testing

After the formative usability testing, I decided to make a few visual changes to the prototype to try to make it easier to understand how it worked. The same box was used, but a new front and back was made. The new front was made simpler, without any buttons or screen, as this was not relevant for the functions of the radio, and results from usability testing showed that this was not necessary. It only had a loudspeaker and volume adjustment. The Raspberry Pi was now fitted inside the box with the NFC reader in the ceiling, as this was strong enough to communicate with the blocks through the box. The back cover contained a on/off switch, holes for usb and hdmi cables and a single power socket. A step-down converter was used to convert 12 volt input to 5 volt for the Raspberry Pi, as the amplifier needed 12 volt. On the top of the box, a simple frame was glued to it to show were the block should be placed. New wooden blocks were also created, in approximately the same size as the old ones. Compared to the old ones, the new blocks were more cleanly cut and sanded down. They also had new stickers with the radio channels logo on them. Figure 6.1 show the prototype used in the summative usability tests.

### 6.1.6 Compensation of age impairments

Elderly people suffering from decline in fine motor skills have reduced *accuracy* and struggle to fidget with smaller buttons and fine-tuning mechanisms. Remembering and adjusting frequencies require *fluid intelligence* beyond the active capabilities of many of the elderly people within our empirical context. As the analogue FM broadcasting is scheduled to be phased out of operation within 2017, in favor of Digital Audio Broadcasting (DAB), operating a radio will require even further cognitive capacity as users will have to learn new frequencies to find their favorite channels. Many current commercial radios have too small print or screen text for elderly people suffering from reduced *sensory* functions to read, thus I remove the need for buttons and screens, and provide a radio that only requires physical configuration of a wooden block to function, with focus on *intuitiveness* and *simplicity*.

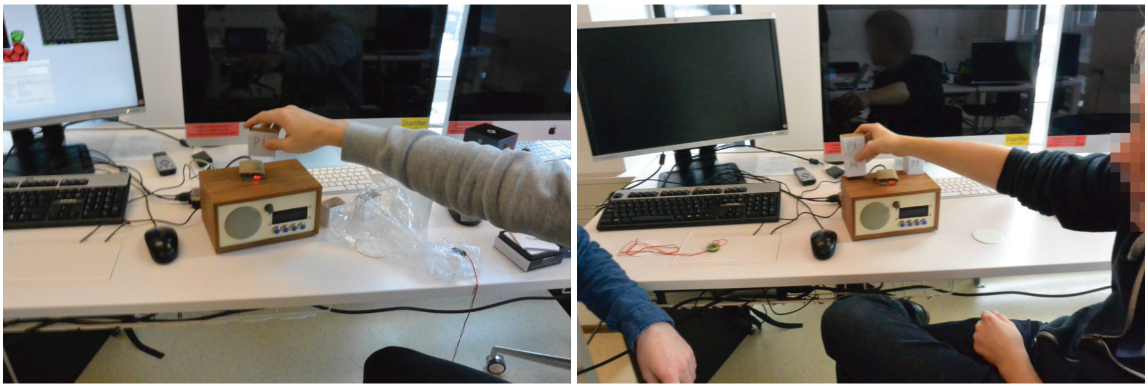
## 6.2 Formative usability tests

This section reports the results from the formative usability test (section 5.6.2) of the T-Radio, with expert users (section 5.4.1). The formative usability testing of the T-radio, involved testing of how participants understood what the prototype was, and their thoughts about elements such as screen and buttons. It also involved thoughts about materials used and where and how they would place the block representing the radio channel. This was tested to understand which interactions seemed natural and to provide design implications for further improvement of the prototype, with regard to simplicity. The participants preferences are shown in Table 6.1. The table shows whether the participants wanted screen and buttons, their preferred materials of box and blocks, where they would prefer to place the block to play a channel, and how this area should be marked.

Most of the participants understood that it was a radio and tried different channels with success, see Figure 6.4. There were a few who did not understand that it was a radio, where one participants thought it was a answering machine, while another got confused by the text on the blocks and suggested to clarify this to text to better indicate that it was radio channels. A few participants tried to first place a block on a round metal piece on the table, while another tried to place a block next to the reader on the radio, but this was an intended mistake.

Table 6.1: Expert users preferences on T-radio

| User # | Screen | Buttons | Material | Material of block | Placement of block | Marking of placement |
|---|---|---|---|---|---|---|
| 1 | No | No | Wood | Same as box | Top | Frame |
| 2 | Yes | Hidden | Wood | Ok | Middle on top | Inset |
| 3 | No | No | Wood | Same as box | In front on top | Inset |
| 4 | No | No | Wood | Same as box | Top | Inset with text |
| 5 | No | No | Wood | Same as box | Top | Podium with inset |
| 6 | No | Yes | Wood | Ok | Middle on top | Inset |
| 7 | No | No | Wood | Smaller | Top | Something steady |
| 8 | No | No | - | - | Top | Marking |
| 9 | No | No | - | - | Down on top, tilt up to play | Marking |
| 10 | No | No | - | - | Anywhere on top | Marking |
| 11 | No | No | - | - | Top | Inset |
| 12 | No | No | - | - | Top | Marking with diodes |
| 13 | No | No | - | - | Anywhere on top | Marking |
| 14 | No | No | - | - | Top | Marking with colors |



(a) (b)

Figure 6.4: 6.4(a) and 6.4(b) shows different expert users testing T-radio.

### The Block

Multiple participants thought that the blocks should match the material on the box (Table 6.1) to make it easier to understand that they belong together. Nevertheless, it should be possible to distinguish between the box and the block. It was important the blocks would not be too light and that they were sturdy so the users would not be afraid to break them. Multiple participants mentioned that it should be easier to read what channel the block represented, either by providing the full name of the radio channel, use their logo or even make block look like small radios. A possible problem would arise if you lost a block, as you would also lose a radio channel. To make this a less likely scenario it was suggested to make the blocks more visible on a messy floor and should therefore not be white, and it should be visible for those who are colorblind.

### Placement of the block

All participants agreed that it should be better explained or indicated where to place the block, preferably with some text "Place here" or a special shape that matches the block. Table 6.1 shows where the different participants preferred to place the block and how the area should be marked. All the participants preferred to have the block and reader placed on the top and it was mentioned that this was the most attractive. Most agreed that the reader should be placed in the middle on the top, but a few also suggested to have it a little more to the front to make room to store remaining blocks at the back or to work more like a docking station for iPod. Two participants suggested that in a final version of the product, it should be possible to place the block anywhere on the top to make it play. This was said to be helpful for elderly users struggling with tremors. It was important that the block stand steady and therefore needed something to hold it in place. There were many suggestions for marking where to place the block, including a small frame, inset, podium, marking with text, magnets and diodes that changed color depending on the presence of the block.

### Functionality

Most of the participants said that volume adjustment alone was enough, and that buttons or a screen were unnecessary (Table 6.1). However, some wanted buttons and screen. One participant preferred a small screen, another said that this was unnecessary and that one could see which radio channel was playing by looking at the block. Another participant mentioned that many had grown up with buttons and that this was something they were used to, and thought that it would be good to have those as well. A few test participants tried to distinguish between elderly users and users that are more advanced and argued that a volume adjustment was enough for elderly, but that they personally would want functionality that is more advanced. It was important that volume adjustment and any other switches were large and easy to see, preferably with strong colors and contrasts on the radio. A small led light to indicate if the radio was turned on was missing. Some of the participants also mentioned that more radio channels should be provided and that the maximum volume was a little low. It was commented that it did not look so great on the top, but that it worked well. It was also mentioned that it should be functional, but discreet.

## 6.3 Summative usability test

This section presents the results from usability test (section 5.6.2), with elderly users (section 5.4.2). The summative usability testing of T-Radio, involved showing the participants the radio box and the blocks, and asking them to try to put on a channel without telling them how, as seen in Figure 6.5. Table 6.2 shows the age of all of the participants, time used to turn on a channel and the number of mistakes made.

Table 6.2: Summative evaluation of T-Radio

| User # | Age | Time to turn on channel (seconds) | Mistakes |
|---|---|---|---|
| 1 | 68 | 3 | 0 |
| 2 | 79 | 2 | 0 |
| 3 | 74 | 3 | 0 |
| 4 | 83 | 20 | 1 |
| 5 | 82 | - | - |
| 6 | 78 | 3 | 0 |
| 7 | 75 | 7 | 0 |
| 8 | 90 | 3 | 0 |
| 9 | 75 | 4 | 0 |
| 10 | 90 | 3 | 0 |
| 11 | 83 | 2 | 0 |
| 12 | 76 | 5 | 0 |
| 13 | 77 | 2 | 0 |
| 14 | 71 | 2 | 0 |
| 15 | 74 | 2 | 0 |
| 16 | 68 | 3 | 0 |
| 17 | 79 | 11 | 0 |
| 18 | 70 | 7 | 1 |
| 19 | 84 | 21 | 0 |

| User # | Age | Time to turn on channel (seconds) | Mistakes |
|---|---|---|---|
| 20 | 81 | 4 | 0 |
| 21 | 73 | 9 | 1 |
| 22 | 75 | 5 | 0 |
| 23 | 82 | 12 | 1 |
| 24 | 75 | 4 | 0 |
| 25 | 83 | 3 | 0 |

(a) (b)

Figure 6.5: 6.5(a) and 6.5(b) shows participants trying the T-Radio.

Most of the participants did not have any problems in understanding how to use this radio and the placed the block on the marked area, a few participants did however make a mistake (Table 6.2). A few participants did not understand how to use it at first and studied the radio trying to work out how to use it; this is evident in the table. One participant expressed that he thought it was a little hard to understand how it worked, but when he first got it to work, it was very easy to use. There were big differences in how the participants explored the interface of the radio. Most participants grabbed a block and looked at the radio to try to understand where to place it. However, one of the participants did not look so much on the blocks and concentrated more on the box. He tried the volume and felt his way to the back of the radio where he managed to turn the whole radio off. He then asked:

> "Where is the tuner?"

One participant wondered where the receiver was, while another kept saying:

> "I don't understand anything"

He was then referring to the technology. One of the participants had arthritis, which made the fingers to not cooperate, but this was no obstacle for using this prototype. This particular participant called it a smart solution and liked the large font on the blocks. Overall, the radio seemed to be well understood, and multiple participants said that it was easy to use. Other comments included:

> "So it's just to put it on", "fun solution" and "beautiful"

Most of the participants often listened to radio and the most prominent problem was to find the channel they wanted. One participant called both FM and DAB hopeless (appendix D.2.1).

## 6.4 Analysis

In this section I analyze the results from the summative usability test by using the proposed framework (section 4.4).

### 6.4.1 Mistakes

In the summative evaluation of the T-Radio, there were four participants that made a mistake (Table 6.2), meaning that they placed the block next to the frame rather than inside it, and caused their time on the task to increase. While the reason for this mistake is unknown, I can use our proposed framework (section 4.4) to try to understand it. It can for example be caused by declines in *spatial cognition*, making it less obvious that the block should be inside the frame. It can also be caused by reduced *fluid intelligence*; it is important to note that there is not enough data to make such an assumption. On the other hand, the interface might not have been *intuitive* enough. This seems unlikely since the 20 other participants did not have this problem. The participants did not seem to be struggling with shaking hands and loss of *self control* or *accuracy*.

### 6.4.2 Time on task

The average time to turn on a channel on the T-Radio was 5.8 seconds, with 17 participants using 5 seconds or less, as seen in Table 6.2. Four participants did standout, using more than 10 seconds, with two of them using 20 seconds or more. A few did look around carefully before placing the block, making sure they placed it right, which may be one reason for the long time used by some. It can also be affected by declines in *fluid intelligence*. The participants who used 20 seconds or more seemed less focused on the task, indicating that *attention* is a factor to be considered. However, the test with these two participants were done in pairs, where two people participated in the usability test together, which also can be a factor for their loss of focus. Another user who seemed absentminded did however only use 3 seconds to complete the task. Mobility, referring to the use of wheelchairs and walkers to move around, and other diseases like arthritis did not seem to affect the time on task. Age did not seem to be crucial factor, with two participants at 90 years completing the task in 3 seconds. The participants that used the longest time were however in their 80s.

### 6.4.3 Statistical analysis

In this section, I compare the results of testing the T-Radio from the two research contexts to see whether there are significant differences when between the research contexts, where Table 6.3 shows the results divided by research context. To find whether there are significant differences, I use a one-tailed t-test.

Table 6.3: Turn on channel on T-Radio, divided by research context

| | **Time on task** | |
|---|---|---|
| **Participants** | **Research Context 1** | **Research context 2** |
| 1 | 3 | 3 |
| 2 | 2 | 2 |
| 3 | 3 | 5 |
| 4 | 20 | 2 |
| 5 | 3 | 2 |
| 6 | 7 | 2 |
| 7 | 3 | 3 |
| 8 | 4 | 11 |
| 9 | - | 7 |
| 10 | - | 21 |
| 11 | - | 4 |
| 12 | - | 9 |
| 13 | - | 5 |
| 14 | - | 12 |
| 15 | - | 4 |
| 16 | - | 3 |

Table 6.4: Radio t test

| | Time on task | |
|---|---|---|
| | **Research Context 1** | **Research context 2** |
| Mean | 5,625 | 5,9375 |
| Variance | 35,9821 | 26,4625 |
| Observations | 8 | 16 |

| | |
|---|---|
| Hypothesized Mean Difference | 0 |
| df | 12 |
| t Stat | 0,1260 |
| P(T<=t) one-tail | 0,4509 |
| t Critical one-tail | 1,7823 |
| P(T<=t) two-tail | 0,9018 |
| t Critical two-tail | 2,1788 |

Table 6.4 shows the results from the t test, where I used a 95 % confidence interval, where the difference is significant with $p<0.05$. Although Table 6.4 show the full results from the t test, the most important is the value of P(T<=t) two-tail, which in this case is 0.9018 and is greater than 0.05, thus the difference between the two groups is not significant.

### 6.4.4 Comparing to another project

In another project at the Department of Informatics at the University of Oslo, a radio designed for elderly was also created (Johnsson et al. 2013). They tested it with five participants how long it took them to find their favorite channel; the result was an average of 1 second. In our test, with 24 participants the average time used to turn on a channel was 5.8 seconds. There are however big differences in sample size and some participants who stands out, as seen in Table 6.3. In addition, there is a question of how accurate the measurements were. I conducted the tests alone and can't say that the measures were absolutely accurate. They are however a good indication. The other project by Johnsson et al. (2013), also measured time on task on two commercially available DAB radios, with 42 and 52 seconds in average to find their favorite channel in the first group, and 38 and 27 seconds in the second group. If I compare our average of 5.8 seconds to these results, the difference is significant, although their report does not give us enough data to use a t-test.

# Chapter 7

# Payless

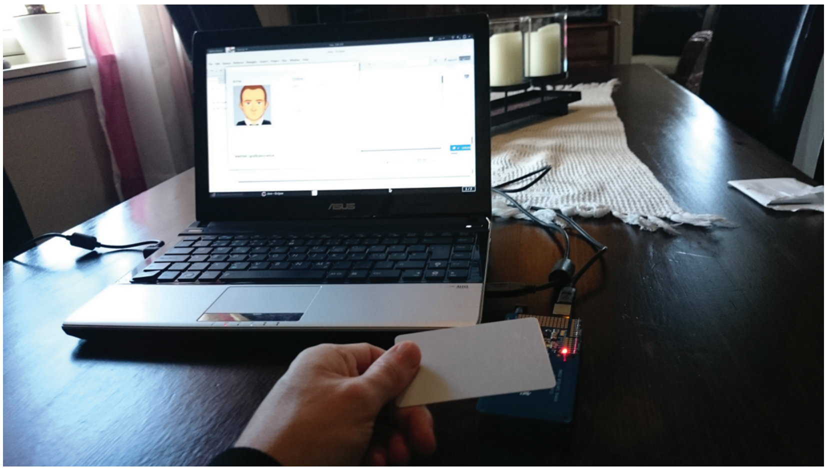


Figure 7.1: Final prototype of Payless

## 7.1 The prototype

### 7.1.1 Idea

As mentioned in section 5.3.1, residents at research context 1 are using RFID key cards to unlock the door to their apartments. The idea of this prototype is to extend the use of their personal RFID key card with payment functionalities. I want to extend the functions of this card; they carry their card with them at all times. Currently they have to pay per meal in the canteen, and pay for other services they use within research context 1 (like hairdresser, foot therapy and trainer). I want to use this personal RFID key card to let them pay for these services, focusing on the canteen, without the use of credit cards or cash. The advantage of using this card is that it does not introduce a completely new way of interaction, as they already use this card to open the door to their apartment. The idea is that all of the use of this card for payment, adds to bill of the monthly residential rent. Safety is ensured by having the key card display an image of the user behind the cashier's desk, and the cashier can verify their identity before approving the purchase. A screen is also visible for the users to verify the amount before scanning their RFID key card at the cashier's desk for moneyless purchase.

#### Purpose

The purpose of this prototype is to explore alternative design solutions, and not to provide a finished design. The focus is on finding a solution that compensates for challenges the elderly have with the way they pay for services today, by using tangible user interfaces.

### 7.1.2 Technology

As the key cards to unlock the door to the apartments at research context 1 (section 5.3.1), already use RFID, I will continue using this technology with the help of an Arduino Uno with a RFID shield connected to a computer. The prototype uses the following components:

- Arduino UNO[1]
- PN532 RFID/NFC card reader
- RFID/NFC cards
- Graphic user interface showing picture, items and price

### 7.1.3 First Prototype

I created the first prototype using an Arduino connected to a RFID card reader, see Figure 7.1. The Arduino is programmed using a suitable library [2] for the RFID reader to be able to read the UID values of RFID cards. A graphical user interface (GUI) was created in Java to show the picture and the name of the resident, and to show the order. The Java program reads the UID value of the detected RFID card that is close to the RFID reader, from the Arduino. When a buyer scans their RFID card on the reader, a short sound is emitted to confirm that the card was successfully read, and their picture and name is shown in the GUI. The cashier can then see if the key card belong to the person in front of them and choose to allow the person to pay for the food with the card. The buyer can then see the

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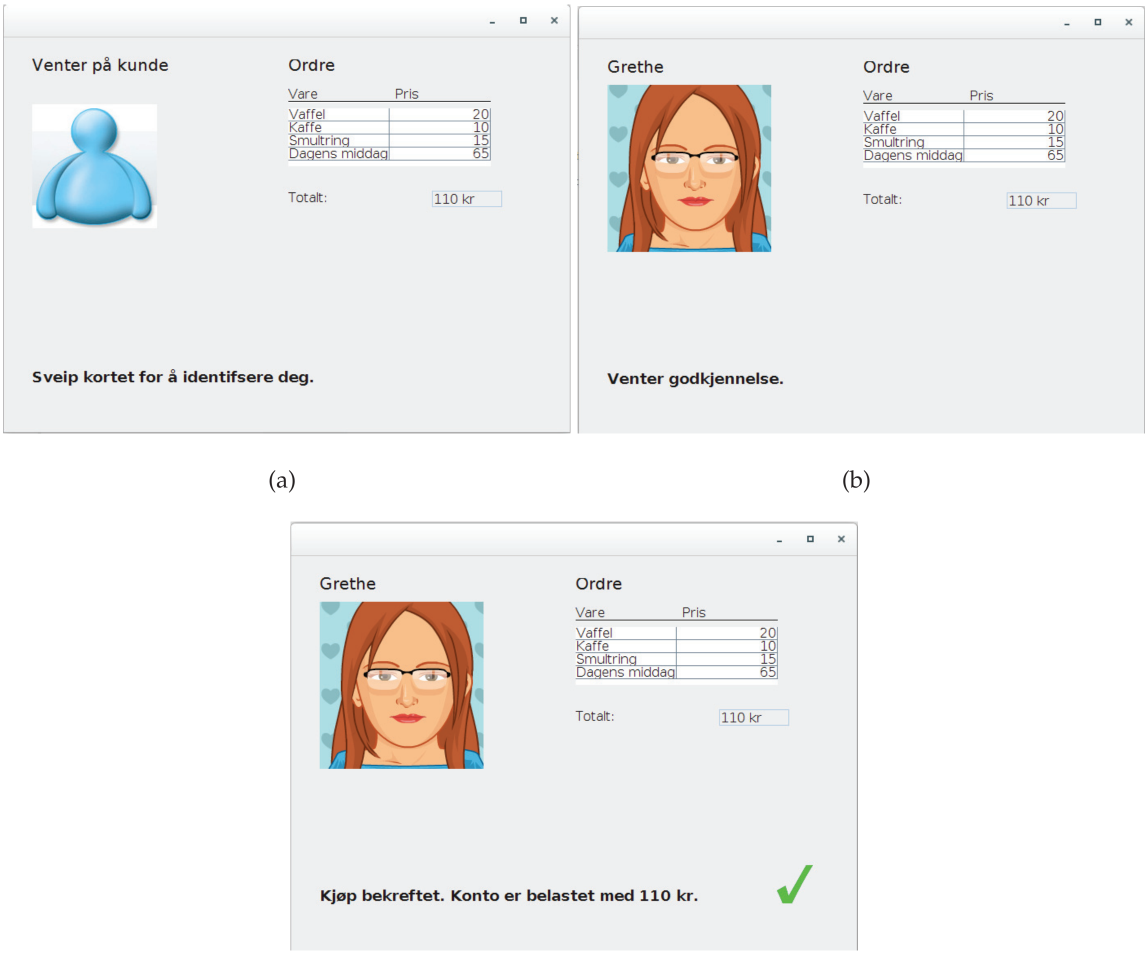
[1] `http://arduino.cc/en/main/arduinoBoardUno`

[2] `https://github.com/adafruit/Adafruit_NFCShield_I2C/`

order and swipe the NFC card in front of the reader for the second time to confirm the buy, adding the order to the residential bill.

### 7.1.4 Changes after usability testing

After the formative usability testing, I made a few small changes to the prototype. All the text in the GUI was made a little bigger and a green check mark was added to be shown when a purchase was confirmed (Figure 7.2(c)). The most significant change was that the user now only had to scan the card once, to let the cashier see if the photo that came up on screen matched the user and confirm the purchase.



Venter på kunde

Ordre

| Vare | Pris |
|---|---|
| Vaffel | 20 |
| Kaffe | 10 |
| Smultring | 15 |
| Dagens middag | 65 |

Totalt: 110 kr

**Sveip kortet for å identifsere deg.**

(a)

Grethe

Ordre

| Vare | Pris |
|---|---|
| Vaffel | 20 |
| Kaffe | 10 |
| Smultring | 15 |
| Dagens middag | 65 |

Totalt: 110 kr

**Venter godkjennelse.**

(b)

Grethe

Ordre

| Vare | Pris |
|---|---|
| Vaffel | 20 |
| Kaffe | 10 |
| Smultring | 15 |
| Dagens middag | 65 |

Totalt: 110 kr

**Kjøp bekreftet. Konto er belastet med 110 kr.** ✓

(c)

Figure 7.2: 7.2(a) The first screen of Payless, 7.2(b) the screen after an RFID key card scan, and 7.2(c) the screen after approval from cashier

### 7.1.5 Compensation of age impairments

The prototype aims to help elderly people who are struggling with manual payment due to reduced fine motor skills and *accuracy*, which makes it more difficult to find the right amount in cash or to type in their PIN code when using a credit card. Some may have difficulties remembering their PIN code and others trouble with screens due to visual impairments. The system compensates for memory problems and reduced *fluid intelligence* by providing a *simple* and *intuitive* interface with *physical and sensory support*. It also aims to make the payment procedure a little easier by providing extended use of an already known artifact.

## 7.2 Formative usability test

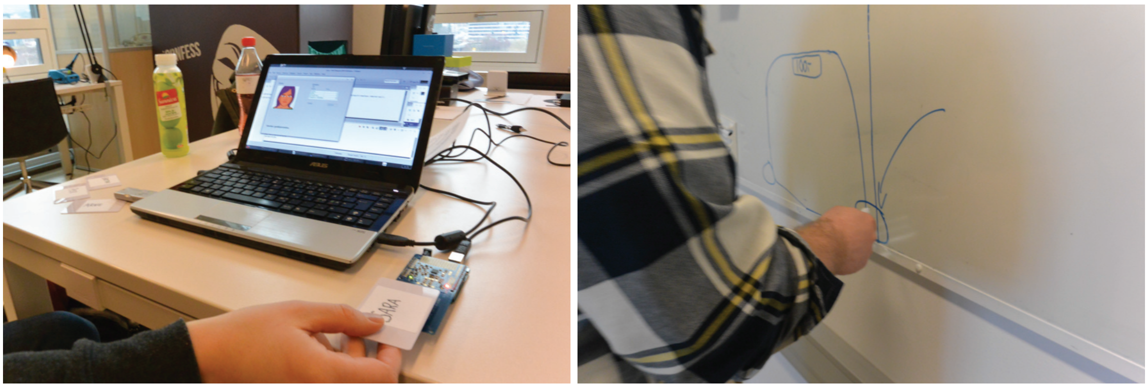
This section reports the results from the formative usability test (section 5.6.2) of the Payless prototype with expert users (section 5.4.1). The formative usability testing of Payless, involved letting the participants complete a purchase on a laptop connected to a RFID reader using a chosen RFID key card, see Figure 7.3(a). It also involved finding out where they preferred to have the reader and optionally a screen in relation to the cash register drawn on a whiteboard, see Figure 7.3(b). The participants preferences are shown in Table 7.1. The table shows how many scans the participants preferred to complete a purchase, where they preferred the reader to be placed and if a screen for customers were necessary.

None of the participants had problems completing a transaction and paying for food and beverages; they did however have some comments. One of the participants said that he liked the idea as he liked that an object can have multiple uses, referring to the key card used at research context 1 (section 5.3.1). Another participant said that elderly users should not need to face new user interfaces, thus this system should be made to be very similar to the interaction they are used to.

Table 7.1: Expert users preferences on Payless

| **User #** | **Scans necessary** | **Placement of reader** | **Screen for customers** |
|---|---|---|---|
| 1 | - | Laying down | Yes |
| 2 | - | Standing next to cash register | Yes |
| 3 | - | Adjustable | Yes |
| 4 | 1 | Standing next to the top of the cash register | Total price |
| 5 | 1 | Standing next to the top of the cash register | Total price |
| 6 | 1 | Laying down in front of the cash register | No |

| User # | Scans necessary | Placement of reader | Screen for customers |
|---|---|---|---|
| 7 | 1 | Laying down or mounted on the top of the cash register | Total price |
| 8 | - | Laying down next to bank card terminal | - |
| 9 | - | Laying down next to bank card terminal | - |
| 10 | 1 (2 is ok) | Laying down next to the cash register | Total price |
| 11 | 1 | On a stand together with bank card terminal | No |
| 12 | 1 | Next to bank card terminal | Total price |
| 13 | 1 | Laying down in chest height or on bench | No |
| 14 | 1 | Middle of the cash register | Total price |



(a)

(b)

Figure 7.3: 7.3(a) A participant performing a purchase with Payless, 7.3(b) a participant drawing the preferred placement of the key card reader.

### Security

The measurement of security is a little outside the scope, but are important for peoples acceptance and how safe they feel. It was suggested that the photo on the card should be updated every 6 or 12 months to make it more secure. One participant was unsure if you could trust the cashier to see that the person standing in front of them is matching the person on the picture. The rest of the participants did see the point of scanning the card twice and thought that once was enough. One participant said:

> "It feels like you are done after the first scan. It is not enough security payoff with two scans."

Another participant said it was like a three step authentication with two scans and that it can be hard for the elderly to understand that they need to scan the card twice. A possible problem is that the users could forget what they have bought and use a lot of money in the canteen, and then get a shockingly large bill. It was therefore suggested to have the ability to transfer money to the card and automatically block the card when there is no more money left. Such a system would also need a feature to check how much money is left on the card. Another idea to show that a payment was approved is to have a green light on the reader that will light up when the cashier approves the transaction.

### Placement of the reader and screen

This was a test to find out where the reader and screen should be placed in the canteen and was illustrated on a whiteboard, where the participants were asked to draw where they thought was the best place to have the reader and the screen.

All of the participants agreed that the reader should be located close to the cash register, but there different opinions on height, placement and orientation (Table 7.1). Some wanted the reader to be standing, others laying down or slightly angled. Some emphasized that the reader should be next to the bank terminal, to make similar to what the users were used to.

Only a few wanted to change the location of the reader depending on whether the card was located in a cardholder around the neck or in a pocket. One participant said that he was open for changes depending on where the user kept his card, but that there is a height difference on the users that must be considered, it would therefore be possible for everyone to scan their card if the reader was located laying down next to the cash register. It was important that the reader is right in front of the customer and the cashier. One participant suggested that the cashier be able to raise or lower the reader to make it easier for the user to use regardless of whether the user had the card around his/her neck or in his/her pocket. Most of the participants did not see the necessity of a big screen (Table 7.1) with the order, as long as the total price was visible either on the cash register or on a small separate screen. It was mentioned that people are more used to getting a receipt rather than looking at a screen before they buy something, it is unnecessary to introduce something new just because it is “cool”.

### The user interface

A few participants said that things should be clearer in the interface. More colors should be used, e.g. a green tick next to the text when the cashier has approved the user and a red cross if the user was not approved. There could be moving dots next to "Venter godkjenning"/"Awaiting approval" to more clearly express that it is waiting for something. It was also a little unclear who it awaited approval from and it should be more clear that it was awaiting approval from the cashier. One participant warned about the use of the word "sveip" / "swipe" and suggested to use the word "skann" / "scan" instead. The word "sveip" / "swipe" reminds us of how we used credit cards before we got the chip and may be confusing. A few participants were unsure about how easy it was to understand the information, and suggested to increase the font size of the text and try to use strong contrasts to distinguish between the different elements in the interface.

## 7.3 Summative usability test

Similar to the formative test, the summative usability test of Payless involved letting the participants complete a purchase on a laptop connected to a RFID reader using a chosen RFID key card, see Figure 7.4. It also involved finding out what they thought about a screen for customers and how easily they understood the scanning of the key card, see Table 7.2. The table shows the number of scans of the key card by each participant and if they preferred a screen for customers.

Table 7.2: Results from testing Payless with elderly user

| User # | Scans | Screen |
|---|---|---|
| 1 | 2 | No |
| 2 | - | - |
| 3 | Laid | No |
| 4 | 5 | No |
| 5 | - | No |
| 6 | Laid | No |
| 7 | 2 | No |
| 8 | 3 | Yes |
| 9 | 4 | No |
| 10 | 3 | No |
| 11 | 1 | No |
| 12 | 4 | Yes |
| 13 | 1 | Yes |
| 14 | 3 | Yes |

| User # | Scans | Screen |
|---|---|---|
| 15 | 2 | Yes |
| 16 | 1 | Yes |
| 17 | 10 | No |
| 18 | 1 | Yes |
| 19 | 4 | No |
| 20 | 1 | No |
| 21 | 2 | Yes (Not necessary) |
| 22 | 4 | Yes (Not important) |
| 23 | 1 | No |
| 24 | 1 | No (good for some) |
| 25 | 2 | Yes |

(a)

(b)

Figure 7.4: 7.4(a) A participant from research context 1 performing a purchase with Payless, 7.4(b) a participant from research context 2 (section 5.3.2).

While nobody had problems understanding the system, most held their card over the reader for a long time, as seen in Table 7.2. One participant had arthritis and had trouble using her hands. She experienced that this system was smarter than using credit card or cash, as she had experienced that her credit card had been swallowed by the ATM several times. Another participant also said that he had typed in the wrong code multiple times, when using a credit card. One participant called himself old fashion as he only used cash, but seemed to like the prototype as he said:

> "This was phenomenal stuff"

It was said that elderly people often use a long time, especially when using a credit card. A participant expressed how easy it was to use the system and said:

> "... is that it?"

Some compared it to other systems, where one had used a similar system in a canteen at a bank that she previously worked for. Another compared it to how she used her golf card:

> "It is the same as with the golf card"

One of the participants also stated that he liked this system better than T-Radio and Natural Charge, as this was more relevant for residents at research context 1 (section 5.3.1).

### Security

Some also had some concerns on the security of such a system, while many said that they trusted the people in their respective canteen. One participant said that you need to trust the system, it should be foolproof, and doubted that anyone would control what they bought. Others were a little more skeptical and were worried about how money could be withdrawn from their account. One participant suggested a limit on the amount of credit available on the card or how much you could pay for with it. Another said that it would be secure enough if you had a screen. It was also mentioned that it is important that the bill is accurately specified with what you have bought.

### Screen

For most of the participants, a screen seemed unnecessary, but some also liked the idea of having a screen to see the order, as seen in Table 7.2. Some of those who did not want a screen said that they would not have looked at it, and one of the participants was worried that others also could see it and would prefer a receipt. Another participant was worried that a screen would delay the transaction causing a queue. There were also some positive sides of having a screen. Some said that it helped to see that the order was correct. It gave the user a little extra control and could prevent fraud. One participant said that it was more difficult to object to something after the transaction is complete.

### Placement of reader

Most of the participants from research context 1 (section 5.3.1) carry their key card around the neck, a few participants did however prefer to have it in their pockets. As a results there were different opinions of where the reader should be placed, either in a height where the users could reach it without taking out the card from the holder around the neck, or by the bank card terminal which is more convenient when you have the key card in your pocket.

## 7.4 Analysis

In this section I will analyze the results from the summative usability test by using the proposed framework (section 4.4).

### 7.4.1 Scanning

In the summative evaluation of Payless, only 7 out of 23 participants scanned their key card one time, as seen in Table 7.2, which is the normal and required amount. Thus, 16 participants scanned their key card more than one time. Scanning the card a few time can be understandable, after all, they were facing a new interface. Despite a beep being emitted for each scan, indicating that the card has been scanned, 11 participants scanned the key card more than two times. Where two of them laid the card down on the scanner, and one stood out by holding the key card over for 10 scans. It raises the question on whether the participants heard the sound or if they did not understand the meaning of it. Reduced *fluid intelligence* may have prevented them from understanding the *perceived coupling* between the scanning of the card and the confirmation in the form of a beep. It is possible that sound together with the screen did not provide enough *physical and sensory support* or that they *simply* did not understand the information presented, as they may not have encountered a similar interface before. Those with experience from similar systems (golf and library cards) only used one scan, although the participant with similar canteen experience used three scans. However, she may not have encountered this type of technology. The interface may not be *intuitive* enough to not require a small learning process, but we are talking about a very small process.

### 7.4.2 Screen and safety

There were different opinions on the participants preference of a screen to see what they bought and the process of purchase. 14 of 24 participants would prefer not to have a screen, leaving 10 participants that would prefer it, but some of them said that it was not important. Many said that they trusted their respective canteen staff; however, some were more skeptical regarding how they actually would pay (bill or transferring money to card).

# Chapter 8

# Natural Charge

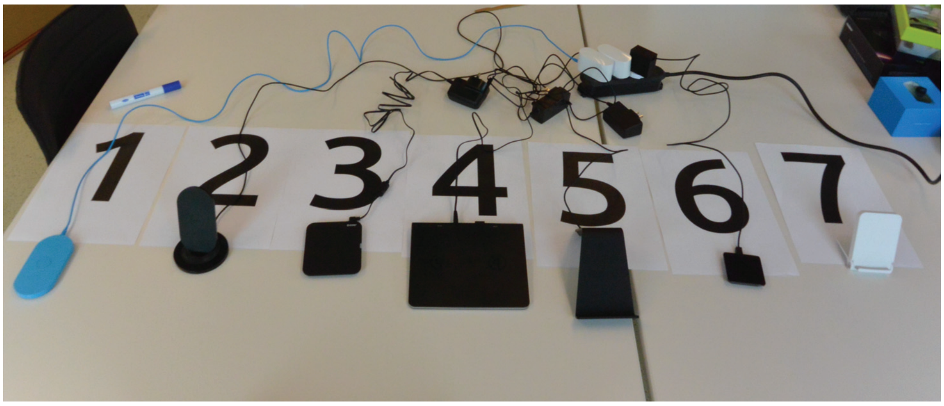


Figure 8.1: Induction chargers in numbered order

## 8.1 The prototype

### 8.1.1 Idea

Each apartment at research context 1 (section 5.3.1) comes preinstalled with a 11,6" Windows tablet that help the residents to arrange, plan and have an overview of everyday activities. It also provides basic opportunities for communication, namely telephoning and text messaging, as well as entertainment services, e.g., radio and an Internet browser. It also allows them to order meals from the downstairs canteen straight from the device. This tablet comes with a wall-mounted charger and a docking station that few elderly people manage to use due to the precise docking procedure required. The idea is to explore other options for charging the tablets using wireless induction charging. This not a traditional prototype, instead I have gathered a total of seven different induction chargers with varying colors, shapes and sizes; that I have used in the search for the best charging configuration, see Figure 8.1. The goal is to find the interface that best supports charging of the tablet by allowing the residents to select the configuration that suits their natural movements and capabilities the best.

**Purpose**

The purpose of this prototype is to explore how elderly users perceive the interaction, and find which configuration that best suits the individual users. It involves finding out how easy it is to use compared to the elderly users perception of using the docking station with the preinstalled tablet at research context 1 (section 5.3.1).

### 8.1.2 Technology

The most popular inductive charging standard for cell phones today is Qi, which is an interface standard developed by the Wireless Power Consortium. The current Qi standard offers up to 5 watts output power (Consortium 2013). As cell phones today require 5V input power, this results in a theoretically max output of 1 ampere. A little less is realistic to get on the receiving end, as there is a loss in power caused by the wireless transmission. This is a little lower than the standard power adapter of tablets, but it will still charge a tablet; it only takes a little longer.

The tablet which all residents at research context 1 (section 5.3.1) have, is of the type Samsung Slate 700T and is basically a complete computer wrapped in a tablet case and it therefore requires more power than many other tablets on the market. It has a 40-watt power adapter and we cannot charge this tablet using the Qi standard. The Wireless Power Consortium is currently working to extend the Qi low power specification to deliver up to 15 watts. They are also working on a medium power specification to deliver up to 120 watts and a high power specification to deliver up to 2 kW[1]. Since todays standard only supports up to 5 watts of transmitting power, I use a Nexus 7 (2013) tablet[2] to demonstrate the concept. In the tests, I use the following Qi chargers:

1. Nokia DT-900 Wireless Charging Plate[3]
2. Nokia DT-910 Wireless Charging Stand[4]
3. Zens Single Wireless Charger[5]

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[1] `http://www.wirelesspowerconsortium.com/developers/the-wpc-work-plan.html`

[2] `http://www.asus.com/no/Tablets_Mobile/Nexus_7_2013/`

[3] `http://www.microsoft.com/en/mobile/accessory/dt-900/`

[4] `http://www.microsoft.com/en/mobile/accessory/dt-910/`

[5] `http://www.makezens.com/shop/zens-single-wireless-charger-black/`

4. Tenergy Dual Qi Wireless charger[6]
5. Tylt VÜ Wireless Charger[7]
6. Nexus charging plate[8]
7. LG WCD-100 Wireless Charger[9]

The numbers in the list are the same used to represent the chargers in the tables presenting results from the usability tests and in Figure 8.1.

### 8.1.3 Compensation of age impairments

The use of the docking station of the current tablet at research context 1 requires precise positioning to work. This makes it especially hard for those residents with reduced fine motor skills to use. In addition, the components are small and difficult to spot for those suffering from visual impairments. Few of the residents at research context 1 have the strength required to lift and maneuver a 11,6" tablet with just one hand. The number of broken charger plugs has consistently been high due to this difficult charging process. I will therefore explore the use of induction charging of tablets that require less use of fine motor skills, *accuracy* and *muscle strength*, in addition to having *physical and sensory support*.

## 8.2 Formative usability test

This section reports the results from the formative usability test (section 5.6.2) of the Natural Charge prototype, with expert users (section 5.4.1). The formative usability testing of Natural Charge, involved letting the participants try to charge a Nexus 7 tablet using seven different wireless chargers, as shown in Figure 8.2. It also involved finding out how easy they thought the different chargers were to use and letting the participants choose a preferred model. Table 8.1 shows which models they were able to get to charge on their first try (natural placement) and which model they preferred. All participants would personally consider using wireless charging, but had different preferences. For example, a standing charger was said to be preferred at the office or by the TV, while a flat charger is preferred by the bed.

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[6] `http://www.tenergy.com/51050`

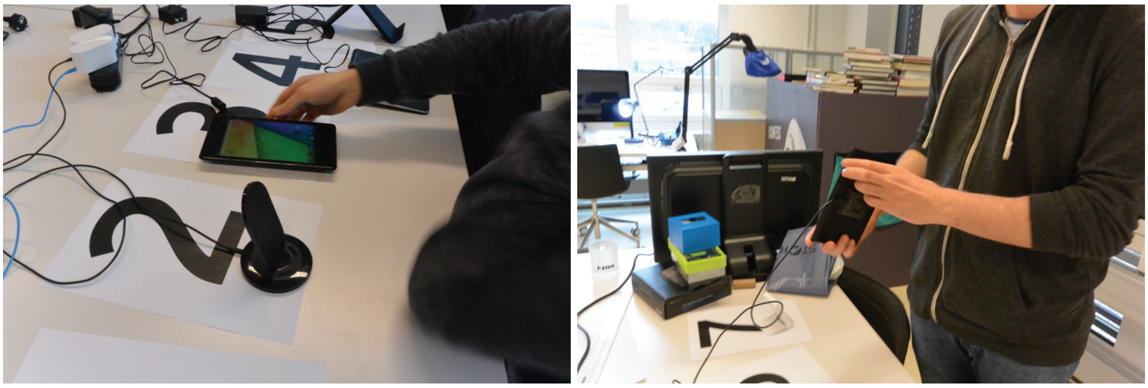
[7] `http://www.tylt.com/vu/`

[8] `https://play.google.com/store/devices/details/Nexus_Wireless_Charger?id=nexus_wireless_charger`

[9] `http://www.lg.com/no/mobiltilbehor/lg-WCD-100`

Table 8.1: Expert users experiences and preferences of Natural Charge

| User # | Natural placement | Preferred model |
|---|---|---|
| 1 | 1, 3, 4 | 3 |
| 2 | 1, 6 | 6 |
| 3 | 1, 6, 7 | 5 |
| 4 | 1, 6 | 5 |
| 5 | 1, 4-7 | 5 |
| 6 | 1, 5-7 | 5 |
| 7 | 1, 4, 6 | 3 |
| 8 | 1, 6, 7 | 5 |
| 9 | 1, 2, 5-7 | 5 |
| 10 | 1, 4-6 | 5 |
| 11 | 1-4, 6, 7 | 6 |
| 12 | 1, 6, 7 | 1 |
| 13 | 1-7 | 2 |
| 14 | 1, 2, 5-7 | 1 |


(a)

(b)

Figure 8.2: 8.2(a) and 8.2(b) shows participants trying different wireless chargers.

The Nokia DT-900 wireless charging plate was one of the easiest to use (Table 8.1), with all participants managing to charge the tablet on their first attempt (appendix D.1.1). The Nokia DT-910 wireless charging stand did however require more attempts as most of the participants placed the tablet in a standing position, which did not work. The reason for this is that the chargers are designed to work with smaller devices and not a 7" tablet. Thus, the participants were required to place the tablet sideways on the charger.

The Zens Single Wireless Charger was one of the hardest to use, as it did not work by placing the tablet in the middle of the charger. It was a little tricky to charge, requiring the participants to place the tablet on the right hand side of the charger. However, some participants liked it because of its design, the material and the charging light. The Tenergy Dual Qi Wireless charger also had a charging light, but this was not visible when the tablet was placed correctly. The most prominent problem of this charger was that the participants placed the tablet across both of the charging surfaces.

The Tylt VÜ Wireless charging stand had the same problem as the Nokia Charging stand. The participants tried to place the tablet in a standing position, but were required to place it sideways. This was the model that most participants preferred (Table 8.1) and was said to be a good charger for elderly people, because it was sturdy and easy to use, it was also well liked because it was easy to use the tablet while it was charging. The Nexus charging plate was the smallest of all the chargers and featured a magnet that follow the tablet when you lift it up. Some participants liked this, while others disliked it because they feared that the charger would fall on the floor and get damaged.

The LG WCD-100 Wireless charging stand, as with the other standing chargers, required the participant to place the tablet sideways. Although many seemed to have learned from the previous standing chargers, some still placed the tablet in a standing position, which did not work. This charger was also considered somewhat flimsy for charging a tablet.

## 8.3 Summative usability test

The summative usability testing of Natural Charge, involved letting the participants try to charge a Nexus 7 tablet using seven different wireless chargers, as shown in Figure 8.3. It also involved finding out how easy different chargers were to use. This was measured by observing the number of trials before they got the tablet to charge, and also by letting the participants choose a preferred model, see Table 8.2. The participants from research context 1 were also asked about their existing tablet, which revealed that many had problems with charging the tablet (appendix D.2.2).

Table 8.2: Number of trials of each participant on the different charger models

| | Number of trials | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **User #** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Preferred model |
| 1 | 1 | 1 | 3 | 2 | 2 | 3 | 1 | 1 |
| 2 | - | - | - | - | - | - | - | - |
| 3 | 1 | 4 | 2 | 3 | 2 | 2 | 1 | 1 |
| 4 | 1 | 3 | 4 | 10[10] | 1 | 2 | 1 | 1, 5 |
| 5 | - | - | - | - | - | - | - | 2 |
| 6 | 1 | 1 | 5 | 2 | 3 | 3 | 2 | A |
| 7 | 1 | 2 | 5 | 3 | 1 | 1 | 1 | 1, 5 |
| 8 | 2 | 6 | 16 | 8 | 1 | 1 | 1 | 1, 7 |
| 9 | 1 | 2 | 5 | 1 | 3 | 2 | 2 | 5, 7 |
| 10 | - | - | - | - | - | - | - | - |
| 11 | 1 | 4 | 3 | 1 | 2 | 1 | 1 | A |
| 12 | 1 | 4 | 6 | 4 | 2 | 5 | 2 | 1, 3 |
| 13 | 1 | 1 | 3 | 2 | 2 | 1 | 2 | 6 |
| 14 | 1 | 2 | 6 | 5 | 4 | 1 | 1 | 1 |
| 15 | 5 | 4 | 5 | 5 | 2 | 2 | 1 | 5 |
| 16 | 1 | 2 | 3 | 3 | 1 | 1 | 1 | 7 |
| 17 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 5 |
| 18 | 1 | 6 | 1 | 4 | 3 | 2 | 3 | 5 |
| 19 | 1 | 6 | 5 | 7 | 3 | 1 | 1 | 1 |
| 20 | 1 | 3 | 3 | 4 | 2 | 2 | 1 | 5 |
| 21 | 1 | 1 | 1 | 6 | 1 | 1 | 1 | 1, 2 |
| 22 | 1 | 2 | 5 | 4 | 6 | 1 | 2 | 5 |
| 23 | 1 | 7 | 4 | 8 | 2 | 1 | 4 | 4 |
| 24 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 4, 6 |
| 25 | 1 | 1 | 3 | 5 | 2 | 1 | 1 | 5 |
| 26 | - | - | - | - | - | - | - | 5 |

---

[10] Lost count of trials and intervened

(a) (b)

Figure 8.3: Figure 8.3(a) and 8.3(b) shows a participant trying different models in Natural Charge.

The use of wireless charging was said to be smart and a good solution, one participant asked

> "When will this be available?"

Another participant liked it so much that he tried to place his phone on one of the chargers to see how it looked. While most of the participants had one or two chargers that they preferred, some also said that all the chargers (A) were okay to use once they had learned how to use them, see Table 8.2. Some preferred the standing chargers, while others preferred the flat ones. One participant said that it should be easier to place the tablet correctly and have it charging. Many participants needed multiple tries to get the tablet to charge on some chargers. One of the reasons for the highest number of trials in Table 8.2, is that there is a delay before the tablet signals that it is charging and some participants were a little hasty in changing the position of the tablet, and one participant said:

> "Patience is a virtue"

Similar to the formative usability test, the Nokia Wireless Charging Plate was one of the easiest to use, according to the number of trials in Table 8.2. The most prominent problem of using the standing chargers, Nokia DT-910, Tylt VÜ and LG WCD-100, was that most of the participants placed the tablet in a standing position first, which did not work (appendix D.2.2). When working with the Nokia DT-910, one participant tried to lay the tablet down partially on the foot, and another participant tried to place the tablet with the screen facing the stand, none of these worked. Someone also mentioned it having a small gripper, referring to the foot of the stand.

The Zens Wireless Charger was one of the hardest to use, as it was very tricky charger to use. The problem with the Tenergy Dual Qi Wireless charger was that most participants placed the tablet across both charging surfaces. However, several participants liked the idea of being able to charge multiple devices at the same time.

The Tylt VÜ Wireless Charger got the most praise. Most of the participants said that it was steady, which made it easy to place the tablet. A few participants said that it was the best charger for elderly users with unsteady or shaking hands, and one participant said:

> "8/10 of elderly users would choose this charger"

For some participants, the Nexus charging plate was a little hard to use. Because it was so small, they had trouble removing the tablet from it. However, most of the participants managed to get the tablet to charge fairly easy. The LG Wireless Charger was said to be missing a light that indicated that it was charging, which made it difficult to use. Another participant meant that this charger was more responsive than the others were.

## 8.4 Analysis

In this section I will analyze the results from the summative usability test by using the proposed framework (section 4.4).

### 8.4.1 Ease of use

The Tylt VÜ was the most liked charger, as 10 out of 24 participants had this as one the chargers they would prefer, as seen in Table 8.2. However, Table 8.3 shows that this charger was only fourth easiest to use based on the number of tries the participants used to get the tablet to charge. The Nokia charging plate was the easiest to use with 19 participants managing to get the tablet to charge on their first try, it was also the second most favored model with 9 participants having it as one of their preferred models.

Table 8.3: Average number of trials on each charger

| Charger | Average number of trials |
|---|---|
| 1 - Nokia Wireless Charging Plate | 1.27 |
| 2 - Nokia Wireless Charging Stand | 2.95 |
| 3 - Zens Wireless Charger | 4.09 |
| 4 - Tenergy Dual Qi Wireless Charger | 4.14 |

| Charger | Average number of trials |
|---|---|
| 5 - Tylt VÜ Wireless Charger | 2.18 |
| 6 - Nexus Charging Plate | 1.68 |
| 7 - LG Wireless Charger | 1.45 |

### 8.4.2 Average number of trials

Note that the tablet used in this test was larger than the devices the different chargers were designed for. This caused some complications, e.g. charging lights could not be seen when the tablet was correctly placed on one model, and that the tablet needed to be placed sideways on the standing chargers (No. 2, 5, 7). This caused an increase in the number of trials to get the tablet to charge. As seen in Table 8.3, the average for the Nokia charging stand is 2.95, while the Tylt VÜ and LG charger have averages of 2.18 and 1.45 respectively. The gradual decrease in the number of tries on the standing chargers may be caused by the participants gradually learning what worked and what didn't, increasing their *literacy*. The Zens and Tenergy chargers were undoubtedly the hardest to use with 4.09 and 4.14 in average number of tries. Despite the Nexus being small, it was one of the easiest to use.

### 8.4.3 Using the framwork

*Spatial cognition* was not relevant here as there was no specific form that indicated that the tablet should fit into. *Flexibility* was also not an issue with regard to reduced range of movement. However, one participant struggled with picking up the tablet when it was laying down. *Accuracy* could be a factor in how they placed the tablet on the chargers, but it is hard to observe when you do not know what they aim for. Questions can be asked about the *intuitiveness* and *simplicity* of the chargers with regard to *fluid intelligence* of the participants. Did the participants understand how to interact with the chargers? They certainly managed to get the tablet to charge on all of the chargers, but the two models that were hardest to use could be improved by better *sensory support*, to better indicate where tablet should be placed. For example, the Zens charger only had a small recess around the area that the device should be placed to be able to charge, by introducing contrasting colors instead, the charger could possibly improve the ease of use.

Another reason for some of the high number of trials was that some participants were too hasty in changing the position of the tablet. However, this seemed to improve with trial and error, as they gradually learned how the concept worked, indicating that some chargers were *intuitive* enough, while others required a short learning process.

# Chapter 9

# LightUp

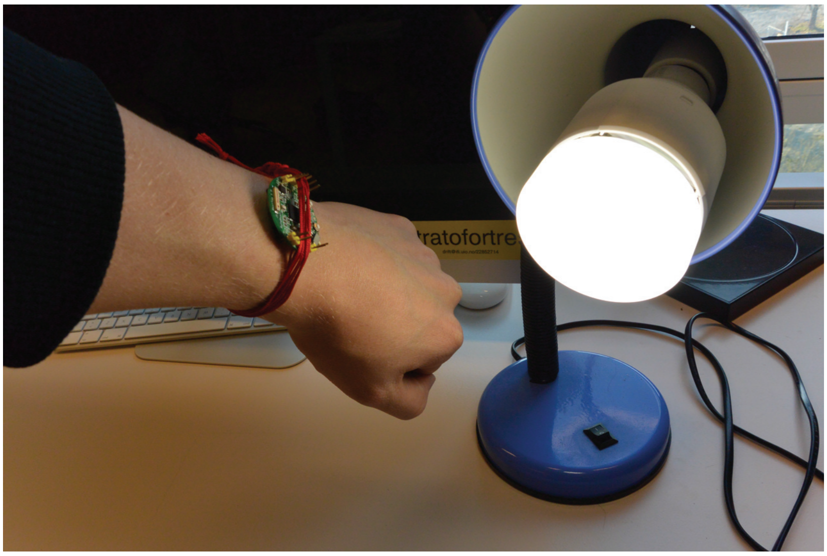


Figure 9.1: Final prototype of LightUp

## 9.1 The prototype

### 9.1.1 Idea

The basic idea is to create system where the color of the light changes according to the temperature in the room. The idea originally consisted of adjusting the color of the light according to body temperature, however the room temperature were used instead as this were easier to measure with the currently available technology. This means that the color of the light is colder (more blue) when the temperature is low, and warmer (more red) when it the temperature is higher in the room. This idea is based on the assumption that some elderly people undergo dips in their metabolic rate and therefore end up feeling colder and may simultaneously be more exposed to related illnesses such as hypothermia (Smolander

2002). The prototype is therefore to give elderly people an indicator of the temperature in the room, which can help to regulate the heating level in their homes.

#### Purpose

The purpose of this prototype is to provide a tool for thinking and exploring new ideas. The LightUp prototype is a new concept without similar interfaces, and I need to explore whether the concept has potential applications and can help elderly people. This prototype is less a finished product, rather than a simple test of a concept.

### 9.1.2 Technology

To read the temperature in the room, I used a wireless sensor that uses Bluetooth technology. More specifically it uses Bluetooth Low Energy[1] (BLE) , also called Bluetooth Smart, which is a wireless technology featuring a ultra-low power consumption which gives it the ability to run for years on a standard coin cell battery. It is developed to be a low cost technology with multi-vendor interoperability. Bluetooth Low Energy differentiates between central and peripheral roles, where only devices with central role support can scan and initiate a connection to another device. Thus, I needed a temperature sensor in a peripheral role, and device in a central role to read the temperature and communicate with a light bulb.

### 9.1.3 The first prototype

The first prototype that I created consisted of the following components:

- Easybulb light system[2]
- Arduino UNO
- Adafruit CC3000 Wifi breakout board[3]
- RedBearLab BLE Mini Bluetooth Low Energy breakout board[4]
- Bytereal RealTag Bluetooth sensor[5]

I created the first prototype using an Arduino connected to a WIFI breakout board and a Bluetooth Low Energy breakout board, see Figure 9.3. The Bluetooth board was used in a

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[1] `http://www.bluetooth.com/Pages/Bluetooth-Smart.aspx`

[2] `http://easybulb.com/`

[3] `http://www.adafruit.com/product/1469`

[4] `http://redbearlab.com/blemini/`

[5] `http://www.addta.com/wiki/index.php?title=RealTag-Sensor`

central role to connect to a Bluetooth temperature sensor in a peripheral role, using a suitable library [6]. The WIFI board was connected to a EasyBulb light system, using the boards provided library [7]. The EasyBulb system features a small WIFI box that control other LED bulbs which fit in a standard E27 socket, see Figure 9.2. These bulbs can also be controlled by an app on Android or iOS, and allows the control of the lights color temperature, and brightness. The prototype used a white bulb which featured ten levels of color temperatures, from cold white to warm white. The Arduino read the room temperature from the Bluetooth device and adjusted the color temperature of the light accordingly. If it was cold in the room, the Arduino adjusted the light to be colder, and if it was hot in the room a warmer color was chosen. The light system had some limitation, i.e. it was only possible to adjust the color temperature up or down and not possible to set it to a specific level, the same applied to the brightness. Another bulb from EasyBulb was also tested, which features 255 different colors. This bulb also had a setting for white color, but it was not possible to adjust for warm or cold white. Another problem with this prototype was that the Bluetooth connection sometimes had some stability problems and a bad reading of the temperature sensor would occur, reporting the temperature to be 7 °C. This prototype was therefore never tested with any users.

(a)

(b)

Figure 9.2: 9.2(a) EasyBulb White bulb, 9.2(b) EasyBulb Wifi box

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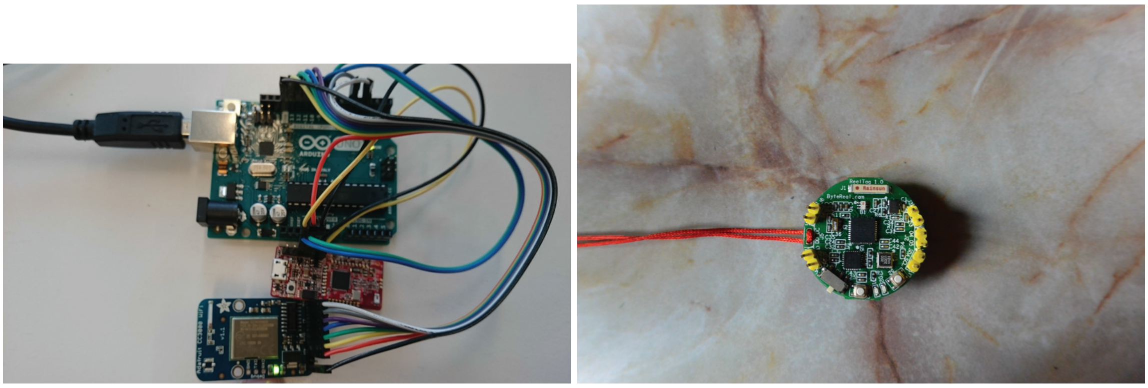
[6] `https://github.com/RedBearLab/BLE_HCI`

[7] `https://github.com/adafruit/Adafruit_CC3000_Library`



(a) (b)

Figure 9.3: 9.3(a) Arduino UNO with BLE and WIFI breakout boards, 9.3(b) Realtag Bluetooth sensor

### 9.1.4 The second prototype

The second prototype that I created consisted of the following components:

- LIFX light bulb[8]
- Raspberry Pi B+
- Micro-SD memory card
- Wifi USB dongle
- Bluegiga BLED112 USB Bluetooth Low Energy dongle[9]
- Bytereal RealTag Bluetooth sensor (see Figure(9.3(b))

I created the second prototype by using another light bulb called LIFX (Figure 9.4(a)). This bulb fits in a standard E27 socket and is controlled over WIFI. It features 16 million colors where hue, saturation, brightness and kelvin can be adjusted separately. The prototype uses a Raspberry Pi with a USB BLE dongle in a central role (Figure 9.4(b)). This connects to the Bluetooth sensor (Figure 9.3(b)) in peripheral role with a suitable library [10] written in python. Unlike the first prototype, this setup provides a stable Bluetooth connection with accurate reading of the temperature sensor. The LIFX bulb is controlled through the LIFX python library [11] where the color temperature (Kelvin) can be adjusted

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[8] `http://www.lifx.co/`

[9] `https://www.bluegiga.com/en-US/products/bled112-bluetooth-smart-dongle/`

[10] `https://github.com/jrowberg/bglib`

[11] `https://github.com/arrian/lifx-python`

from 2500 Kelvin (warm color) to 9000 Kelvin (cold color). The LIFX bulb also features a transition delay to give a smoother transition from different color or brightness levels. The color temperatures in this prototype are divided on 20 different temperatures, where coldest is 10 °C or lower which gives a color temperature of 9000 Kelvin, and the warmest is 30 °C or higher which gives a color temperature of 2500 Kelvin. The Raspberry Pi reads the temperature in the room from the temperature sensor on the Bluetooth device and adjusts the color temperature on the light bulb accordingly.

(a) (b)

Figure 9.4: 9.4(a) LIFX light bulb, 9.4(b) Raspberry Pi with Bluetooth dongle

### 9.1.5 Changes after usability testing

After the formative usability test, I decided to change the temperature scale based on the feedback. The scale was moved so the system would have the coldest color (9000 Kelvin) at 15 °C or colder, and the warmest color at 25 °C or warmer.

### 9.1.6 Compensation of age impairments

This prototype can be helpful to assist the prospective memory of elderly people suffering from cognitive disabilities by actively reminding them to adjust the temperature in the room. In addition, elderly people who experience dips in their metabolic rate are more likely to get cold, and more likely to get illnesses such as hypothermia.

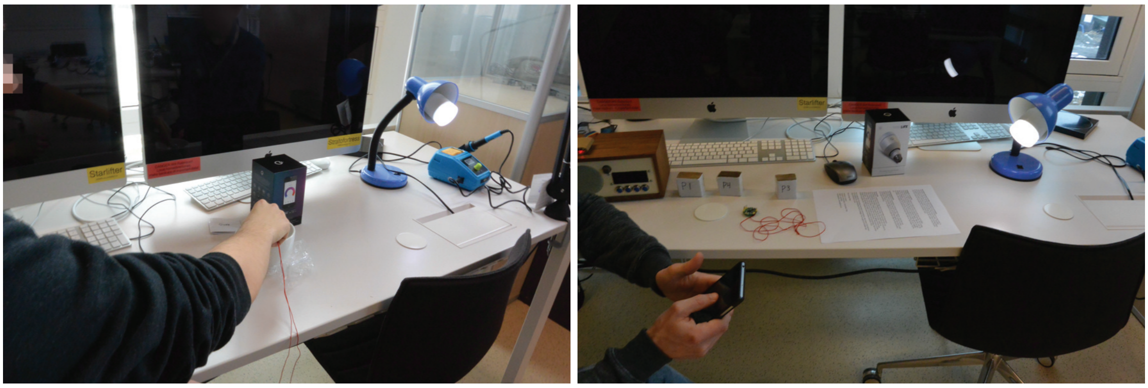
## 9.2 Formative usability test

This section reports the results from the formative usability test (section 5.6.2) of the LightUp prototype, with expert users (section 5.4.1). The formative usability testing of LightUp, involved letting the participants cool down and warm up the sensor to change the color of the light, as seen in Figure 9.5(a). Sometimes there were technical problems and a smartphone app was used to change the light, as seen in Figure 9.5(b). The participants were shown the coldest and warmest color of the light and were asked to give their comments on the representation, and which temperatures the light should represent for indoor use. Table 9.1 shows the temperature the participants thought the light should represent for indoor use, at both the warmest (2500 Kelvin) and coldest (9000 Kelvin) color. It also shows what the participants thought of how the color of the light represented the temperature.

The participants had strong opinions regarding the color of the light, and very different opinions on warm and cold.

Table 9.1: Expert users testing LightUp

| User # | Warmness of color | Coldness of color | Color representation |
|---|---|---|---|
| 1 | 25 | 15 | Difference |
| 2 | 25 | 15 | Ok |
| 3 | 26 | 19 | Ok |
| 4 | 25 | 16 | Warmer |
| 5 | 25 | 18 | Warmer |
| 6 | 27 | 19 | Ok |
| 7 | 30 | 15 | Warmer |
| 8 | 25 | 19 | Warmer |
| 9 | 24 | 19 | Warmer |
| 10 | 24 | 17 | Ok |
| 11 | 20 | 14 | Warmer |
| 12 | 30 | 14 | Ok |
| 13 | 24 | 17 | Ok |
| 14 | 25 | 15 | Ok |



(a) (b)

Figure 9.5: 9.5(a) A participant cooling down the sensor with ice to change the light, 9.5(b) participant changing the light with a smartphone app.

### Color of the light

One participant said that it was hard to see if it is cold or warm when they first entered the room and that there wasn’t big enough difference between the cold and warm color of the light. One participant said that the coldest color, which is 9000 Kelvin, was not blue enough, but all the other participants agreed that this was a very cold color. On the other end of the scale, the warmest color (2500 Kelvin), most participants agreed that this color did not look warm enough. One of the participants commented that it looked like it was beginning to be warm, but it did not look the warmest and that it should be redder at its warmest. It was said that the link between light and temperature was not strong enough. We are used to warm light and neutral light would therefore seem cold.

### Temperature

The participants were asked what indoor temperature they thought the color of the light should represent, regarding what they thought was cold and warm indoor temperatures. Multiple participants suggested to move the temperature scale to 15 °C at the coldest and 25 °C at the warmest, but other participants had different perceptions of cold and warm. Table 9.1 shows what the participants thought of as a cold indoor temperature and has an average of 16.57 °C, the participants thought of the warmest indoor temperature was 25.36 °C on average.

## 9.3 Summative usability test

The summative usability testing of LightUp, was intended to let the participants warm up the sensor. Because of severe network stability issues, causing the LIFX lightbulb to disappear from the local network, a smartphone app was used to show the coldest and warmest color of the light. The concept was explained to the participants and they were asked what they thought about such a system. Table 9.2 shows whether the prototype worked or not, and some comments from the participants regarding the concept. Figure 9.6 shows participants testing the prototype.

Table 9.2: Results from the summative tests of LightUp

| User # | Did the prototype work? | Comments regarding the concept |
|---|---|---|
| 1 | Yes | Smart |
| 2 | - | Left before the test |
| 3 | Yes | Neat solution. Hard to understand the concept |
| 4 | No | - |
| 5 | No | - |
| 6 | No | - |
| 7 | Yes | Positive, could be of help after some familiarization |
| 8 | Yes | Liked this prototype the most. Could show if it was cold. |
| 9 | Yes | Okay |
| 10 | - | Left before the test |
| 11 | Yes | Can help some people |
| 12 | No | - |
| 13 | No | - |
| 14 | No | - |
| 15 | No | - |
| 16 | No | Not a good idea |
| 17 | No | - |
| 18 | No | Liked the idea, good for many elderly people instead of unreadable thermometers |
| 19 | - | Left before the test |
| 20 | - | Left before the test |
| 21 | Yes | Did not see the advantage of such a system |
| 22 | Yes | Not so interesting |

| User # | Did the prototype work? | Comments regarding the concept |
|---|---|---|
| 23 | Yes | Not so interesting, is a very warm person |
| 24 | Yes | "Why not?", instead of looking at a thermometer |
| 25 | Yes | Interesting for some who are not in good shape |

(a) (b)

Figure 9.6: 9.6(a) and 9.6(b) shows a participant testing LightUp.

There were different opinions regarding this prototype, some liked it, some accepted it and some did not see the advantage of such a system, as seen in Table 9.2. Four participants said that this system was not a good idea, not interesting or saw no advantage of such a system, however one of them commented:

> "If this had been in the bathroom this morning, it would have been blue"

One participant said it was smart, and that the warmest color indicated approximately 23 °C, while normal indoor temperature was said to be 21-22 °C. The warm color was said to be more normal as the participant preferred a warmer color on her lighting. This opinion was shared by most of the participants, where one participant said that the warm color was the same color he had in his sconces. The warm color was therefore perceived as room temperature. The cold color was however perceived as very cold, or freezing cold. A few said that this could be good system to help elderly people, instead of looking at unreadable thermometers. One participant thought that it could help some people to see if they were healthy. If the light is warm and they are freezing, they could be running a fever. One participant was especially fond of this system and liked this solution best of all the prototypes he had tested.

## 9.4 Analysis

In the summative evaluation, LightUp was intentionally tested last. The reason being that this prototype is more abstract and require more thinking by the participants. The testing was also limited by the prototype only working in 11 of 21 cases, and that four participants left before this test. The feedback from the usability tests were very mixed, it therefore raises the question whether the concept was a bad idea or if it should aim for a more limited group of users. Some of the less positive comments seemed be coming from people who just thought of how they would relate to the prototype, and not thinking of others. However, there were some more positive comments that some might find this useful, but not necessary themselves. There were also one participant that seemed to have some trouble in understanding the concept, which may be caused by me not giving a good enough explanation or that the prototype did not provide enough *simplicity*.

The representation of the temperature in regard of light is important in this prototype, which may not have been clear enough to give the necessary *physical and sensory support* needed. However, there were still a few users did like the idea, and especially one that would want this kind of system.

# Chapter 10

# Analysis

In this chapter, I merge the analysis of the prototypes to find answers to the main objectives in regard of the research question (section 1.2). I look at the overall problems and findings through further analysis of the results from the summative usability test (section 6.3, 7.3, 8.3 and 9.3), to extract common problem areas and design implications.

## 10.1 Compensating for age related challenges

All of the prototypes were designed to compensate for age related challenges by providing alternative tangible user interfaces. The T-Radio was designed to compensate for elderly suffering from decline in fine motor skills and *accuracy* that make it harder to use small buttons and switches, and *sensory* functions that make it hard to read small prints or screen texts. None of the participants struggled with any of these challenges during the summative usability test (section 6.3), as the only action required was to place a block on top of the radio. Similarly, Payless was designed to compensate for reduced fine motor skills and *accuracy* when using cash or credit card to pay for food and beverages in a canteen, making it harder to find the correct amount in cash or to hit the correct buttons on credit card terminal. It is also designed to compensate for problems in remembering the PIN code of the credit card and reduced vision (*physical and sensory support*) that make it harder to see the buttons and the information on the screen of the credit card terminal. The summative usability tests (section 7.3) indicate that most of these problems were compensated for as the participants only had to scan their RFID card on a RFID reader. However, the prototype also included a screen where one participant had to put on reading glasses to be able to see the information clearly. The opinions of the necessity of this screen varied, and if we ignore it, the prototype was successful in compensating for the intended age related challenges.

The chargers included in Natural Charge were intended as an alternative to the docking station for the presintalled tablet at research context 1 (section 5.3.1), as it requires the residents to place the tablet in a very specific way. The residents have to hold the tablet over the docking station, requiring *muscle strength*, and use fine motor skills and accuracy to place it correctly. It also depends on the use of vision (*physical and sensory*) to see where and how the tablet fits in the docking station. These problems were less visible on Natural Charge, but it depended on the different chargers. The chargers were less tricky about the placement of the tablet, but some were trickier than others were and required the user to be more observant to understand how the tablet should be placed. Overall, the chargers provided an alternative way to charge tablets that were less demanding on the skills of the user.

The LightUp prototype aimed to assist the prospective memory of elderly people suffering from cognitive disabilities by actively reminding them to adjust the temperature in the room. This prototype is a new solution without any other solutions to compare it to, and is thus more a tool for thinking and exploring possibilities of tangible user interfaces. Based on the results from the usability test, it is not possible to determine whether this prototype compensate problems regarding prospective memory. However, multiple participants liked the concept for providing additional *physical and sensory support* to easily give an indication when it is cold. To understand whether it compensated for any other problems, it should be tested in a real use context.

Overall, the prototypes worked well in compensating for age related challenges they were intended to. One can argue that some of the participants were less hampered by the age related challenges mentioned, but some also were. The most obvious challenges observed were arthritis, mobility and vision, and did not inflict their performance on the tasks presented.

## 10.2 Understanding the interaction

The results of the T-Radio prototype shows that 17 out of 24 participants managed to correctly place a block and turn on a channel under the average time, which was 5.8 seconds. This means that there were only a few that pulled up the average time and the problems of using this prototype was minimal, with only 4 of out 24 participants that did make a mistake. By using the framework (Section 4.4), we can say that in 20 out of 24 cases, the prototype was *intuitive* in the way that the users were able to manipulate the system without a learning process. However, this process was short as all participants were able to control the system (*self control*). Some were a little uncertain of the radio worked, but all doubt disappeared as soon as they placed the block correctly, and the radio instantly played the selected channel.

Question can however be raised regarding how well the participants understood the interaction on the Payless prototype, as the average number of scans with the RFID key card was 2.7 scans with two participants that laid the card on the reader. The participants from research context 1 (section 5.3.1) already uses a similar interaction when they open the door to their apartments, and the interaction was therefore expected to be easily understood, but that was not the case.

To provide extra feedback in addition to the picture changing on the screen, a sound signal (a beep) was played for every scan. This meant that if they held the RFID key card over reader, it would be continuously play a beep every second until the key card was removed from the reader. To me, the sound signal is a clear indicator that the scan was successful and that I am done with the interaction, thus the sound signal was not perceived the way it was intended to, as many participants held the RFID key card over the reader for a long time (Table 7.2). Many participants did therefore not understand the *perceived coupling* (section 4.3.4) between the sound and their interaction. The sound was at its loudest at 1712Hz, which is inside the recommended frequency range of 500-2000 Hz presented by Farage et al. (2012) (section 3.2.2), however it may have been under the recommended 60 dB limit. Although all participants were able to control the system (*self control*), some participants requires a short learning process in understanding the interaction. Reaction time is also a factor to be considered, as the sound signal repeat itself very fast.

The results from the formative (section 8.2) and summative (section 8.3) usability tests of the Natural Charge prototype show that there are big differences in how easy the different chargers were to use. The easiest being the Nokia charging plate with 1.27 average number of trials, and the hardest being the Tenergy dual charger with 4.14 average number of trials (Table 8.3). As the chargers were designed to work with smaller cell phones and not a 7" tablet, the standing chargers (Nokia charging stand, Tylt VÜ and the LG charger) required the tablet to be placed sideways to be able to charge. This was not obvious to the participants at first, but the results indicate that the participants gradually learned and increased their *literacy*, making the average number of trials to decrease as they tried more of the standing chargers. One obvious problem was that there was a delay from when the tablet was correctly placed on a charger, to its signaling that it was charging. This signal was essential for the participants in understanding when they had gotten the tablet to charge. Some participants were hasty in changing the position of the tablet, and the delay of the signal caused them to skip the correct position. All participants were able to get the tablet to charge on all models and maintain their *self control*, however the *intuitiveness* varied on the different charger models they tried.

The LightUp prototype did not require any action of the participants, it is a part of the natural movement of the user; corresponding with the performative action category of the framework presented by Hornecker et al. (2006).

## 10.3 Comprehending the information presented

The T-Radio prototype only had volume adjustment and a frame on top of it to indicate where the blocks should be placed. While the average times used to turn on a channel was 5.8 seconds, there was a few that used significantly longer time, where the one with the longest time used 21 seconds. The reason being that they did not understand where to place the block, and even though there was a frame on the radio, a few also placed the block next to it. Although the interaction itself is very easy, the prototype did not provide enough information on where the block should be placed in regard of *simplicity*. This did not inflict the performances of the majority of the participants, but more information should be considered to remove any doubt.

In the Payless prototype, all participants were able to complete a purchase and understand the concept. The participants were however showed where to scan their RFID key card if they had any doubt, as the RFID reader used did not have a housing and was only a circuit board. Similar to the radio, this prototype could have benefited from having better description of where they should scan their RFID key card. One participant had to switch to reading glasses to be able to see the information on the provided screen, indicating that it did not provide enough *physical and sensory support*. There were some different opinions on the necessity of a screen to show the order, where 14 out of 24 of the elderly participants (Table 7.2) and most of the expert users (Table 7.1) said that it is unnecessary. Multiple participants said that they would not have looked at the screen anyway. The total price was far more important. It is obvious that many elderly people want it as *simple* as possible, and that the screen were perceived as unnecessary information by many of the participants.

The Natural Charge prototype consisted of seven different chargers, and how *simplicity* and *physical and sensory support* were perceived therefore varied on the different chargers. The Zens and Tenergy chargers were the hardest to use as the participants had a hard time in understanding where and how the tablet should be placed on these chargers. They were also the only ones that actually provided some indication to where the tablet should be placed, as the other chargers just required the tablet to be placed on middle of the chargers. This indicate that these interfaces were not *simple* enough for the participants to understand the information presented, thus resulting in a higher number of trials. This is also supported by participants comments saying that it should be better indicated where to place the tablet.

The testing of the LightUp prototype indicates that I have missed the representation of the warmer temperatures. The warmer colors of the light bulb were perceived as normal, as people are used to having warm light. What the prototype do, is offering *physical and sensory support* to make it easier for users to see how cold it is. Comments from the usability tests (section 9.3) shows that there were several participants that did not see the advantage of such a system or did not feel that it were something they might have use for, indicating that prototype should aim for a more limited user group that is more prone to health challenges. However, one participant mentioned that the user still needs to be somewhat ambulatory to understand the meaning of the light. *Simplicity*, from our framework (section 4.4), is important to understanding how well the users is able to understand the information presented, meaning the light, although the participants in the usability tests did not seem to have any problems in understanding it.

## 10.4 Summary

I have identified design requirements and challenges designing for elderly users through the framework presented in 4.4. This framework also works to provide guidelines for design, by considering physical and cognitive changes that causes challenges when aging. In addition to more general concepts that empathize the importance of having user interfaces that is easy to understand and use. In addition, I can derive a few design implications from the analysis of the results:

**Limit information and functionality** to the most basic to provide interfaces that are easy to use. However, some information is essential to understand how to interact with the interface and may well be oversimplified. In the T-radio prototype, the information and functionality were limited and was easy to use, but some participants were unsure where the block should be placed, indicating that more information should be given on how to interact with the interface. In the Payless prototype, results show that the information could be even more limited by removing the screen, and that it need better information on where the RFID key card should be scanned.

**Feedback for every action** is essential in understanding the interaction. It should be provided instantly and be readily recognizable by the user, e.g. the feedback given in Natural Charge was important for the participants to understand when they had placed the tablet correctly, but delays gave problems for some participants that were fast in changing the position of the tablet. In the Payless prototype, not all were able to understand the feedback and scanned their RFID key card multiple times, although a sound was played for every scan.

**Adapt the interface to the users skills and needs** by compensating for the challenges of aging to increase usability. In Natural Charge prototype, the participants were introduced to an alternative way to charge tablets compared to using the preinstalled tablet with docking station at research context 1 (5.3.1). It reduced the need for fine motor skills, accuracy and muscle strength and were therefore easier to use and more adapted to their skills. In the LightUp prototype, there were multiple participants that did not like the concepts, indicating that it was not something they needed and that it should be aimed for a more limited user group.

# Chapter 11

# Discussion

## 11.1 Finding a framework for designing tangible user interface suitable for elderly people

My first objective was to identify design requirements and challenges designing for elderly users (section 1.2), which I have done through literature review, focus groups and interviews. This resulted in the framework presented in section 4.4. It uses the framework by Hornecker et al. (2006) as a base that I build on. They have some interesting elements in the framework, e.g. lightweight interaction, isomorph effects and tailored representations, that I have interpreted and looked about how the elements can be suitable for elderly people in section 4.3. However, the framework does not consider any challenges of aging and design implications for elderly users. Mazalek et al. (2009) states that tangible interaction frameworks focusing on domain-specific technology and experience are rare, but lists two of them. Zuckerman et al. (2005) focuses on tangible interfaces for education and Antle (2007) focuses on tangible systems for children. These frameworks focus on helping children to learn and falls outside of my scope, in addition to children being easy learners compared to elderly people. A process of learning to use a system is to be expected, but the focus should rather be on making the learning process as short as possible and provide very simple interfaces. The list provided by Mazalek et al. (2009) are from 2008 and more frameworks are likely to have emerged, however the only tangible interaction framework focused on the domain of elderly users that I have found is the one by Cho et al. (2013), although they only include general concepts that is useful for designing for everyone. A few of these concepts were however found useful and included in the proposed framework, in addition to different concepts revealed in chapter 3.

There are other frameworks on tangible user interface, e.g. Koleva et al. (2003) and

Wensveen et al. (2004) which are similar in the way that both focus on the coupling between physical and digital objects. The coupling is important for the user of an interface to understand the interaction, and I could have included some elements from the frameworks to better describe the coupling. However, the frameworks do not address problems regarding usability or user experience, which are important when designing for elderly people with reduced motor skills and fluid intelligence. Another framework by Jacob et al. (2008) focuses on peoples skills for interacting with the environment and others. The framework leads to some implications for design, e.g. accessibility, where they state that

> "There are many cases when reliance on strict realism can prevent some users from interaction, making the interface less accessible."

By considering the users skills, we could create interfaces more accessible for specific user groups. However, the framework is primarily descriptive and do not provide details of how it relates to user experience. The advantage of using the frameworks by Hornecker et al. (2006) and Cho et al. (2013) in creating the proposed framework (section 4.4) are that they include descriptions on how to measure the different concepts of tangible interaction, in addition to cover a broader view of what tangible interaction is.

The concepts regarding challenges of aging in the proposed framework may not cover all the bases, as it is directed at explaining the prototypes, and some concepts were moved to appendix A.1. However, the analysis of the results from the usability tests uncover that the framework to some degree have missed out a few important challenges that should be considered. These are the use of fine motor skills and cognitive challenges related to memory, and are relevant for what some of the prototypes compensate for. Some of the included concepts like *muscle strength*, *accuracy* and *fluid intelligence* can to some degree cover for the missing concepts, but they have proved to be important enough to require their own place in the framework.

## 11.2 How the prototypes assists elderly users

The T-Radio prototype was fairly easy to use, although I have not tested other commercially available radios to compare it with, but there are other that have done it. Thus meaning DAB radios as the FM broadcasting is scheduled to be phased out of operation within 2017 in Norway. Johnsson et al. (2013) found weaknesses in the interface DAB radios offers older users today (section 6.4.4). In a another project by Langdon et al. (2008), the results shows that even after training elderly people to use a DAB radio, and then introduce a new radio with identical interface but another layout, the time on task increased with 4 minutes. There is therefore a strong indication that many of the available DAB radios are not adapted to elderly users and their *digital literacy*. There are probably some exceptions and many radios have buttons that can be programmed to specific radio channel making it easy to change between these channels once programmed. However, I found through the interviews that the most prominent problem for many elderly regarding radios was to find the channel they wanted (appendix D.2.1). This is also a problem on the T-Radio prototype, as each channel needs to be programmed into a block.

The concept of the Payless prototype was generally easily understood by the participants, but the interaction was less understood in the way that many participants did not understand or perceive the feedback. In a system by Häikiö et al. (2007), where elderly people used a mobile phone with NFC technology to order meals by holding it close to a tag, feedback was given through text and through vibration on the mobile phone when an order was confirmed. It was also evident in this system that the feedback was not enough to clearly identify if the action was successfully completed or not, as most of them would hold the phone for an unnecessary long time close to the tag. In a system by Criel et al. (2011), large, visual feedback through picture and LEDs were used and were found to be very crucial for the elderly users understanding by giving them a sense of awareness and control of the environment. Feedback were also a problem for some of the participants when using Natural Charge as there was a delay from the participants placing the tablet on a charger, to its notifying that it was charging. This further empathize the importance of clear feedback, and something to look further into on the Payless and Natural Charge prototypes.

The results from testing the LightUp prototype shows that the participants perceived the colder colors of the light as cold, but the warmer colors were perceived more as room temperature as many people are used to warm light. This indicate that the representational significance, as described by Hornecker et al. (2006), is not strong enough, meaning that the physical and digital representations are not of the same strength and importance for the warmer temperatures. However, participants said that it could work as an indicator of how cold it is. Sharlin et al. (2004) states that successful TUIs contain successful physical/digital mappings, which would mean that LightUp is less successful as a TUI. I would not go so far to call it unsuccessful as the physical/digital mappings of the colder colors were well represented, but the mappings of the warmer temperatures may need further work.

Another thing to be considered is that people may have different perceptions of warm and cold. Fernaeus et al. (2008) states that most systems that adapt their behaviour based on inferences made from available contextual sensor data, assumes that the designer and the user of the system make the same interpretations of the sensor data. This is no necessary the truth and he states that

> "All interpretations must be understood through users' bodily experiences of being in the world"
> Fernaeus et al. 2008

Some people are more prone to be feeling warm, and some more prone to be feeling cold, and it therefore may not be a system that is universally representative for all. This does however not mean that the LightUp prototype cannot work as an indicator of the temperature, but it may be less accurate for some people. Alternatively the prototype could be made to learn an individual's bodily experience, Fernaeus et al. (2008) presents an example were a thermometer is used to determine the warmth of the water in a bath, and this could be meaningful if we interact with the device over time to create mappings between the numbers on the thermometer and our bodily experience.

Spreicer (2011) states that age-related impairments and hard to learn user interfaces prevent a high percentage of the elderly population from using new technologies. These technologies presented by the prototypes, were not observed as hard to learn or that any age-related impairments were of significant influence. Some performed the tasks better than other did, but that is to be expected. The main thing is that there were not any easily observable age impairments that caused the difference, and might be caused by differences in *fluid intelligence* and that people simply are different. Veldhoven et al. (2008) argues that even if coming generations of elderly users may be more capable of handling computers and new technologies, problems related to reduced fine motor skills and limited cognitive resources will always be an issue. The prototypes compensated for these problems and it were therefore hard to identify if any of the participants struggled with these problems. It was however evident that the participant struggling with severe arthritis had problems regarding fine motor skills, but had no problems using the prototypes.

## 11.3 Tangible user interfaces suitability in compensating for the challenges of aging

Spreicer (2011) states that ease of use and learning is the key factor for the acceptance and adoption of new technologies. His findings indicate that tangible design allows the development of easy to learn technologies that is suitable even for elderly users without prior computer knowledge. My findings are similar, as the learning process of using the T-Radio, Payless and Natural Charge were very short. Prior computer knowledge is not necessary relevant, but those that have it may have a higher *digital literacy* and be more prone to try other technologies as well, e.g. Häikiö et al. (2007) found that prior use of a mobile phone strongly correlated with the willingness to try a new application on the phone. However, I have included participants that have worked with computers and other technologies, and other participants where their technological expertise are limited to operating a TV and an old radio, and all were able to operate the prototypes without much trouble. It is hard to say anything about their willingness based on prior knowledge, as the prototypes introduced new ways for interaction. However, one participants compared the use of her golf card with Payless, and were able to understand the interaction and only used one scan. It can be a little thin to say something about the relationship between prior knowledge and their performance based on one participant, especially when the participants from research context 1 (section 5.3.1) did not understand the correlation between the way they open their apartment doors and the interaction with Payless.

The prototypes provided alternative interfaces and interactions to other technologies, giving the participants in the usability tests a basis for comparison and revealing some problems they have with the way they do things today. E.g. arthritis and fine motor skills make it harder to hit small buttons, cognitive changes make it harder to remember their PIN code, and that loss of *accuracy* combined with *muscle strength* make it harder to place a tablet in a docking station. These are some of the problems that the prototypes have compensated for, and are consistent with the findings of Ijsselsteijn et al. (2007), stating that interface design for elderly users should minimize the burden on functions that may have suffered decline. Spreicer et al. (2010) states that age-related changes in cognitive or sensory functions make it difficult to use traditional user interfaces, e.g. a graphical user interface on a computer. Tangible user interfaces opens the possibilities to compensate for many age-related challenges, as demonstrated by the prototypes. There are possibilities to build on already known artifacts to enhance their understanding, or create entirely new interfaces. Criel et al. (2011) states that it is essential to provide elderly with technology that offers tangible and mechanical experience, e.g. pressing a button or turning a knob is preferred over using a touch screen. However, elderly people are a heterogeneous group with different preferences, but tangible user interface shows great potential in providing interfaces that are easy to use.

## 11.4 Discussion of extracted design implications

### 11.4.1 Feedback for every action

Hornecker et al. (2006) emphasizes the importance of feedback through their concept of lightweight interaction, where feedback should be given to the user for every action that is performed. The T-Radio prototype gave instant feedback when a block was placed correctly, by playing the selected radio channel. Natural Charge gave feedback in form of a sound signal when the tablet was placed correctly on a charger. This worked well, except that there was a delay from when the tablet was placed to the sound being played, causing problems to some participants that were fast in changing the position of the tablet. In the Payless prototype the feedback seemed less successful as there were many participants that scanned the RFID key card many times. As discussed earlier, Häikiö et al. (2007) and Criel et al. (2011) also empathize the importance of feedback.

> "It is essential to provide consistent, *large* and *visual* feedback that are recognisable to seniors so that they know what is happening around them and how they can control it."
> Criel et al. 2011

It can be given in form of text or images on a screen, auditory, blinking lights, tactile (vibration) or other forms, preferably a combination of these forms to provide *physical and sensory support*. It is also important that any delays should be minimized to prevent confusion.

### 11.4.2 Limit information and functionality

As stated in section 3.2.3, elderly people are less able to select information in the environment, and are more subjected to be overflown with information, which can cause confusion. It is therefore a need to limit the presented information in regard of *simplicity*.

> "Where 'upgrading' products seems to be the tendency for modern electronic devices, in terms of user needs and system functionality, 'downgrading' would be more appropriate designing products for elderly users."
> Veldhoven et al. 2008

Veldhoven et al. (2008) states that the usability can be improved by limiting the complexity of a prototype to a basic level. In my prototypes, I have already limited the functionality and information, apart from the varied opinions about the necessity of a screen in the Payless prototype, and it was therefore not a problem. Some information are however essential for understanding how to interact with an interface, e.g. the T-Radio lacked explicit information about where the block should be placed, and the Payless prototype could have benefited from better description of where the RFID key card should be scanned. In the testing of the Natural Charge prototype, multiple participants said that they missed better information on where tablet should be placed on the different chargers. Two of the chargers had some information on where the tablet should be placed, but these chargers were also the hardest to use, indicating that the descriptions were not easy and visible enough. Nonetheless it is important to limit information and functionality to the most necessary, which can make interface easier to understand (*simplicity*), have a shorter learning process (*intuitiveness*) and let the users be in control (*self control*). The testing of commercial radios done by Johnsson et al. (2013) and Langdon et al. (2008) shows that too much information and complicated functionality can cause severe usability problems.

### 11.4.3 Adapt the interface to the users skills and needs

The elderly people struggles with different challenges and some are lucky to be less affected by some challenges of aging. In the summative usability tests, I found little evidence for an obvious link between the participant's performance on the task and their age. There were some that struggled more than others did, and a couple of them were in their 80s, but there were also multiple participants around the same age that had less problems. Findings by McCreadie et al. (2005) indicate that chronological age is far less important than people's felt need. It is therefore important to not put everyone in the same category, based on his or her age. It is for example evident in the tests of the LightUp prototype, where the opinions of its usefulness varied. There are however many challenges of aging that is relevant for the larger part of the elderly population, and interfaces should be adapted to these challenges and be designed after the users need, or as stated by Ijsselsteijn et al. (2007)

> "... interfaces should be adaptable to compensate for particular functional limitations (sensory, motor or cognitive) of elderly users"

In the testing of prototypes, e.g. T-Radio and Payless were perceived as easy interfaces as they did not require the use of fine motor skills, heavy use of cognitive functions, *accuracy* or *muscle strength*.

## 11.5 Validity

### 11.5.1 Representation and recruitment

In the summative evaluation (section 5.6.2) of the prototypes, 25 participants ranging from 68 to 90 years old were involved. The 16 participants from research context 2 (section 5.3.2) were considered relatively healthy as none of the used walkers and they lived in their own houses or apartments. The 9 participants from research context 1 (section 5.3.1) showed more evidence of age impairments, as most of them were in need of walkers or wheelchairs and one participants struggled with arthritis. It raises the question whether this group is representative in evaluating design solutions for assisting senior citizens living situation. People age differently and the diversity is not easily represented without including a large number of participants. I have captured some of this diversity, but it would be interesting to see how participants with even more severe age impairments would have evaluated the prototypes. The elderly people are so different that I could have chosen 25 other participants from the same places and get different results, thus the reliability are low.

It was evident that recruiting older people to participate in a usability test were challenging, especially at research context 1 (section 5.3.1). The main difference between the participants at the different research contexts, is that those at research context 1 were generally less healthy than those from research context 2 (section 5.3.2), and is a factor to be considered when understanding the differences in recruiting.

Four users left before completing all the tests in the summative evaluation. One user left after testing the T-radio and said that he could not bear to do anything computer related after having several strokes, and I was not able to convince him that he did not have to do anything computer related before he left. Another user left before testing Natural Charge. He was a 90-year-old civil engineer that was more interested in the technology, which he did not understand, and was more interested in how they made the tablet than using the chargers. Two other participants that tested the prototypes together, left before testing LightUp. One of them said that she did not have the time to test anything more and then both of them left. When I talked to her later, she apologized for leaving so fast and said that the testing was not as she had thought. *Anxiety* is a probable a factor in why these participants left, although they did very well before they left. This was also evident when I tried to recruit some participants, where a common answer was:

> "I am not so good at using technology and computers"

It was not a requirement to be good at anything, on the contrary, as I wanted to see how easy the prototypes were to use by those with less experience in use of technology and computers. I was able to convince a few by further explaining the prototypes, but some simply did not want to try. This were also evident in the tests by Veldhoven et al. (2008) where several potential test subjects decided not to participate, since they were scared of new technology. Many elderly also have a limited opportunity to participate, resulting in fewer participants on some of the methods, e.g. focus groups, workshops and contextual interviews.

### 11.5.2 Ecological validity

The Payless and LightUp prototypes are limited by low ecological validity, as they were not tested in a real life context. Payless should be tested in a real canteen where the users could purchase and get food and beverages, or at least get the illusion of it so the users would get a better impression of how it worked. The LightUp prototype were difficult to test by only looking at it for a few minutes, and would need to be tested over a longer period in a house or apartment of a potential user, to truly find out how useful it is. However, this prototype also had some technical difficulties that prohibited this option, but are something to be considered in a future project if the prototype is more stable.

### 11.5.3 Measurements

Measurements in the summative evaluation were done to understand the usability of the prototypes and if it can help senior citizens living situation, and I have through analysis, showed how the results relate to the initial goal. It could be interesting to measure time on task on the different chargers, in Natural Charge, but I was limited to being only one to person to facilitate the tests, and I found it challenging to talk to the participants and record data at the same time. One question regarding security of the Payless prototype were a little outside the scope, but it proved important as many participants mentioned issues regarding security before the question came up. The participants were generally very positive to the concepts of the prototypes, and some negative to the LightUp prototype. However, the Halo effect[1] were not taken into account and may have inflicted the results and caused cognitive bias. There are also the Hawthorne effect (Preece et al. 2002, p. 356), that also not been taken into account and might have caused the participants to act differently because they were aware that they were being observed, e.g. affected their *anxiety* and willingness to participate.

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[1] *Halo effect* is a term used to describe situation were an evaluator's perception of a feature affects the perception of other features

# Chapter 12

# Conclusions and future work

This chapter summarizes the work and contribution of this thesis. A brief overview of the whole process is given, and a summary of the most important findings in this thesis are then presented. Finally, the possible directions for future work of the prototypes with results and implications from this study are considered.

## 12.1 Summary

This thesis has investigated how tangible user interfaces can assist senior citizens, first by reviewing related work and theory of age impairments. Frameworks on tangible user interfaces were investigated in their suitability to compensate for age impairments. Then, the common challenges of aging were put together in proposed framework, based on previous frameworks (Hornecker et al. 2006; Cho et al. 2013). In addition to conducting focus groups, contextual interview and workshops, four different prototypes were created to compensate for different age impairments using tangible user interfaces. These prototypes were taken through formative usability tests with experts from the HCI community, and the prototypes were improved based on the results. Then summative usability tests of the prototypes were conducted with potential users at two different sites; a local care home and a senior center. The results from these tests gave a basis for analysis on how the prototypes were able to help the elderly, by using the proposed framework. The analysis led to three problem areas that were investigated, before the implications for design were presented.

## 12.2 Contribution

The purpose of this thesis has been to investigate how tangible user interfaces can assist elderly peoples living situation. The work in this thesis has been based on four main objectives: (1) identify design requirements and challenges designing for elderly users, (2) develop prototypes using tangible user interfaces, (3) demonstrate how tangible user interfaces can compensate for the challenges of aging, and (4) find design implications of tangible user interface for elderly users. The main contribution being the proposed framework (section 4.4) that uses concepts of aging combined with concepts of tangible user interfaces to provide some guidelines in designing for elderly users, in addition to being useful to analyze results from usability tests. I have also demonstrated how different prototypes using tangible user interfaces can compensate for age impairments, and how they are compared to the way they do things today (e.g. payment in a canteen, charging a tablet), showing that there are great potential in tangible user interfaces for doing things easier or different than today. The analysis of the results from the usability tests leads to three design implications for designing for elderly people (section 10.4).

## 12.3 Findings and design implications

The prototypes were well received by the participants in the usability tests, although not all liked the concept of LightUp. The learning process was found to be very short by observing the participants performance in using the prototypes, showing some of the potential in using tangible user interfaces. There were however a few problems that were observed in multiple of the prototypes, including indistinct feedback, missing information about how to interact with the system, in addition to no clear consensus about the screen in the Payless prototype. The proposed framework (section 4.4) has shown to be useful as guidelines for design and assisting the analysis. Further analysis led me to three design implications for designing for elderly users:

- Limit information and functionality
- Feedback for every action
- Adapt the interface to the users skills and needs

## 12.4 Future work

In this section, further implementations of the prototypes are suggested and explained.

### 12.4.1 T-Radio

In the design of the T-Radio prototype, I have only considered the interaction of turning on a predefined set of radio channels. Thus, the use of other channels has not been considered, and it is therefore not possible to play other channels in the prototypes current state. In a future prototype, a better solution would be to store the Internet address of the radio channels directly inside NFC tags of the blocks, and make the radio read this address to play a radio channel. This would make it easier to create new blocks that represent other radio channels. The blocks could then be easily programmed with a NFC-enabled smartphone. However, this means easy for me or other familiar with the NFC technology, and is less likely to be easy for most elderly users. Thus, the elderly users would still require help in programming the channels they wanted. It could be possible in my prototype to provide a easy system or smartphone app for programming the blocks were made to program the blocks, but they would still need to go through a long list of radio channels to find the one they wanted. Another solution would be to provide a large amount of blocks were each would represent different radio channels, but this would require a lot of space to store them. The results do however show that there are a limited number of channels that the elderly users listen to. The prototype should however include better description of where the blocks should be placed, either with text, icons or other visually visible signs. The volume control should also have more detailed description of what the highest and lowest point is.

### 12.4.2 Payless

In a future prototype, the RFID reader should get a plastic housing with a logo or text to indicate that they scan their RFID key card here. To further emphasize that the reading of the RFID key card was successful, in addition to the sound signal, I would add green LED lights that blinked when the RFID key card was scanned. It should also not be possible for the users to scan their RFID key card more than one time, as it would then be up to the cashier to accept or decline the user. However, it was informative to let the participants scan their RFID key card multiple times in the usability tests to see how they understood the interaction.

Although there have been some different opinions regarding the position of the scanner in a canteen, depending on where they keep their key card, I would place the reader at a low position next to the credit card terminal. The reason being that there are several residents at research context 1 (5.3.1) that uses a wheelchair, although this may depend on the different sites. Another viable solution would to have the reader on an adjustable arm, as suggested in the formative usability test (section 7.2), but then it would also require the cashier to adjust the arm depending on the user.

There have also been some different opinions on the necessity of a screen to show the order. However, as 14 out of 24 of the elderly participants (Table 7.2) and most of the expert users (Table 7.1) say that it is unnecessary, I therefore deem it as not important in a future prototype as long as the total price is clearly visible.

### 12.4.3 Natural Charge

In a future prototype, more information should be provided on how the tablet should be placed, e.g. with clear marking or text. To further empathize where the tablet should be placed, a small frame could be used. It would however be a frame customized for a specific tablet, unless the frame was adjustable. To make it easier to understand when the tablet is correctly placed on a charger, the delay before tablet plays a sound to signal that it is charging, should be minimized. There is also the possibility to integrate the chargers into furniture, e.g. the wireless charging from IKEA [1]. It would then be possible to lay the tablet on the nightstand, on a dresser, table or other furniture a charger can be built into. It will be interesting to see how the Qi wireless charging technology are developing, as more high-powered chargers are planned (section 8.1.2), which hopefully will enable us to provide wireless charging to the existing tablet at research context 1 (section 5.3.1).

### 12.4.4 LightUp

When I designed the LightUp prototype, several ideas of how it would work surfaced. The prototype were used to measure room temperature for adjusting the lights, as this were more easy to make work and that I did not know how the representation of the light would be perceived. The temperature sensor is wireless, which may seem unnecessary for measuring room temperature, but the ideal solution was to measure body-temperature and thus a wireless sensor is good to be able to further expand the functionality. Then the body temperature of the users could automatically function as input to the heating- and ventilation control systems in their apartment. Skin-temperature could be monitored through a watch or something similar, but the skin is more prone to be warmer where you have the watch and the question of how the bodily temperature should be measured is still unanswered and something to look further into. Another thing to be considered is that people may have different perceptions of warm and cold and the prototype should be able

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[1] `http://www.ikea.com/no/no/catalog/categories/departments/wireless_charging/`

to adapt to the individuals preferences.

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# Appendix A

# Framework

## A.1 Framework

Table A.1: Additional elements for the proposed framework

| Hornecker et al. 2006 | Concept | Health challenge | Evaluation criteria |
|---|---|---|---|
| Full body interaction | Endurance | Reduced ability to sustain prolonged activity | To what degree Is the user able to complete a task of prolonged activity? |
| Full body interaction, Inhabited space | Elasticity | Reduced lung capacity and efficiency of walking | To what degree the user is able to physically move in the environment? |
| Inhabited space, Full-body interaction | Muscle power | Declines in muscle strength and speed | To what degree is the user able to physically move around in the environment? |
| Isomorph effects, performative actions | Crystallized intelligence | (Not a health challenge, ability to exploit previous knowledge) | Is the user able to recognize the system or the interaction and understand what it is? |
| Tailored representation | Accessibility (Cho et al. 2013) | Reduced fluid intelligence and increased anxiety | To what degree is the user able to move freely in the system? |

# Appendix B

# Forms

## B.1 Informed consent

### Forespørsel om deltakelse i forskningsprosjekt

**Bakgrunn og formål**
I forbindelse med min mastergrad gjennomfører jeg et prosjekt hvor jeg ønsker å undersøke brukbarheten av ulike prototyper laget med tanke på eldre. Hensikten med prosjektet er å undersøke hvordan ny teknologi kan gjøre eldre brukeres hverdag lettere. Prosjektet vil bli utført av undertegnede i samarbeid med min veileder ved institutt for informatikk ved universitetet i Oslo.

**Deltagelse i prosjektet**
Deltagelse i prosjektet innebærer at jeg ønsker at du skal være med å brukerteste fire ulike prototyper og svare på noen spørsmål underveis. Prototypene består av en radio som bruker klosser til å velge kanal, en betalingsløsning for en kantine ved bruk av RFID kort, trådløs lading av nettbrett ved bruk av induksjonsladere, og et lys som endrer farge (kald og varm hvitfarge) etter hvor mange grader det er. En gjennomgang av alle prototypene tar normalt 15 til 20 minutter. Det er frivillig å delta og du kan til enhver tid trekke deg og din samtykke tilbake: både før, under og etter din deltagelse i prosjektet, eventuelle opplysninger om deg vil da bli anonymisert.

**Innsamlingsmetoder**
Under utførelsen av brukertestene vil det gjort observasjoner, samt stilt noen spørsmål der svarene vil bli notert med penn og papir. Disse notatene ønskes supplert av bilder. Du kan frabe deg å være med på bilder og/eller frabe deg at visse informasjoner noteres.

**Anonymitet**
Deltagelse i prosjektet krever ingen form for persondata. All informasjon anonymiseres, bilder vil sensureres og vil ikke kunne tilbakeføres til deg. Hvis det skulle være noe personidentifiserbar informasjon, er det kun meg og mine veiledere som vil kunne ha innsikt i denne informasjonen. Veileder vil også kunne få innsikt i notater og usensurerte bilder. Utover dette er det ikke andre som har tilgang til denne type informasjon, som du har gitt, og som enda ikke er bearbeidet. Personnavn vil ikke fremgå noe sted. Resultatene av studien vil bli publisert som gruppedata, uten at den enkelte kan gjenkjennes. Prosjektet forventes å avsluttes sommeren 2015.

Studien er meldt til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste AS.

Har du spørsmål i forbindelse med denne henvendelsen, eller ønsker å bli informert om resultatene fra undersøkelsen når de foreligger, kan du gjerne ta kontakt med meg på adressen under.

Med vennlig hilsen

Prosjektleder
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*Samtykkeerklæring*
Jeg gir herved min samtykke til å delta i forskningsprosjektet. Kryssene i feltet nedenfor angir om jeg ønsker å være med på bilder og om jeg ønsker å se gjennom notater.

Jeg godkjenner bruken av bilder:
Ja [ ]
Nei [ ]

Jeg har lest og forstått ovenstående og ønsker å delta i dette forskningsprosjekt:

| | |
|---|---|
| ............................................................ | ................................................................ |
| Dato/sted | Signatur |

## B.2 Evaluation plan for formative usability tests

Brukertest

Tenk høyt. Si det du gjør.

### Radio

Radioboksen er kun for å illustrere en radio og for å spille av musikk gjennom høyttaleren.

Test 1:

1. Sett på en radiokanal
2. Stopp avspilling av radiokanal
3. Sett på en annen radiokanal

Test 2:

1. Markering av hvor klossen skal plasseres. Hvor burde klossene kunne plasseres?
2. Hvordan burde området der klossen skal plasseres markeres? Markert område, opphøyning eller ramme på toppen. Eventuelt hvor høyt? Eller hvor stort?
3. Hvordan burde klossene se ut?
4. I hvilket materiale? Størrelse?

Spørsmål:

1. Hvordan funket prototypen?
2. Er det noen funksjoner du savner? Knapper, skjerm?

### Lys

Lyset endrer seg etter temperaturen. Dette skal gi en indikasjon for eldre på hvor varmt det er.

Test 1:

1. Gjør sensoren kald ved å legge den i is. Se på lyset.
2. Hvilken temperatur passer lyset du ser nå til?

Test 2:

1. Gjør sensoren varm ved å holde en finger over den. Se på lyset.
2. Hvilken temperatur passer lyset du ser nå til?

Spørsmål:

1. Hvilken farge passer til nåværende romtemperatur? Kaldere eller varmere?

2. Hvilken farge passer til temperaturen ute?

3. Er endringene i lyset tydelige nok eller burde skalaen endres?

4. Hvilke romtemperatur er passe?

5. Når er det kaldt (inne)?

6. Når er det varmt (inne)?

## RFID butikk

Dette er en betalingsløsning beregnet for eldre i en kantine der RFID kort brukes som ID.

Test 1:

1. Stell deg i kassen med et ID-kort.
2. Følg instruksene på skjermen.
3. Identifiser deg.
4. Vent på godkjenning.
5. Gjennomfør et kjøp.

Spørsmål:

1. Var det lett å gjennomføre et kjøp?

2. Føles det som en sikker løsning?

3. Noe som burde være annerledes?

4. Layout? Tydeligere beskjeder? Tydeligere Ordreinformasjon?

Test 2:

1. Tenk at tavla er kantina og du skal betale.
2. Hvor ville du helst hatt leseren om du hadde ID-kortet rundt halsen? Marker på tavla både eksakt punkt og ring rundt akseptabelt område.
3. Hvor i forhold til leseren ville du hatt skjermen som viser ordre og sum? Marker.
4. Ville du hatt leseren og skjermen et annet sted hvis du hadde ID-kortet i lomma? Marker.
5. Ville dette endret seg hvis du tenker at du er gammel?

## Induksjon

Vil introdusere induksjonslading for eldre, siden flere sliter med koble til små kabler og å sette en Tablet-PC i docking stasjon.

PS: Det er litt forsinkelse fra du plasserer enheten på platen, til den registrerer at det lader. Lager lyd når den begynner å lade og når den stopper.

Test 1:

1. Prøv å få enheten til å lade på alle ladeplatene.

Spørsmål:

1. Hvem er enklest å få den til å lade på?
2. Hvem likte du best?
2. Er dette noe du kunne tenkt deg å bruke? (Hvis du ikke allerede bruker det)

## B.3 Evaluation plan for summative usability tests

### Radio:

**Test:**

1. Prøv å sett på en radiokanal
2. Måle tid brukt på å sette på en kanal
3. Antall feil gjort. Både uhell og med vilje.
4. Kommentarer: utseende og funksjonalitet

**Spørsmål**

1. Hvor lett var det å forstå funksjonaliteten?
2. Hvor lett var det å sette på en kanal og plassere klossen?
3. Hvordan er denne radioen i forhold til den du bruker til vanlig?

### Payless:

**Test:**

1. Gjennomføre et kjøp
2. Antall feil gjort og nøling.
3. Kommentarer: utseende og funksjonalitet
4. Passe høyde i forhold til deres plass å ha kortet?

**Spørsmål:**

1. Føles det som en sikker løsning?
2. Forsto du hva som sto på skjermen?
3. Hvordan er dette i forhold til vanlig betaling?

## Induction:

Vise hvordan laderen fungerer og ta utgangspunktet i deres nettbrett.

**Test:**

1. Prøve å bruke alle laderne.

2. Antall feil, små justeringer for å få den til å lade.

3. Kommentarer: utseende og funksjonalitet

**Spørsmål:**

1. Hvem likte du best?

2. Hvem var lettest og mest naturlig?

3. Var det noen problemer? Noen som var vanskelige?

## LightUp:

**Test:**

1. Vise kald og varm farge og spørre hva de synes om representasjonen

2. Er fargen varm eller kald nok?

3. Kommentarer: funksjonalitet

**Spørsmål:**

1. Justerer du varmen på rommet eller er det automatisk?

2. Tror du lyset ville hjulpet deg å se hvor varmt eller kaldt det er?

# Appendix C

# Conference paper

## C.1 Paper on spatial interaction

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6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

# Exploring Spatial Interaction in Assistive Technology through Prototyping

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**Abstract**

This paper reports from usability testing of four particular prototypes designed for elderly people. The prototypes use Tangible User Interfaces (TUI) to provide alternative interactions that are more suitable for elderly people. TUI opens up possibilities of making technology more available to elderly people and can take age impairments into consideration by creating systems that are more adapted to the specific user group. We use the framework of Hornecker and Buur to categorize our prototypes within the theme of spatial interaction. This is seen as a subcategory of TUI where the humans and objects in space is central, and how the relationship and interaction between human and objects interplay. We explore how we can investigate spatial interaction during prototyping of assistive technology for elderly people through the four prototypes from our own empirical context.

*Keywords:* Tangible Interaction; Spatial Interaction; Elderly People; Assistive Technology

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### 1. Introduction

Tangible User Interfaces (TUI) is a broad term involving many different forms of interaction. The aim of this study is to look at how TUIs can impact the design of assistive technologies for elderly people to help compensate for age-related impairments. Findings presented by Spreicer [1] shows that tangible design allows for the development of new technologies that are easy to learn and suitable for elderly users without prior knowledge of technical systems. As presented by Ishii and Ullmer [2], TUIs are interfaces that connect digital information to physical objects and

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environments. Hornecker and Buur [3] argue that there is a broad range of systems that falls in the category of tangible interaction and present a framework for TUI consisting of four different themes. In this paper, we focus on the theme of spatial interaction. This theme is described as interaction that uses your own body or objects in space, and uses the positioning of these objects or the body as a form of interaction. The goal of this paper is to explore how we can investigate spatial interaction during prototyping of assistive technology for elderly people based on tangible interaction. We start by looking at how spatial interaction is defined as a part of tangible interaction in related work. We then look closer at related work to find examples of tangible interaction used in the context of assistive technology that lies close to the theme of spatial interaction. We use the framework by Hornecker and Buur [3] and the five categories that make up spatial prototyping to help facilitate a usability test of our own prototypes. The method and prototypes are described before reporting from the results of the usability test. The paper ends with a discussion of spatial interaction.

## 2. Spatial Interaction

Sharlin, Watson, Kitamura, Kishino and Itoh [4] focus on the relationship between human and physical objects and present three heuristics; physical/digital mappings must be successful spatial mappings, unify input and output space and enable trial-and-error activity. They further define spatial TUIs as a "subset of TUIs that mediate interaction with shape, space and structure" (p. 338), and state that TUIs can exploit previous knowledge of how people acts in their environment, using abilities learned early in life. Using these abilities along with intuitive spatial mappings of physical objects, we can create successful TUIs. Another definition of spatial interaction is presented by Cho, Kim and Kim [5] who has gathered key properties of TUIs to create a framework focused on elderly people. This framework includes spatial interaction and is defined as "skills for controlling and coordinating within their environment, while being aware of their own physical bodies" (p. 50). Fernaeus, Tholander and Jonsson [6] describe TUIs as a shift from an information-centric to an action-centric approach. A more philosophical view is chosen where physical artifacts are understood as having "deeper social and personal purposes in shared, collaborative space of physical and bodily activity that users engage in" (p. 225).

Kim and Maher [7] focuses on spatial cognition, but states that the "meaning of 'space' to the designers is not an abstract of empty space, but rather of the identity and the relative locations of the objects in space" (p. 83). Space can be seen as something that can be decomposed into objects and the spatial relationship among these objects, to let a design be able to satisfy intended functions, these relationships may have functional reasoning. They also state that touch can be referred to as a spatial modality, accentuating its close linkage between motor and spatial processes. Klemmer, Hartmann and Takayama [8] suggest that the purposes of tangibility is to provide natural mappings and leverage our familiarity with the world, and exemplifies this with using virtual objects positioned in virtual space by moving physical handles in physical space. They state that a "body-centered view looks at how the actions that we perform with a system contribute to task transparency" (p. 142). Marshall, Rogers and Hornecker [9] study how TUIs can facilitate learning and how sharable interfaces support participation in a group setting. Theor work suggests that TUIs can offer learning benefits in collaboration through shared space that can increase visibility of action, increase awareness and learning. It can also enable users to manipulate physical artefacts outside the interactive space to help with social organization and planning.

### 2.1. Tangible interaction as assistive technology for elderly people

Gamberini et al. [10] have created an interactive tool consisting of a tabletop computer with pens to interact with the table in order to engage elderly people in social activities and training of specific cognitive abilities. Jung, Kim, Park and Kwon [11] also created a tabletop game with multiple tangible objects. The system is designed to both improve gross motor skill and cognitive functions, and a cookie making game was designed for the system. Five experts evaluated the system found it suitable for cognitive training. A prototype of another tabletop game based on the Air Hockey was created by Marques, Nunes, Silva and Rodrigues [12] and aimed to stimulate cognitive and motor systems. Results indicate that tangible objects can be a viable option to stimulate cognitive function and motor skills, and that those with greater decline in motor skills often moved their arm energetically without being told to do so. In a paper by de la Guía, Lozano and Penichet [13], the focus is also on cognitive rehabilitation. Their system uses

NFC tags paired with pictures, a NFC reader, monitor and a touch screen for making games. The system is designed to provide cognitive rehabilitation and stimulation for patients with Alzheimer and dementia. Criel, Geerts, Claeys and Kawsar [14] are however more focused on everyday activities and use NFC cards to let elderly people program their own smart house behavior. This system helps elderly people to remember and it can be used to turn on the light above the garbage can to help elderly remember to take out the garbage. Häikiö et al [15] also use NFC technology and investigate user experiences of elderly people using a touch-based system for ordering meals, where the user scans a NFC tag representing a meal with their phone. This paper takes some age impairments into consideration and state that impaired motor skills do not prevent or complicate the use of the system. The system can also reduce the cognitive load by allowing a direct and natural interaction.

## 3. Framework for Spatial Interaction

Hornecker [16] presents parts of a design framework for collaboratively used tangible interactions systems, and mentions spatial interaction as an interaction that is embedded in real space. We are spatial beings that live and meet each other in space, and our body is a reference point for perception. "Spatial interaction is observable and often requires performative aspects" (p. 26). Design of TUIs can use the qualities of space and the resources it offers. Hornecker and Buur [3] further developed a design framework for tangible interaction consisting of four themes; tangible manipulation, spatial interaction, embodied facilitation and expressive representation. Our focus is on spatial interaction which in this framework is divided into five concepts: inhabited space, configurable materials, non-fragmented visibility, full-body interaction and performative action.

*Inhabited Space (IS)* refers to if the space is a meaningful place, and if people and objects meet. This concept should not be a problem regarding any age impairments, as long as you have the ability to meet objects. This concept covers a lot of ground as long as there is a meaningful place, and there are systems covering these concepts that are not suitable for elderly, but it is not easy to point out any age impairments directly involving this concept. *Configurable Materials (CM)* refers to the meaningful re-arrangement or movement of materials in the environment. This does not only include movement of objects, but can also include the movement of your body. This concept is in many ways wide and there are multiple age impairments that can complicate the use of this concept, depending on the system. Declines in motor control can make it hard grab small or big objects [17], and if your struggling to move it can be hard to use the interface if its relies on the movement of the body. Declines in working memory [18] can make a system that involves multiple steps that need to be followed complicated, and declines in spatial cognition can cause more trial and error if the system involves placing objects in a very strict way. *Non-fragmented Visibility (NFV)* refers to a space's ability to allow everybody to see what's happening without fracturing the picture. Visual impairments can make it harder to see, but systems should compensate for that. It can also be harder to follow the visual reference with declines in the working memory. The tabletop game mentioned [10] in the previous section is a good example of non-fragmented visibility where everybody can see whats happening on interface. *Full-Body Interaction (FBI)* involves large and expressive movement that has a meaning in interacting with a system. This can involve the use of your whole body. The use of large movement or the whole body is significantly harder for elderly with motor impairments or muscle weakness which is a dominant risk factor for falls [19]. *Performative Action (PA)* refers to that your actions or movement can be used as a communicative effect which can be used to trigger an action. The most prominent age impairment would in this case be motor control. Actions that previously was easy to do can get harder with increased age because of declines in sensitivity and motor control, forcing the use new actions.

## 4. Method

In this section, we present four particular prototypes from our own empirical context. We use the framework from the previous section to categorize our prototypes within the theme of spatial interaction. For each prototype we have used traditional aging symptoms and the aforementioned framework to derive metrics that can help us investigate and analyze the different spatial aspects of the prototype. The prototypes have been tested through a formative usability test in controlled environments in our design laboratory. We recruited a gender-neutral group consisting of 14 participants from the HCI community, namely faculty, research fellows and graduate students, and the aim of the study was to explore whether building test metrics around the spatial aspects of the prototype could provide insightful feedback on the design of our prototypes.

### *4.1. Empirical context*

This study is part of a larger long-term research project focusing on newly acquired welfare technology in local care homes in Oslo Municipality, and the prototypes are designed to fit the smart homes of elderly people residing in their individual apartments in a local care home facility in Oslo. The local care home consists of 91 individual apartments for elderly people, and is organized with common reception, cantina and recreation room. Outside of their apartments they have immediate access to basic services such as hairdressing, foot therapist, gym and cinema, and they also have a cantina where they serve dinner every night. The local care home aims to be a smart house, and each apartment is built to actively utilize technology in order to prolong the time elderly people can remain independent in their own homes before being admitted to a nursing home. Each individual apartment comes pre-installed with a set of new technologies, including automated lighting, heating and ventilation control, stove guard, electrical sockets with timers, motion sensors in all rooms, video calling, door locks with radio-frequency identification (RFID), and a customized tablet.

### *4.2. Prototypes*

*T-Radio* is a regular radio that is operated with the help of wooden blocks. Each wooden block carries the logo of a radio channel and when placed on top of the radio, the radio plays the corresponding channel. Removing the wooden block turns off the radio. The volume is set to a predefined level selected by the user, and should accordingly not require adjustment under normal circumstances. The design idea behind the radio was to simplify the required interaction from elderly people who wanted to listen to the radio by removing small buttons and difficult frequency sliders. Elderly people suffering from decline in fine motor skills struggle with smaller buttons and fine-tuning mechanisms, and remembering and adjusting frequencies require cognitive abilities beyond the active capabilities of many of the elderly people within our empirical context. As the analogue FM broadcasting is scheduled to be phased out of operation within 2017, operating a radio will require even further cognitive capacity as users will have to learn new frequencies to find their favorite channels. Finally, many current commercial radios have too small print or screen text for elderly people suffering from visual impairment to read, and by removing the need for buttons and screens, it only requires physical configuration of a wooden block to function. The screenless and buttonless interaction mechanisms and the design of the T-Radio requires only placement of blocks on top of the radio and we have placed it in the *configurable materials (CM)* category.

*LightUp* is a prototype built to help elderly people with regulating the heating levels in their homes, as well as adjusting the color intensity of the light in the home based on how the residents are feeling. By equipping elderly residents with a temperature sensor, their body temperature can automatically function as input to the heating- and ventilation control systems that are preinstalled in their apartments. In addition, LightUp can adjust the lighting in the room to reflect on the body temperature of the resident by automatically adjusting the lighting in the room when the body temperature moves outside normal levels. One or more specially designed light bulbs adjust their intensity (Kelvin) based on how cold or warm the person is feeling. If the resident is feeling cold, the bulb will turn to a colder color (9000K), and if the person is feeling warm, it will fade to a warmer color (2500K). The idea behind LightUp is to assist the prospective memory of elderly people suffering from cognitive disabilities by actively reminding them to adjust the temperature in the room, and if they were to forget, it can automatically set the correct temperature for them. In addition, we see that elderly people undergo dips in their metabolic rate and therefore end up feeling colder and may simultaneously be more exposed to related illnesses such as hypothermia. Since LightUp does not require any actions itself, it is a part of the natural movement of the user; hence we have placed it in the *performative action (PA)* category.

The elderly people staying at the local care home currently have to pay per meal when they eat their dinner in the common cantina. Similarly, the have to pay for hairdresser, foot therapy, trainer and other services they use within the local care home. The goal with *Payless* is to extend the use of their personal RFID key cards that currently unlock their apartment with payment functionalities. We want to build on this card as it is already a wearable device that all residents carry around their neck at all times, and its use does not introduce any new interaction mechanisms. Payless has the potential to be of great use to elderly people who are struggling with manual payment due to reduced fine motor skills, difficulties remembering their PIN, or trouble with screens due to visual impairment, to use services around in the local care home that requires payment. Safety is ensured by having the key card display an image of the owner behind the cashier's desk, and the cashier can verify their identity before approving the purchase. The card itself has no value outside of the local care home. The rest of the setup involves a big screen behind the cash register where the elderly person can verify the amount before beeping their RFID key card at the cashier's desk for moneyless purchases. Because this prototype finds its meaning in situated places rather than spaces, and we believe this prototype to further enhance the atmosphere of the place in which it exists, we argue that this prototype belongs in the *inhabited space (IS)* category.

Each apartment currently comes preinstalled with a 10" tablet that helps the elderly people arranging, planning and keeping an overview of everyday activities. It also provides basic opportunities for communication, namely telephoning and text messaging, as well as entertainment services, e.g., radio and an Internet browser. Finally, it allows them to order meals from the downstairs cantina straight from the device. However, the tablet comes pre-installed with a wall-mounted charger with a docking station that few elderly people manage to use due to the precise docking procedure required. The components are small and difficult to spot for those suffering from visual impairments. Most elderly people residing in the local care home are struggling with fine motor skills, and few have the strength required to lift and maneuver a 10" tablet with just one hand. The number of broken charger plugs has consistently been high due to this difficult charging process. *Natural Charge* is a prototype exploring optional ways of charging the tablets with the help of wireless induction charging. A total of seven induction chargers with varying colors, shapes and sizes were included in the search for the best charging configuration. They goal of this design case is to find the interface that best supports charging of the tablet by allowing the residents to select the configuration that suits their natural movements and capabilities the best. It further demonstrated how different interfaces can serve the same purpose and how different people have different preferences when you study "natural" movements. This prototype seeks to utilize the natural movement of the user and therefore belongs in the *performative action (PA)* category. Figure 1 shows the four prototypes mentioned in this section.

Fig. 1. (a) T-Radio; (b) LightUp; (c) Payless; (d) Natural Charge

Table 1. Overview of the four prototypes with the corresponding category of spatial interaction and metric used during evaluation

| # | Protoype | Aging compensation | Main category | Metrics |
|---|---|---|---|---|
| 1 | T-Radio | Declines in fine motor skills, Visual impairment, Decline in working memory | Configurable materials (CM) | Preferred material, meaningful placement, best placement height, marking position |
| 2 | LightUp | Prospective memory, increased sensitivty to cold | Performative actions (PA) | Warmness of color, coldness of color, color representation, environmental representation |
| 3 | Payless | Fine motor skills, Memory, visual decline | Inhabited space (IS) | Bodily position, relative position, information visibility |
| 4 | Natural Charge | Fine motor skills, visual decline | Performative actions (PA) | Natural movements, meaningful placement and preferred model |

## 5. Results

Since the goal of this paper is to discuss how we can explore the spatiality of tangible interaction during prototyping, we do not present any detailed explanation or interpretation of the test results gathered from our users. The reason for including the test data from the users is to give an overview of how we used these metrics to collect opinions on various aspects of the spatial dimension of the proposed prototypes. Table 2 presents an overview of the different metrics used for the prototypes, as well as the corresponding category of spatial interaction. The user table on the right demonstrates what types of answers that were collected.

Table 2.Overview of the different metrics evaluated for each prototype

| | | **User #** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metrics** | **Category** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| **Prototype 1: T-Radio** | | | | | | | | | | | | | | | |
| Preferred material | CM | W | W | W | W | W | W | W | W | O | O | O | O | O | O |
| Meaningful placement | IS | T | M | O | T | T | M | O | O | D | A | T | T | A | T |
| Best placement height | IS | C | C | C | O | O | O | O | O | O | O | O | O | O | O |
| Marking position | NFV | F | I | I | I | P | I | P | P | F | P | I | P | P | P |
| **Prototype 2: LightUp** | | | | | | | | | | | | | | | |
| Warmness of color | PA | 25 | 25 | 26 | 25 | 25 | 27 | 30 | 25 | 24 | 24 | 20 | 30 | 24 | 25 |
| Coldness of color | PA | 15 | 15 | 19 | 16 | 18 | 19 | 15 | 19 | 19 | 17 | 14 | 14 | 17 | 15 |
| Color representation | NFV | C | O | O | C | C | O | C | C | C | O | C | O | O | O |
| Environmental representation | IS | C | C | O | O | C | O | O | C | C | O | O | C | O | O |
| **Prototype 3: Payless** | | | | | | | | | | | | | | | |
| Bodily position | FBI | C | C | C | O | O | O | C | O | O | O | O | O | O | O |
| Relative position | IS | C | C | C | C | C | O | C | O | O | O | O | O | O | O |
| Information visibility | NFV | C | O | O | O | O | O | O | C | C | O | C | O | O | C |
| **Prototype 4: Natural Charge** | | | | | | | | | | | | | | | |
| Natural placement | IS | 3 | 6 | 3 | 5 | 6 | 5 | 6 | 7 | 1 | 4 | 6 | 6 | 3 | 5 |
| Preferred model | PA | 3 | 6 | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 5 | 6 | 1 | 2 | 1 |
| Natural movement | PA | 1, 3-4 | 1, 5-6 | 1, 6-7 | 1, 6 | 1, 4, 6-7 | 1, 5-7 | 1, 4-6 | 1, 6-7 | 1,2, 5-7 | 1, 3-6 | 1, 2-3, 4, 6-7 | 1, 6, 7 | 1-6 | 1,2, 5-7 |

As we can see from Table 2, the spatial dimension of interaction can be studied through many aspects. For some metrics, we only explored whether the users felt any adjustments were necessary, e.g., best placement height on the T-Radio or color representation of the light bulb of LightUp, while we for other had more open-ended questions, e.g., meaning placement for T-Radio. For LightUp we had to use a quantified measure to find the appropriate levels of warm and cold sensations, and for Natural Charge, the prototypes were evaluated in a comparative manner where we evaluated 7 different prototypes, hence the numbers reflect the model number.

For T-Radio we focused on the material and placement of both the radio itself, as well as the position of the wooden blocks that initiated the interaction. There were no other suggestion on preferred material than wood (W), but there was a stronger difference in opinion on placement, both in the relative position between the radio and the blocks, as well as the preferred position of the radio. Only 3 of the participants desired change to our placement height, while there was no clear consensus on the meaningful place (top, middle or down) or marking position (frame, inset or podium). To test the relationship between the users and the environmental temperature, we asked participants to identify temperature values for warm colors and cold colors, as well as to what extent our color levels signaled correct bodily state. 7 out of 14 did not like our color representation, and 6 out of 14 felt we missed the environmental representation. Hence, we got important feedback on the human-object-environment relation through these results. For Payless we focused on the position of the body towards the RFID card reader, as well as its body relative to the screen and the cashier. We can image different result with elderly people in need of assistive devices (e.g. walkers or crutches), but in our expert group only 4 of 14 wanted changes based on their bodily position, while 6 of 14 wanted change to the relative position. We also studied whether the fragmentation of information due to multiple interaction components interrupted the information visibility and only 5 of 14 wanted changes to the design. We used 7 different prototypes to evaluate the design of the Natural Charge. We asked the participants to select the spatial configuration that gave the best natural placement, and we asked the participant to select their preferred model. As we can see in Table 2, this was highly subjective, and there were internal agreement between the participants, even though model 5 and 6 got the best overall score. We finally asked the participant to list all the models that felt natural in the sense that it could be part of a movement they would naturally perform anyway, from which we learned that model 1, despite only being the preferred model of 2 participants, was unanimously perceived as natural.

## 6. Discussion

This paper focuses on how we can explore the spatiality of tangible interaction during prototyping, with a focus on the spatial interaction of assistive technologies made for elderly people. An important challenge in our empirical context has been to compensate for age impairments among this participant group. In this paper, we have explored ways of investigating the spatial dimension through our four tangible prototypes. The framework of Hornecker and Buur [3] consists of multiple themes, and spatial interaction is one part of it, however spatial interaction requires a high level of attention during the design in order to support elderly people living independently at home.

Previous research has provided examples of positive experiences with tangible interaction in the context of assistive technology for elderly people. For instance, Marques et al. [12] present results that indicate that tangible objects can be a viable option also for elderly people, and the work of Häikiö et al. [15] presents a prototype where motor skills impairment does not increase the perceived difficulty of the system. However, these papers are built around the general concept of tangible interaction rather than with a fixed focus on the spatial interaction, even though they fulfill all the characteristics specified in Hornecker and Buur's framework [3]. This is also observable in the work of other researchers, e.g. de la Guía et al. [13] or Criel et al. [14], where presented prototypes fit the description of spatial interaction, yet there is little talk about the concept of spatial interaction.

By investigating what actions and movements that felt natural to the participants in our own empirical context, we strived to make our design blend into the daily routines of the elderly people. The use of *configurable materials* does not necessarily have to be any harder than moving a cup of coffee if we can learn the habits and routines of the participants. Similarly, we can find *performative action* to that allows us to give new functions to old habits. By building our design around familiar interfaces, we can provide interaction mechanisms that are easier to comprehend and operate. The biggest challenge when designing for elderly people within this theme of spatial interaction is that age impairments (e.g. decline in sensitivity and reduced motor control) can make old habits and natural movements harder to perform. For instance, elderly people are more sensitive to cold and the indoor temperature should not drop below 18 degrees Celsius [20]. Fernaeus et al. [6] presents an example of how a thermometer can be used to determine the warmth of water before taking a bath, and by interacting with a system that reads temperature over time we could create mappings between numbers on the thermometer and the bodily experience of touching the water. In a similar fashion, LightUp could be calibrated to fit the individual user by creating mappings of temperatures and how we experience the lights temperature. Different age impairments may require different spatial reconfigurations, and it is important to be able to adapt a system to the individual user or user groups. The rapid changes of the aging bodies alter the human-object, as well as the human-context relationship, something which encourages us to build systems that can adapt to changing needs. In addition, there is also a high level of subjectivity in the preferences of the spatial reconfiguration; what is natural for one person is not necessarily perceived as natural for another. We saw this in our research during the evaluation of the Natural Charge where in the test of 7 different induction chargers, the preferred model did not converge. Nor did more than 2 participant select model 1 as their favorite model, despite that particular model being the only one that felt natural to all participants. Finally, by utilizing *inhabited* we can enhance the atmospheric value of established places by opening up to new opportunities. Payless demonstrates how familiar and established places with meaning can become even more meaningful by building interaction on top of them.

## 7. Conclusions

In this paper, we have explored how we can investigate spatial interaction during prototyping of assistive technology for elderly people based on tangible interaction. We have used the definition of spatial interaction from the framework of Hornecker and Buur [3]. We have used the five categories that make up spatial interaction to describe and analyze four prototypes from our own empirical context. Through our prototypes, we have demonstrated the importance of considering the spatial aspect of TUIs. Findings from our usability test indicate that there is a high level of subjectivity regarding preferences in the configuration of the prototypes which complicates designs that aim to fit all elderly people. We did however find some configurations that were natural to the majority of our participants. In the future, we plan to test our prototypes with participants within the intended user group.

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# Appendix D

# Additional results

## D.1 Formative usability tests

### D.1.1 Natural Charge

**1 - Nokia DT-900 wireless charging plate**

Almost all the participants managed to charge the tablet with the Nokia charging plate on their first attempt. They said that it was one of the easiest chargers to use. It was popular with most of the participants. One participant wanted a combination of the Nokia charging plate and the Zens charger, this is bacause the Nokia plate was very easy to use but the Zens charger was more stylish. Some participants said that it was very responsive, while one particular person felt that the tablet was balancing on the plate and that it should have been bigger.

**2 - Nokia DT-910 wireless charging stand**

At first, many of the participants tried to stand the tablet on the Nokia charging stand. This did not work. There were no problems trying to get it to charge by placing the tablet sideways. Someone said that the stand did not take much space and was handy in that the tablet could be used while it charged. However, a few participants said that it did not feel stable enough for charging a tablet.

**3 - Zens Single Wireless Charger**

Most of the participants had trouble getting the tablet to charge on this charger and one participant did not get it to charge at all. Some of the participants also had trouble understanding that they could not place the tablet in the middle of the charger and found the required placement of the tablet very tricky. One person said that the surface was a little small for the tablet, but that it worked well once he/she knew where to place the tablet and this person liked this charger because he/she could just lay the tablet down on it. Although many struggled with this charger, its design was popular. A few participants referred to it as stylish and discreet. It was also mentioned to be suitable for travel because it was slim, but that it would be better if it were redesigned to be easier to use like the Nokia charging plate. The chargers material and charging light was popular.

**4 - Tenergy Dual Qi Wireless charger**

The problem with this charger was that it was a dual charger and it did not work when the tablet was placed over both charging plates. One of the participants suggested there be a clearer slit between the two charging surfaces so that it was more apparent that it had two separate charging areas. The charger had a light that indicated if a device was charging or not. This was handy, but this was not helpful because the tablet covered the light when placed properly. Some said that a large surface was good, but that it should work with the tablet laying across the surfaces. This charger was also a bit slippery.

**5 - Tylt VÜ Wireless charger**

At first most of the participants tried to stand the tablet on this charger. This did not work, but there was no problems getting it to charge when placing it sideways. A few participants had however learned from the Nokia charging stand and placed the tablet sideways. This charger was popular. The biggest disadvantage with it, according to most of the participants, was that they could not charge the tablet in a standing position. The rubber material used on this charger was comfortable to hold the tablet. It felt like that the tablet was standing steady, and was not slippery like the Tenergy Dual charger. A few participants said that this was a good charger for the elderly, because it was sturdy and easy to use. Another reason for its popularity was that it was easy to use the tablet while it was charging.

**6 - Nexus charging plate**

There were different opinions on this charger, some thought it was easy to use while others struggled a bit more and thought it was a bit small. This charger had a magnet that some participants liked because it enabled then to lift the tablet up and use it while it charged, but a few disliked the magnet because they feared that it could fall on the floor and damage the charger. Some participants said that the charger should have been easier to remove from the tablet.

#### 7 - LG WCD-100 Wireless charger

When using this charger, most of the participants tried to place the tablet in a standing position first, this did not work. It worked well when placing the tablet sideways. One participant said that it wasn't very attractive, and a few other participants said that it did not look very sturdy and they were afraid to damage it. It was also said that the charger was a bit wobbly and that the tablet did not seem to be very steady lying on this charger. This charger was said to be good if you were traveling, because of its small size and ability to fold.

### D.1.2 LightUp

Another test user suggested that it should be possible to override the system and allow other colors at night. It should be okay to let it be colder at night. Many people have a timer that automatically lowers the temperature to 17-18 °C at the night, and there should therefore be a night-mode for the light offering a different range relationship between temperature and light. Another suggestion was to measure the temperature every ten minutes and monitor if the temperature was sinking, and try to warn the user before it got too cold.

## D.2 Summative usability test

### D.2.1 T-Radio

#### The use of radio in their homes

Table D.1: Radio use

| User # | Radio | Use |
|---|---|---|
| 1 | TV | Scansat og svensketopper |
| 2 | DAB+ | P4+ |
| 3 | - | Watches TV and reads newspaper |
| 4 | DAB+ | Metro, P1 |
| 5 | FM | P1 |
| 6 | DAB? | P1, Radio Norge |

| User # | Radio | Use |
|---|---|---|
| 7 | FM | P1, Radio Norge |
| 8 | - | Watches TV |
| 9 | FM | P1, been on since the channel first aired |
| 10 | FM | - |
| 11 | - | Watches TV |
| 12 | FM | P4 on the kitchen |
| 13 | DAB+, TV | DAB+ in the cottage, STB at home .P1+, scanset |
| 14 | DAB+ | P1+, music form the 60s |
| 15 | DAB+ | P1+ |
| 16 | FM | In the car |
| 17 | DAB+ | P1 |
| 18 | DAB+ | FM and DAB is hopeless |
| 19 | FM | P1 |
| 20 | DAB+ | P1+ 24/7 |
| 21 | DAB, FM | P1, 1 DAB+ , 4 FM radios |
| 22 | FM | In the car |
| 23 | FM | P4, P1 |
| 24 | DAB+ | P1, P4 |
| 25 | FM | Tandberg Sølvsuper 2, Kurer radio (1938) |

Many of the test users already owned a DAB+ radio, while some still used FM or radio through the TV set-top box (Table D.1). P1 seemed to be the most popular radio channel followed by P1+, P4, Radio Norge, Scansat and Metro. One of the test users said that the radio was always on and "it has been on and playing P1 since the channel first opened". A few did not use a radio at all and preferred watching TV or reading newspapers. One of the test users had as many as five radios, one in every room. Another liked the old radios and had a Tandberg Sølvsuper 2 from 1938 and a Radionette Kurér from the 50s. Several users said that they liked to listen to music from the 50s and 60s. Some had a few problems with their radios, and one of the test users said that FM and DAB readies were hopeless. The most prominent problem was that there were too many channels and therefore very hard to find the channel they wanted. One user could not find a channel that was playing music from the 50s that he used to listen to before. Another problem was to find a local radio station from other counties on the TV set-top box.

### D.2.2 Natural Charge

**The tablet at research context 1**

Several users had problems with charging the tablet. They also said that the tablet suddenly lost power and that it was hard to place it correctly in the docking station. One user also said that the tablet was hard to turn on and off, he also struggled with hitting the intended spot with the pen on the screen, and preferred to use his finger. Another user thought that it was not so hard to charge tablet, once you had learned how to place it in the docking station. There are various uses of the tablet, one user said that he used it to check the dinner menu, read newspapers and surf the web, while another user only used it to check center activities and dinner.

**1 - Nokia DT-900 wireless charging plate**

According to the number of trials in Table 8.2, the Nokia Wireless Charging Plate was one of the easiest to use. It was said to be one of the easiest to use and was favored by several participants. One of the participants said that for elderly people, this was the easiest one to use. Another said, "Just lay it on".

**2 - Nokia DT-910 wireless charging stand**

The Nokia Wireless Charging Stand was the first charging stand that the participants tried. The most prominent problem was that most of the participants placed the tablet in a standing position first, and this did not work. One participant did also try to lay the tablet down partially on the foot of the stand, while another participant tried to place the tablet with the screen facing the stand, none of these worked either. It was also said to have a small gripper, referring to the foot of the stand.

**3 - Zens Single Wireless Charger**

The Zens Wireless Charger was one of the hardest to use. It was very tricky to place the tablet correctly in the charger. One of the participants said that many elderly users would have trouble using it. The most prominent problem was that the participants placed the tablet in the middle of the charger, which did not work. This charger had a marked area a little to the left of the middle, and this is where the tablet should have been placed.

### 4 - Tenergy Dual Qi Wireless Charger

Another difficult charger to use was the Tenergy Dual Qi Wireless. Most of the participants did not realize that it was a dual charger and placed the tablet across both charging surfaces. There were only a few who noticed that it was a dual charger. Even so, one of them still laid the tablet across both surfaces. They found it illogical and hard to use. One participant seriously struggled to get the tablet to charge, and I lost count of number of attempts, and decided to intervene to tell him that it was a dual charger. Even so, several participants liked the idea of being able to charge multiple devices at the same time. Some liked the big surface of the charger, but others said that it occupied too much space.

### 5 - Tylt VÜ Wireless Charger

The Tylt VÜ Wireless Charger got the most praising comments. The most prominent problem was that participants tried to place the tablet in a standing position at first, just as with the Nokia Wireless Charging Stand. Several participants said that it was sturdy, which made it easy to place the tablet on it. A few participants said that it was the best charger for elderly users with unsteady or shaking hands, and one participant said, “8/10 of elderly users would choose this charger”. It was also said to elegant and some called it "a handsome charger".

### 6 - Nexus Charging Plate

Some participants found the Nexus charging plate a little hard to use. However, several participants were able to get the tablet to charge fairly easy. One participant said that it was very small and hard to place correctly, even though he managed to get the tablet to charge on his first try. It was said to be small and handy, and one participant meant that it was practical to have on his nightstand.

### 7 - LG WCD-100 Wireless charger

The LG WCD-100 Wireless Charger is a standing charger where the most prominent problem was that the participants placed the tablet in a standing position, however many of the participants had learned from the use of the previous standing chargers and this was less of a problem than with the other chargers. One participant said that it did not have a light that indicated that it was charging, and that made it difficult to use. Another meant that this charger was more responsive than the other chargers, thus making it easier to see the tablet was charging.

### D.2.3 LightUp

#### Heating at research context 1

A few residents from the research context 1 had some comments about the heating in their apartments. One test user said that it was hard to adjust the thermostat to the preferred temperature. She wanted an easier way of adjusting the heat, e.g. three different settings, and she said that several other residents also wanted this. This was because people did not understand the adjustments, and either set the heat to full or low. Another test user said that they had a display where they could adjust the temperature from -3 to +3 with small steps in between, but the display did not show how many degrees each increment represented. The heating would stop if a window or door was open, and a picture of a door would be visible in the display.