”I just wanted a beautiful phone”
Checklist-based evaluation of smartphones usability for the elderly users

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M.Sc. Thesis
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December 2013

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Minna Kause: “I just wanted a beautiful phone” – Checklist-based evaluation of smartphones usability for the elderly users
M.Sc. Thesis, 47 pages, 12 appendix pages
December 2013

Mobile phone technology and user interface design have evolved into a multi-functional touchscreen-based smartphones with advanced capabilities and vast amount of applications. One potentially growing user group of the smartphones are elderly persons who have experienced the evolution of the technology during their adulthood. The objectives of this thesis were to chart what kind of requirements the persons over 65 years old have in relation to the mobile devices, and to evaluate how current user interface designs of smartphones fulfill the identified requirements.

The evaluation process followed the existing framework designed for evaluating the usability of mobile phones based on multi-level, hierarchical model of usability factors. The framework provides tools and a process to compare different designs. The process has four phases: plan, prepare, conduct evaluation and analyze results. In the planning phase Windows Phone 8.0 and Android 4.1 Jelly Bean were selected to represent different smartphone user interface designs. Items important from the elderly users’ viewpoint were identified during the preparation phase. Different heuristic checklists and design guidelines developed for mobile phones were also reviewed. Checklists used in the actual evaluation phase were composed by combining items essential to the elderly users and to the characteristics of the mobile phones. The evaluation was conducted by inspecting both Windows Phone and Android user interface designs against the checklists.

The items of the checklists were analyzed and classified into five usability indicators: visual support of task goals, support of cognitive interaction, support of efficient interaction, functional support of user needs and ergonomic support. The classification allowed the comparison of the two designs in more generic level instead of comparing individual items in the checklists. Results of the checklist based expert evaluation indicated that the main differences were in the visual support of task goals and functional support of user needs. Overall simplicity, minimalistic design and fewer functions of Windows Phone reflect better the needs and desires of the elderly users.

Keywords: smartphone, mobile phone, elderly persons, user interface design, usability evaluation

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1. Introduction

1.1. Background and motivation

A trend of the age distribution is shifting to a direction where considerable number of the population will be older than 65 years. According to the current expectation 27 percent of the population will be over 65 years old in Finland by 2040 [Tilastokeskus, 2009]. At the same time everyday life is and probably will be more dependent on information and communication technology (ICT). According to the statistics overall 61 per cent of people between 65 and 74 years old used the Internet in Finland in 2012. Every fourth of them used the Internet on daily basis. In addition 15 percent of the same age group had a smartphone in 2012. [Tilastokeskus, 2012].

The Internet and the mobile technology have transformed communication and ways of finding information dramatically during the past decades. Telephone and radio are familiar from the childhood to the people who have born in 1940's or earlier. Television was a thrilling innovation and many elderly still remember the first time they have watched television. In 1980's most of the households in Finland had a landline telephone, nowadays it is exceptional. Due to the rapid evolution of the technology the elderly persons have a very different technological background compared to the generations born in the 1980's and after that. Assuming that the technological evolution continues at this rate, the generations born in the 1980' and later will face similar situation in their old age.

According to Olson *et al.* [2011] people are likely to keep using technologies that are familiar to them for a long time. Adopting completely new technologies in older age may not be a trivial task and the oldest people may be slow adopters of the new technologies [Olson, et al., 2011][Salovaara, et al., 2010]. From the technology acceptance point of view the elderly mobile phone users can be divided into three groups: those who reject, those who accept, and those who have a neutral attitude towards mobile phones [Gelderblom, et al., 2010].

For the elderly persons adoption and usage of the information and communication technology seem to be connected to the concrete needs and usefulness of a technical solution [Hernández-Encuentra et al., 2009]. If the technical solution cannot be mirrored against the existing knowledge and needs, it can be difficult to see the purpose of the use [Lim, 2010]. In order to prevent the so called "digital deprivation" of the elderly persons, it is essential to encourage them to exploit information and communication technology [Selwyn, 2004]. For example a mobile phone can remarkably improve the quality of life of the elderly persons if benefits of the mobile phone are straightforward and concrete [Gelderblom, et al., 2010].

There are both rational and emotional factors that encourage the elderly persons to adopt and use technical solutions like mobile phones. The rational factors can be related to a chance to live independently or to the ability to attend to their own affairs despite of the reduced mobility for example [Mikkonen, et al., 2002]. The emotional factors can be such as encouragement of the family members or friends, feeling of safety or desire to keep up with the latest development [Salovaara, et al., 2010] [Kurniawan, 2008]. One example of the emotional factor comes from the elderly woman who stated "*I just wanted a beautiful phone, but now I don't know how to use it*". Hearing those words inspired me to study more closely what factors are important for the elderly users in the context of mobile devices and how well those factors are taken into account in the design of smartphones' user interfaces. Interest to focus especially on smartphones emerged from several years of working experience at Nokia's mobile device customization team.

1.2. Research aim and scope

The aim of this Master's thesis is at first to examine the existing literature about requirements that the elderly persons have in relation to the mobile devices. Secondly the aim is to evaluate how current smartphone user interface (UI) designs fulfill the requirements of the elderly users by conducting a checklist based expert evaluation. The target is to identify a set of criteria that can be used to evaluate how user interface designs of different smartphones' operating systems serve the needs of the elderly users, and then inspect smartphone user interface designs based on those criteria. The definition of the elderly persons varies in the literature, but in this thesis the elderly refers to the persons over 65 years old.

The literature review concentrates on the topics related to learning and adoption of information and communication technology in the context of aging, how the elderly persons use mobile devices, what kinds of challenges are related to the usage of these devices, and how those challenges can be overcome. The literature review discusses these topics on general level including findings about usage of personal computers (PC) and different mobile devices like mobile phones, smartphones and tablets. The aim is to apply the findings in the context of smartphones.

In this thesis the focus is on the usability evaluation of smartphones due to the growing penetration of the smartphones among the elderly persons in the developed countries. The difference between smartphones and basic mobile phones, also known as feature phones, has been dissipated over the years. Nowadays the term smartphone is probably more related to the marketing than the actual features of the device. The difference between the smartphones and the feature phones has been diminished from both software and hardware point of view. Features, such as the Internet connection or camera, which were originally typical for the smartphones, are today available to most of the mobile phones. According to the one definition the smartphone is "*a cellular telephone with built-in applications and Internet access. In addition to digital voice service, modern smartphones provide text messaging, e-mail, Web browsing, still and video cameras, MP3 player and video playback and calling. In addition to their built-in functions, smartphones run myriad free and paid applications, turning the once single-minded cellphone into a mobile personal computer*" [Ziff, 2013a]. In addition "*the device must have at least a three-inch touch screen and be able to download apps from an online store*" [Ziff, 2013b]. This definition of smartphone is applied in this thesis. There are several smartphone operating systems like iOS by Apple, Android by

Google, Blackberry by RIM and Windows Phone by Microsoft. Android and Windows Phone operating systems are available for multiple phone manufacturers.

This thesis focuses on the Windows Phone and the Android operating systems with selected devices: Nokia Lumia 620 and Samsung Galaxy S III mini. The operating systems were selected due to the differences in their user interface designs. According to Microsoft [2013] the user interface design of Windows Phone is based on the "infographic" user interface instead of the "iconographic" user interface applied for example in Android's operating system. Figure 1 illustrates the difference between the user interface designs: the "infographic" user interface is heavily based on textual information, whereas the "iconographic" user interface utilizes graphical information like icons. [Microsoft, 2013].

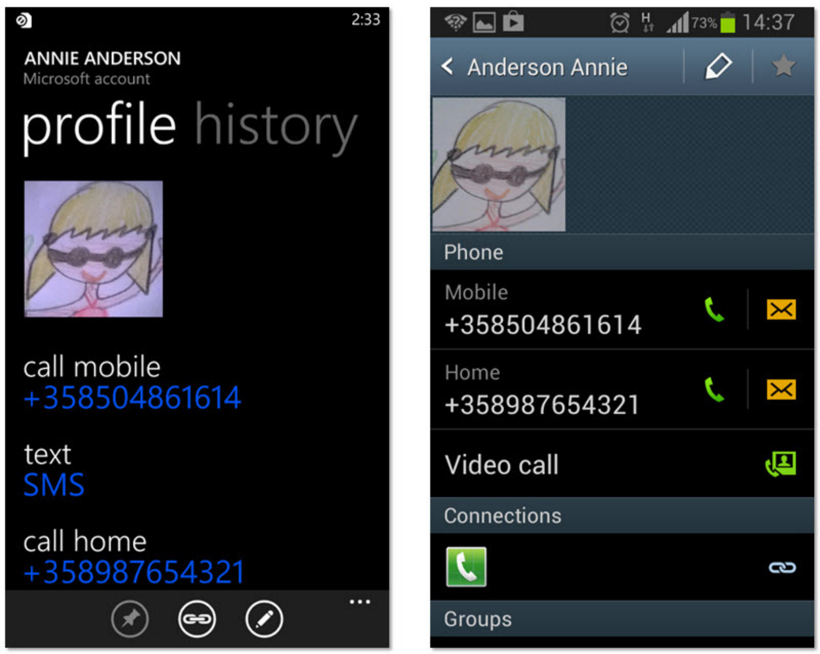


Figure 1. The "infographic" user interface design of Windows Phone on the left and the "iconographic" user interface design of Android on the right.

2. Information and communication technology with relation to the elderly users

This chapter outlines different aspects of aging in the context of information and communication technology in general and in more detail in the context of mobile devices. Age as such does not mean that people in certain age have similar advantages or disadvantages as users of information and communication technology. However, according to the research there are some typical symptoms of aging like diminished sense of sight. Also capacity to process information may reduce; therefore aging may have impact on cognitive skills like learning. On the other hand aging usually leads to a wide knowledge base and widening life experience. The aspects of aging contribute to both the ability to adopt new technologies and to the attitude towards new technologies. In the human-technology interaction (HTI) point of view the characteristics of aging should guide the design solutions. This chapter provides an overview on research related to aging and technology as well as theoretical knowledge base for this thesis.

2.1. Impact of aging to learn and adopt new technologies

Aging does not impact on cognitive skills straightforwardly. According to Suutama [2008] cognitive skills like ability to learn new and process existing information vary a lot in the individual level. Working memory plays a key role in storing and processing both new and existing information. It appears that information processing speed and capacity of working memory abates with age. Hence storing and recalling information may diminish. Efficiency suffers from the reduced capacity of working memory and learning requires more time. As an example task completion time may increase along with age. Impact is more evident when the level of difficulty of the tasks increases. However, even if aging has impact on information processing speed, it has no impact on overall capability to learn or to understand new information. [Lim, 2010] [Suutama, 2008].

According to Lim [2010] age increases the semantic knowledge and aging does not have a major impact on the capability to recognize previously learned information. Wide knowledge base makes it easier to understand, encode, integrate and remember new relevant information. The technological background varies between generations due to rapid evolution of information and communication technology during the past decades. Hence the elderly persons’ knowledge and skills may not be directly transferable to the current context of information and communication technology. Mental models are built based on the previous experiences and they are the key factors when defining how easy or difficult a product is to use. The mental models have a major impact on learning; the more prior knowledge and experience about the technology, the easier it is to learn to use a new product with similar logic and user interface. [Lim, 2010].

Possibility to learn in their own pace and relevance of information combined with existing knowledge are important factors of learning process for the elderly persons [Suutama, 2008]. According to Leung *et al.* [2012] some elderly persons preferred to learn alone in their own pace, whereas some elderly persons expressed the desire to participate in an elderly-persons-only teaching. Studies indicate that the elderly persons like to get support from friends or family members when learning to use new products like mobile phones [Kurniawan, 2008] [Karahasanovic, et al., 2009] [Selwyn, 2004]. One-to-one support was seen essential for the elderly persons to gain confidence and knowledge on how to embed mobile phone usage as natural part of everyday life [Hardill & Olphert, 2012].

During the learning period many elderly persons have difficulties to remember the exact steps of a task. To overcome these difficulties the elderly persons typically make notes from where they can check how to proceed the next time. The notes have usually textual step-by-step instructions combined with sketches of important parts of user interface (UI) and explanations of terms. [Sayago, et al., 2011]. Leung *et al.* [2012] reported similar results based on their study of the mobile phone usage of the elderly persons. For the elderly users it appears that learning to accomplish a task is more important than understanding the overall technical functionality [Leung, et al., 2012].

Leung *et al.* [2012] also studied how the elderly persons learn to use mobile devices. They found out that while young adults used trial-and-error way of learning, the elderly persons preferred step-by-step instructions. They also read instruction manuals more often than users from younger age groups, although terminology used in the instruction manuals was difficult for a non-technical person to understand. On average the elderly users seem to be more careful not to make mistakes that lead to situations from which they are not sure how to recover. [Leung, et al., 2012].

In addition to the training and support, motivational and attitudinal factors have a significant influence on the learning and adoption of new technologies [Suutama, 2008] [Salovaara, et al., 2010]. Many elderly persons have a positive attitude towards information and communication technology and they are motivated to learn to use new technologies. Previous experience with computers led to the positive attitude towards technology altogether and encouraged the elderly persons to learn to utilize the new technologies. Personal usefulness is the key to motivate the elderly persons to use technology and keep up their technological skills. Positive benefits of technology for the elderly persons can be, for example, new models of social interaction, pathways to lifelong learning, access to information, mean for electronic citizenship and intergenerational connections. All in all, a clear understanding of possible benefits of using information and communication technology motivates the elderly persons to learn to use new technology. [Salovaara, et al., 2010] [White & Weatherall, 2000].

For some elderly persons motivation to use the computer derives from a feeling that they want to keep track of computerized technology. For others the information and communication technology means autonomy despite of reduced mobility; ability to do shopping and bank transactions for example. In addition some special interest like genealogy can motivate the use of the information and communication technology. Those who have used computers during their working life simply continue after retirement, but some lose their interest on information and communication technology completely. According to Selwyn [2004] it looks evident that the elderly persons use a computer if it is useful to complete a certain task and for many elderly persons the usage is restricted to one or two specific use cases. [Selwyn, 2004]. Also costs and availability are important issues when considering the usage of technology. [Sayago, et al., 2011]. Pure enjoyability is one of the factors encouraging the elderly persons to adopt new technologies [Kobayashi, et al., 2011]. According to Leung *et al.* [2012] the most important motivational factors to learn to use smartphones were "*perceived usefulness, ease of use, social influence, familiarity with technology and previous experience with learning resources*".

Mikkonen *et al.* [2002] reported that the elderly persons preferred mobile services which provided freedom to travel alone more safely. The elderly persons also preferred applications that served as a memory aid and in that way increased the feeling of security. Applications to maintain social relationships were seen as beneficial as well as services supporting health care and independent living. [Mikkonen, et al., 2002]. Kurniawan [2006] reported similar results based on her research of elderly women as mobile phone users. Also for the elderly women the main benefit of carrying mobile phone was the feeling of safety and security. The elderly women reported that they mainly used the mobile phone in unexpected situations. The three top most common contacts were partner, children and friends. [Kurniawan, 2006] [Kurniawan, 2008].

2.2. How technology can improve the quality of life of the elderly persons?

Benefits of information and communication technology for the elderly users can be classified into four categories: social, self-understanding, interaction and task-oriented benefits. Increased accessibility to the current interests and information, possibilities to interact with others and have social support are examples of how information and communication technology can bring new meanings to life or help to maintain the existing activities. Also, possibilities to take care of various tasks related to travelling, shopping and financial management were seen as benefits of using information and communication technology by the elderly persons. [Selwyn, 2004] [White & Weatherall, 2000].

White and Weatherall [2000] have identified five themes in reasons for why the elderly persons use computer based technology:

1. Computer technology has relation to other interests and hobbies.
2. Technology provides mental and social stimulation.
3. Cost savings on the use and ownership of information and communication technology.
4. A tool to assist in various tasks like creating a music collection and personal bookkeeping.
5. Communication with family, friends and especially with grandchildren.

Communication and how technology can be utilized in social interaction seems central in the studies of the elderly persons, technology and social interaction. From the quality of life viewpoint especially the lack of communication is a major issue. The elderly persons were keen on maintaining a few close relationships rather than a large social network. Therefore, technologies which allow easy and intensive way of communicating are valued by the elderly persons. According to Salovaara *et al.* [2010] many elderly persons maintained active social interaction with different groups of interest by utilizing information and communication technology. Technology was utilized to tell what is going on, share interesting topics and arrange social events. [Salovaara, et al., 2010]. The elderly persons aimed to communicate in more personal level and they were discreet to contact others [Sayago, et al., 2011]. According to research by Sar *et al.* [2012] the elderly persons who used the Internet and e-mail felt that they get emotional support via these channels and reported decreased loneliness and increased quality of life. Based on these findings it looks like information and communication technology can be one solution to reduce negative feeling of loneliness and increase potential for social interaction among the elderly persons.

Technology can build a bridge between generations. Social factors, like opinion of children and grandchildren, can play an important role in the elderly persons' adoption of technology. For example social pressure from children and grandchildren had a clear impact on the elderly persons' intention to use a mobile device [Gelderblom, et al., 2010]. Influence of grandchildren seems to be vast since grandparents highly appreciate contact with their grandchildren and wish to have regular interaction with them. In 2005 the most common way of communicating after face-to-face was phone call with landline telephone followed by mobile phones and short message service (SMS). Also e-mail was used occasionally by a minority of grandparents. The age of grandparents was not significant factor in e-mail usage. However, the age of grandchild had an influence on communication; traditional spoken interaction was more commonly used with young grandchildren and e-mail was used with older grandchildren. Distance to the grandchild had an influence on the way of communication; the closer grandparents and grandchildren were living the more they used spoken language (face-to-face, landline telephone, mobile phone). Respectively the longer the distance the more often e-mail and SMS were used. [Quadrello, et al., 2005].

According to Sayago *et al.* [2011] the elderly persons invested energy to learning of new ways, such as video chat, to communicate with their young grandchildren (aged 5-9) to enable natural and effective way of communication. Altogether, the elderly persons were willing to make effort in learning to use the most natural and effective way of communicate with different parties. For example e-mail and video chat gave the elderly persons a feeling to be closer, useful and important to their loved ones. [Sayago, et al., 2011]. In cases where children and grandchildren were living abroad, grandparents were more likely to step out of their comfort zone and learn to use new ways of communication like the Internet [Gonzáles, et al., 2012].

2.3. How and why the elderly persons use mobile phones?

According to Kurniawan [2008] people over 60 years old tend to use mobile phones for very limited purposes like calling or sending text messages if they had something to communicate urgently [Kurniawan, 2008]. A slightly newer study by Hardill and Olphert [2012] indicated that the most common use case for the elderly persons was still a phone call. Taking photos and accessing the

Internet were next on the list. [Hardill & Olphert, 2012]. Also Kobayashi *et al.* [2011] addressed that the elderly persons would like to use mobile phones for various tasks like taking and viewing photos, reading newspapers and e-books and playing games. A smartphone was seen especially useful when there was some spare time like during the travelling. [Kobayashi, et al., 2011]. Even though there are a lot of features and applications in mobile phones some of them may not be used simply because users are not aware of them. The elderly users may also be afraid of damaging the device if they are uncertain on how to use a feature or an application. [Leung, et al., 2012].

Kurniawan [2008] identified two patterns of use of mobile phones by the elderly persons: they were either passive users who tended to use a mobile phone only when there were no other options available or they were afraid to use mobile phones at all due to the perceived complexity of doing so. [Kurniawan, 2008]. Hardill and Olphert [2012] identified also active daily users among the elderly persons. They divided mobile phone usage of the elderly persons into three groups based on the activity level. Active daily use of different features of mobile phone and interest to renew the device regularly was described as *confident, pervasive use*. More random usage for rather limited purposes with no interest to use the latest device model was defined as *episodic use*. Using the mobile phone only occasionally for a very specific purpose was described as *fossilized use*. According to Hardill and Olphert [2012] the reason for giving up mobile phone usage completely was related to the problems of remembering how to use the device. For a minority of the elderly people costs were the main reason to give up mobile phone usage. [Hardill & Olphert, 2012].

The way how the elderly person originally obtained a mobile phone seemed to predict future usage: those who obtained the mobile phone as a gift were more conservative and occasional users compared to those who bought the device by themselves. Frequency of use determined the depth and width of the mobile phone usage: those who used the device more frequently tended to use also a wider scale of features. Age indicated users' attitudes and actual usage of the phone: users older than 70 years belonged more often to groups of occasional or non-users. [Gelderblom, et al., 2010].

2.4. Designing mobile phones for the elderly users

A dilemma in designing technology for the elderly users is their need for simplified and easy to use solutions and at the same times the elderly persons' desire to feel socially included and competent technology users. Even though the elderly users are older in years they do not want to be treated as different. According to Sayago *et al.* [2011] designing special solutions for the elderly users is not a good approach. In the end success and acceptance of a product depends on a social aspect; how the person using a product feels, especially how she/he is being perceived and treated by others. If the usage of technology makes a person feel embarrassed or ashamed the technology will not be adopted. Design for the elderly users should leave room for multiple interpretations and not state that user of technology has some special needs compared to the other users. [Sokoler & Svensson, 2007]. In addition limited functionalities of the devices designed specifically to the elderly users will increase digital diversion between the generations [Kobayashi, et al., 2011].

Ease of use is the key factor in encouraging the elderly persons to use technology. Simplicity and user friendliness are even more important to the elderly users than to the other user groups. [Karahasanovic, et al., 2009]. However, instead of designing products specifically for the elderly persons more appropriate approach is to design products in a way that benefits all kind of users [Gonzáles, et al., 2012]. Products can be made more tempting for the elderly user by involving the elderly themselves to the design process [Selwyn, 2004].

According to the research the main flaws of the design are too small displays and keys. Vast amount of functions, complicated menu structures and lack of proper instructions impair usability of many devices. User guides are printed with very small font size and they are too complicated for non-technical users. In addition the prices of applications and services are unclear to many senior users. [Kurniawan, 2008] [Topo, 2008].

Successful design of a mobile device is based on ensuring a full match of characteristics of the device, and the requirements of the user. Hence in the usability point of view both physical characteristic of the device and physical characteristics of the user must be taken into account. For example the display, keypad, buttons and input and output facilities are physical characteristics of the device, whereas hearing, vision and dexterity are physical characteristics of the user. [Gelderblom, et al., 2010].

Many issues concerning mobile phone usage of the elderly persons are linked to physical characteristics of the devices and the users. There are certain topics highlighted in many studies concerning the elderly users and mobile phones. For example van Dyk *et al.* [2012] studied what the elderly persons would like to change in their mobile phones. They divided their findings into five main categories: visual, cognitive, dexterity, audio and other. Each category covers several items [van Dyk, et al., 2012]. Kurniawan [2008] had quite similar findings and categorization in her study. She grouped desired features in four categories: vision, cognitive functioning and memory, haptic and auditory [Kurniawan, 2008]. In addition there are studies concentrating on some special topic in one of the categories. The following sections reveal findings of the different studies in each category in more detail.

2.4.1. Visual

Kobayashi *et al.* [2011] made performance measurements and observational evaluations of a standard mobile touchscreen interface with twenty elderly participants. The participants were asked to perform basic gestures as taps, drags, and pinching motions and use basic interactive components like software keyboards and photo viewers. The target was to study gesture based interaction and keypad usage with bigger (iPad) and smaller (iPod) touchscreen-based devices. One of the tasks measured the hit rate on objects different sizes with both devices. Objects of 30, 50 and 70 pixels were used to represent the typical sizes of the keys in a software keypad, general buttons and icons. With the small device respectively sizes in millimetres were approximately 4.6, 7.6 and 10.7, and with the bigger device approximately 11.5, 19.2 and 26.9. According to the results the error rate was clearly higher with the smallest 30 pixels objects compared to the bigger objects with both bigger and smaller display sizes. According to this study usability issues in touchscreen-based devices were related to the size of an object: the smaller the target the more difficult it was to hit the target. [Kobayashi, et al., 2011]. Results of Kobayashi *et al.* [2011] seem to validate the findings from other studies where the elderly users had issues with too small buttons (e.g. Kurniawan 2008).

Many studies have found that learning to use the mouse is one of the most challenging UI skills for the elderly persons. Even though a keyboard was found to be easier it was considered to be abnormal to use keyboard as a replacement for the mouse [Sayago, et al., 2011]. Similarly applications designed for small devices with touchscreen, should have large enough target area to support usage of fingers instead of awkward pointing devices such as a stylus [Holzinger, et al., 2007]. Also social aspect guides choices. For example the elderly persons who were shown how to use accessibility features like zooming, still preferred to use glasses as they felt that socially more acceptable [Sayago, et al., 2011].

In order to enhance vision the elderly persons preferred bigger devices with a large display. The text should be large enough both on the display and on the keypad and buttons. The elderly persons also suggested different shape and color to help to distinguish the keys. Clear contrast in colors and brightly illuminated display and keypad as well as possibility to adjust the time for how long the display stays active (illuminated) were seen as important by the elderly persons. [van Dyk, et al., 2012] [Kurniawan, 2008].

2.4.2. Cognitive

It can be difficult to find all features of the device if the user has no previous experience in using devices with a hierarchical menu structure. The elderly persons have difficulties with operational procedures and functionalities such as menu-based interaction. Due to the lack of experience the elderly persons have inferior knowledge of a phone menu structure and the limited knowledge leads to lower navigation performance. [Ziefle & Bay, 2004] [van Dyk, et al., 2012]. People over 56 years old had a lower rate of successful interactions with products that had two or three layers menu structures. Therefore, when designing the user interaction it is important to realize that it is difficult for the elderly users to learn and remember multi-layered hierarchical interaction structure. It is recommended to use direct access and low-level of hierarchy in the interaction structure to better serve the needs of the elderly users but also improve user experience in general [Lim, 2010]. Overall it can be said that the more features the more difficult it is to learn to use new systems [Sayago, et al., 2011].

The issues within the software keypad were related to recognition of special keys like backspace and shift. Even if the elderly persons were experienced computer users and familiar with the standard PC-like QWERTY keyboard, they had difficulties to identify the special keys when textual labels were missing. [Kobayashi, et al., 2011]. According to Kurniawan [2008], predictive texting (T9) proposed wrong choices which forced the user to delete wrong characters in order to change the word. Texting with old style keypad (ITU-T defining 12-key keypad layout) caused difficulties to understand correlation between the character selection and the key press (press a key as many times as it takes for the correct character to become selected). [Kurniawan, 2008].

Other findings of Kobayashi *et al.* [2011] revealed that using unintended gestures may invoke unexpected functions that can cause confusion. For example, a double tap on the touchscreen display may invoke zooming. Another source of confusion was applications having different modes. Participants of the study had difficulties to understand mode changes and recognize in which mode application was. For example the camera application may have different modes for video and photos. The participants easily lost track of their current mode especially if the look and feel of the different modes was similar. However, as a conclusion of their study Kobayashi *et al.* [2011] stated that touchscreen mobile interfaces are preferred by the elderly and not too difficult to use. [Kobayashi, et al., 2011]. Similar results have been reported also by van Dyk *et al.* [2012]. According to their study the elderly persons preferred touchscreen with separate keyboard for text and numbers [van Dyk, et al., 2012].

From the cognitive point of view it was found out that the elderly persons preferred simplified and short menu paths, fewer functions and understandable terminology as well as support for different languages. The most important features like making and receiving a phone call, an alarm, calendar and messaging must be easy to access. In Kurniawan's study it was proposed that these features should be accessible via the home screen. The elderly users would also like to see the picture of the caller to help them. In addition there should be easy access to a phone book. The elderly persons said that they needed help in customizing the device e.g. adding contacts to the phone book. Reminder of important appointments and activities, like time to take medicine, was seen essential for memory support. One suggestion to support memory was that it should be possible to see the phone owner's own number easily in the home screen. [Kurniawan, 2008] [van Dyk, et al., 2012].

2.4.3. Haptic

The term dexterity used by van Dyk *et al.* [2012] means in this context the physical feel and usability of the device. Items van Dyk *et al.* [2012] listed under this category resemble the findings that Kurniawan [2008] listed under the term haptic. From this angle the elderly persons wished to have altogether bigger phone including bigger keys and buttons. According to these studies devices were too small to be held comfortably. Buttons were too small and too close to each other which made it challenging to perform even the simplest tasks like answering a phone call. In general the buttons were not tangible enough and the users did not receive any feedback like audio sound (click) of the button press. As a conclusion it was suggested that buttons and keys should be further apart, less sensitive and upraised in order to provide a concrete response. Tactile feedback of key- and button presses was also mentioned. One identified issue was slipperiness of the device. It was suggested that the device could have a rubber cover for better grasp. [van Dyk, et al., 2012] [Kurniawan, 2008].

2.4.4. Auditory

Loud ringtones in addition to an earpiece and hearing aid compatibility were identified as the auditory requirements of the elderly persons. Kurniawan [2008] also listed a speakerphone, easily accessible volume keys and auditory feedback of button presses in auditory category. In addition possibilities to control the device via voice and audio were seen as valid features (e.g. audio input/output, voice-promts, text-to-speech, speech-to-text). Adjusting the speaker's volume and loudness of the ringing tone were also seen as challenging. It was also mentioned that the loudspeaker must have an option to adjust the phone to ring in extra loud volume. [Kurniawan, 2008] [van Dyk, et al., 2012].

2.4.5. Other

There were also general issues not directly related to any of the previously mentioned categories. According to Kurniawan's [2008] research most concerns and annoyance caused by mobile phones were related to inconsiderate use, choice of ringing tones and danger caused by careless use of mobile phone e.g. usage during the driving. Hence concerns of the elderly persons were not related to features of mobile phones as such, but more to the patterns of use. From costs point of view both the device itself and the subscription were expensive and it was unclear which services were included in to the subscription and which cost extra. Battery life was too short since many elderly persons tend to forgot to charge mobile phone often enough. [Kurniawan, 2008]. Van Dyk *et al.* [2012] reported also that the elderly persons desired to have better battery durability or at least a louder audio reminder when the battery charge reaches 25 percent [van Dyk, et al., 2012].

2.4.6. Design preferences based on gender

Men and women emphasized slightly different aspects: women concentrated on features that aim to facilitate feelings of safety and prevent unintended actions, whereas men preferred functions which provide auditory or visual feedback about the use [Kurniawan, 2008]. Among the elder women the most used function in addition to voice call was changing the ringing tone profile e.g. silent, vibrate or loud. The least used function was the video call. In general having too many functions decreased user satisfaction and was experienced as annoying or stressful. [Kurniawan, 2006] [Lim, 2010].

In design choices women preferred bulky devices with bright colors to make device easier to hold and find from a crowded handbag. Men preferred a device that is light and small enough to fit in a pocket. Both genders mentioned large display and especially large text as an important factor. [Kurniawan, 2008]. Also the results of the study conducted by Kobayashi *et al.* [2011] indicated that women prefer physically larger devices as long as the trade-off between weight and size is in balance. Device should be large enough for sufficient reading and light enough to be carried in a handbag. [Kobayashi, et al., 2011].

3. Usability evaluation of mobile phones in context of the elderly users

This chapter discusses the challenges in conducting empirical human-technology interaction research with the elderly users and usability inspection as an alternative evaluation method. Focus of the chapter is on how a usability inspection method like expert evaluation can be utilized in the context of the mobile phones.

3.1. Challenges in empirical research with the elderly persons

Recruiting a representative sample of elderly persons as participants in human-technology interaction (HTI) research has been identified as somewhat challenging. The elderly are a diverse group in many ways and, for example, demographic issues must be considered carefully when planning the research. In many cases volunteers are younger, healthier and have better social networks compared to non-volunteers. Wide ranges of educational background, computer experience and physical condition must be taken into account when considering a research method. [Dickinson, et al., 2007]. Gender, marital status, educational background and age seem to have an impact on computer usage [Selwyn, 2004].

Empirical research methods are not effective when studying the elderly persons due to the diversity of the user group. The elderly persons may have a limited understanding of the new technologies, which makes it challenging for them to express actively their preferences and needs. Conducting a focus group for more than three participants has been reported to be challenging; the elderly tend to discuss off-topic issues and the participants' possible auditory impairment might make it difficult to follow the discussion. [Zajicek, 2006].

Self-reporting is one of the HTI research methods that can produce excellent data. However, quality of data depends on the participants' physical (e.g. trembling hands) and cognitive (e.g. memory) capability to report. When considering self-reporting as a research method it is important to pay attention to the self-reporting technique. Reporting as such should not cause stress to participants. Also the level of computer experience must be considered; for beginners it might be challenging to report nothing but very high level perceptions. [Dickinson, et al., 2007].

Zajicek [2006] proposes that design patterns and guidelines can be used instead of empirical research methods to ensure that the design fulfills the needs of the elderly persons. However, understanding the needs of the elderly is fundamental when creating a pattern or a guideline. The pattern should encompass the special needs of the target users, and provide examples of good design and reasons for using it in an accessible form [Zajicek, 2006]. Many studies related to the elderly and technology conclude to provide recommendations and design guidelines [Kurniawan, 2006] [van Dyk, et al., 2012] [Al-Razgan, et al., 2012]. Those recommendations and guidelines were used in this thesis to evaluate usability from the elderly persons' point of view.

3.2. Evaluating the usability of mobile phones

In the field of human-technology interaction usability evaluation can be categorized into three main classes: usability testing, usability inquiry and usability inspection. There is no clear guidance which method should be used in a given situation. Usability inspection is typically used in a case when involving the real users is challenging. Heuristic evaluation is one of the inspection methods where a group of usability experts evaluates the user interface design by following a set of heuristics or rules of thumb. The main benefits of the heuristic evaluation are speed and affordability. Since heuristic evaluation does not require involvement of the real users it can be conducted at any phase of the design process. Disadvantages of the heuristic evaluation are that it does not resemble the real context of use, and it does not provide information about the frequency of the identified usability problems.

One of the most popular evaluation checklists is the Nielsen's heuristic checklist that was introduced in the early 90's. Nielsen's heuristic checklist covers items related to learnability, efficiency of use, memorability, error prevention and user satisfaction. In relation to the mobile devices the context of use and physical characteristics of the device impact usability and user experience [Ham, et al., 2006] [Ji, et al., 2006] [Inostroza, et al., 2012]. Usability of mobile phones is also influenced by factors such as the target users and their preferences and purpose of the use: different user groups have different needs. Hence, usability evaluation should reflect the needs of the target user group. There are several criteria for how to define the user group like age, social status, ethnicity or occupation. [Ham, et al., 2006].

Ji *et al.* [2006] developed a usability checklist for the usability evaluation of mobile phones. They initiated the development work by analyzing existing mobile device style guides offered by different manufacturers. Based on the analysis they identified key user interface elements that compose the user interface of a mobile phone: UI policies (e.g. menu structure), UI screens (e.g. status screens), UI interactions (e.g. feedback) and UI components (e.g. text field). In the second phase they identified the most important usability principles based on a literature review. Ten usability experts went through several collections of usability principles. After the screening there were 21 usability principles left (see Appendix 1). These principles were also classified into five categories: cognition support, information support, interaction support, user support and performance support. In the third phase they made a pairwise comparison of UI elements and usability principles in order to match UI components and related usability principles. Finally they defined evaluation criteria for each usability principle and made a case study to verify the reliability of the checklist. The goal of the case study was to evaluate three different mobile phones by experts based on the developed checklist. Results of the evaluation were compared to the evaluation results of a usability test that was conducted for the same devices with the real users. As a result greater amount of usability problems were found through the usability checklist than with the usability test. Usability problems that occurred frequently in the usability test were also discovered by the expert evaluation. However, usability evaluation failed to reveal additional usability problems that were closely related to a practical usage of a mobile phone. On the other hand evaluation discovered issues like inconsistency in the icons and labeling that were not revealed by the usability test. Ninety percent of the usability problems found in the usability tests were also discovered in the evaluation. [Ji, et al., 2006].

Inostroza *et al*. [2012] made a study how to enhance Nielsen's heuristic checklist to fit better the touchscreen-based mobile devices. They claimed that heuristics designed for the software systems are not applicable for the mobile context as such; usage of small hand-held devices differs from the usage of PC software. Inostroza *et al.* [2012] based their study on the existing research about special characteristics of touchscreen-based mobile devices. They took Nielsen's heuristics as a base and modified the evaluation criteria according to the findings from the literature. Then they added physical interaction and ergonomics as one item to the checklist (see Appendix 2). They verified the touchscreen-based mobile device (TMD) heuristics by evaluating one mobile phone based on both Nielsen's heuristics and TMD heuristics. The evaluations were done by two separate groups, one group used the Nielsen's heuristics and the other group used the new TMD heuristics. Afterwards the results of the evaluations were compared. According to the comparison TMD revealed overall more usability problems that were evaluated more severe compared to the problems found based on Nielsen's heuristics. However, some of the problems were found only based on Nielsen's heuristics. As a conclusion Inostroza *et al.* [2012] stated that TMD can reveal more usability problems that are ranked more severe compared to the Nielsen's heuristics, but further research is required to validate TMD. [Inostroza, et al., 2012].

Mi *et al.* [2013] developed a heuristic checklist to evaluate accessibility of a smartphone user interface. They focused on the needs of users with sever visual impairment or upper extremity disability causing loss of function in one or both hands. The accessibility checklist development was initiated by investigating existing accessibility standards and guidelines. Requirements of the user group were formulated based on the standards and guidelines. In addition the requirements were evaluated by the actual users. In the end the requirements were classified into 44 different user requirements that constituted a base of the smartphone accessibility design guideline. In the next phase the design guidelines were verified with an actual smartphone prototype. A usability test with the target users was arranged in order to ensure validity and efficiency of the design guideline. In the last phase the accessibility design guideline was converted into a heuristic checklist including items that can be used for evaluating an accessibility of a smartphone (see Appendix 3). Findings of Mi *et al.* [2013] reflect partly also the needs of the elderly: device power button separate from the touchscreen, home key for allowing easy return to the main menu and the need for audio and tactile feedback to improve accessibility. [Mi, et al., 2013].

3.3. The framework to evaluate usability of mobile phones

Both Ji *et al.* [2006] and Inostroza *et al.* [2012] argued that the expert evaluation can efficiently detect usability problems. Usability testing is more effective to elicit issues related to the task performance while expert evaluation is more efficient in finding inconsistency of the design. Expert evaluation based on the heuristic checklist can offer valuable feedback about needed improvements, but it does not offer a good overview to compare usability of different devices. Heo *et al.* [2009] introduced "*a framework for evaluating the usability of mobile phones based on multi-level, hierarchical model of usability factors*". The idea of the framework is to bring usability to the abstraction level where it is possible to calculate a single usability value for the device and compare usability of different mobile phones.

The framework consists of four abstraction levels: the property level, the criteria level, the indicator level and the usability level (see Figure 2). Each level brings usability to a more abstract level by utilizing a multi-facet taxonomy [Heo, et al., 2009]. A multi-facet taxonomy allows classifying a knowledge asset under multiple categories at any level of abstraction. It is difficult to classify unstructured data such as usability findings under one category. Therefore the multi-facet taxonomy is needed to classify data with multiple concepts. [Cheung et al., 2005].

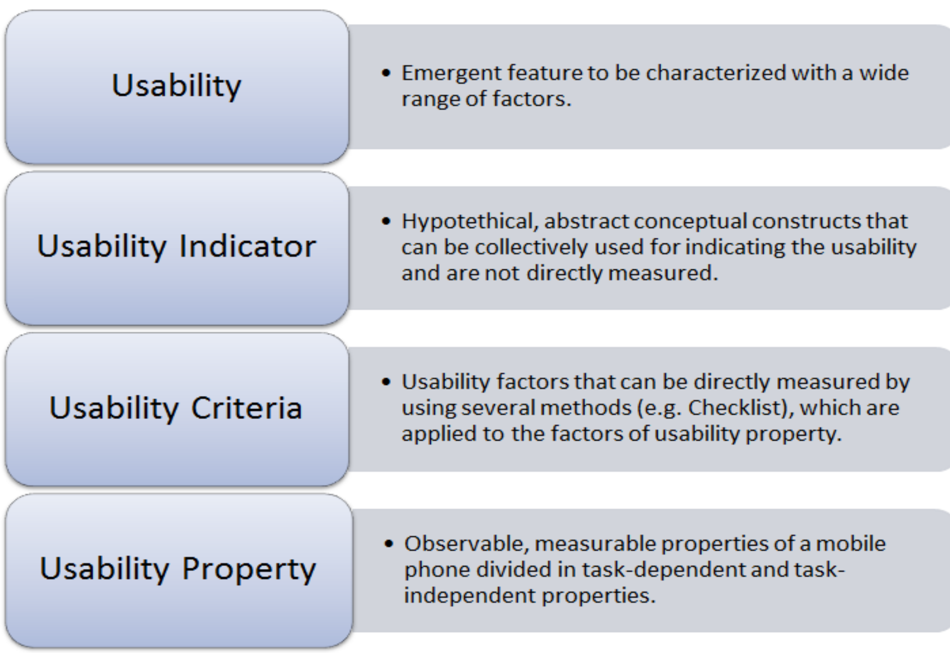


Figure 2. Hierarchical model of usability factors [Heo et al., 2009].

Heo *et al.* [2009] started the development of the framework by collecting usability problems of mobile phones. They examined the previous studies, conducted a web survey and arranged focus group interviews to collect usability problems. Finally 28 mobile phone related issues were selected and classified either as task-dependent or task-independent issues. The task-dependent issues are tied to a task performance while the task-independent issues can be evaluated without a need to perform any specific task. Therefore the task-independent issues are more related to the overall design of the user interface. [Heo, et al., 2009].

Usability of a mobile phone is a summary of different factors. Factors such as what can be seen on the display, how the user can control the device and how information is structured. Heo *et al.* [2009] determined three interface areas to describe task-independent usability factors: Logical User Interface (LUI), Physical User Interface (PUI) and Graphical User Interface (GUI). The logical user interface refers to information contents and structure such as the menu and the navigation structure. The physical user interface refers to physical properties of the user interface such as buttons, keypad and microphone. The graphical user interface refers to the visual components of the user interface like icons and fonts. Each task-dependent usability problem is typically related to at least one task-independent factor. In the evaluation framework this division of different properties is called the **property level**. [Heo, et al., 2009].

The next level in the framework is the **criteria level**. Aim of the criteria level is to measure usability with traditional testing methods such as checklist based usability inspection. Idea is to define a checklist to each property: task-dependent, LUI, GUI and PUI. The task-dependent checklist includes items related to performance, stability and consistency of operation sequence. The LUI-based checklist concentrates on the structure of information, optional ways to perform tasks and the intelligibility of the terminology. Options to adjust the size of the UI components and the display settings are part of the GUI-based checklist. The PUI-based checklist covers topics like how ergonomic the device is, and the correspondence between the controlling mechanism and the target to be controlled. [Heo, et al., 2009].

All the items in the checklists are linked to one or more usability criteria. The ssability criteria were determined based on an analysis of several user interface design principles including Nielsen's heuristics. Usability criteria aim to bring individual usability issues to more generic level. In practice the usability criteria is a set of questions like "*When the users make a mistake, can they recover easily from it?*" that reflects Nielsen's "error prevention" heuristic. [Heo, et al., 2009].

In order to get overall picture of mobile phone's usability there is a need to classify the results of the evaluation on an even more generic level. For this purpose Heo *et al.* [2009] defined five usability indicators: visual support of task goals, support of cognitive interaction, support of efficient interaction, functional support of user needs and ergonomic support. Visual support of task goals, support of cognitive interaction and efficient interaction reflect human information processing capabilities. Functional support of user needs reflects usefulness. And ergonomic support corresponds to the physical interaction. In the evaluation framework this level is called the **indicator level**. [Heo, et al., 2009].

In some situations it would be beneficial to be able to measure the overall usability. Measurement can be useful when comparing two devices for example. To quantify usability Heo *et al.* [2009] proposed a three-steps approach. In their study at first each evaluated item was fitted to semantic grades. Then the semantic values were transformed into the corresponding quantified values (see Table 1). This way each evaluated item in the checklists got a numerical value. After obtaining the quantified value for each item, all the values related to the same usability indicator were summed. In principle the summed value could be high if all items got only positive values. However, in the actual cases some evaluation items usually have a 'minus value' that balances the sum. Finally the single usability value of a mobile phone could be calculated by aggregating the scores of each usability indicator. Hence the final usability score was simply a sum of the scores of the five usability indicators. [Ham, 2013]. Together all the levels formulate the multi-level, hierarchical model of usability factors that provides a single value of **usability**.

Usability level	*Quantified value*
Severe usability issues	-6
Major usability issues	-4
Minor usability issues	0
No usability issues	4
Highly usable	6

Table 1. Usability quantification [Heo et al., 2009].

Figure 3 illustrates the evaluation process based on the framework. The evaluation process has four phases: planning the evaluation, preparing the evaluation, conducting the evaluation and processing the results (see Figure 3). The purpose of the evaluation is defined in the planning phase. Also selection of the target device, the target area and the target users is done as part of the planning. In the preparation phase items to be evaluated are identified. Checklist items can be selected when the scope of the evaluation is clear. The third phase of the process is conducting the actual evaluation based on the checklists and quantifying the findings. Finally findings can be diagnosed based on the results and analysis can reveal areas that require improvement. Also an action plan for how to implement the improvements is established in the final phase. [Heo, et al., 2009].

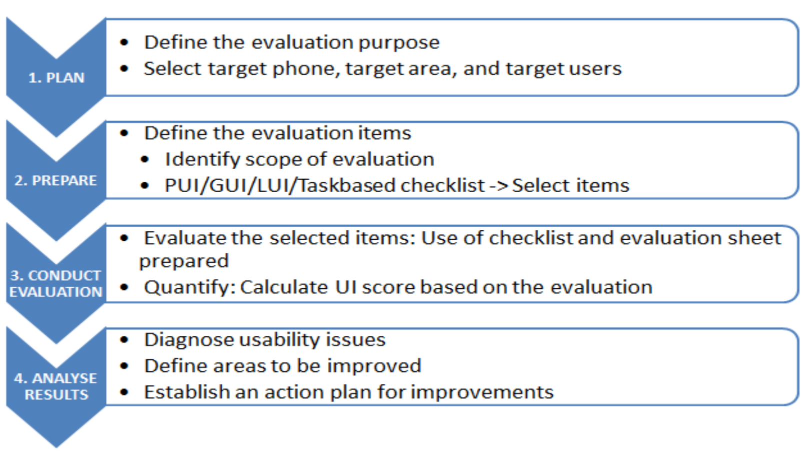


Figure 3. Usability evaluation process [Heo, et al., 2009].

4. Study design

This chapter explains how the mobile phone evaluation framework by Heo *et al.* [2009] was applied in this study to evaluate two different kinds of smartphone user interface designs from the elderly users' point of view. The chapter is divided into sections following the evaluation process: plan, prepare, conduct and analyze. However, the results of the evaluation are described in the next chapter.

4.1. Planning the evaluation

The first step of the process was to define the purpose of the evaluation, target devices, target area and target users. The purpose in this case was to evaluate how the two smartphone user interface designs fulfill the requirements of the elderly persons. The scope was to evaluate features and functions relevant from the elderly users' point of view and especially from the novice elderly users' perspective. Target devices were touchscreen based Nokia Lumia 620 with Windows Phone 8.0 operating system and Samsung Galaxy S III mini with Android 4.1 Jelly Bean operating system. Both manufactures have made their own enhancements to the operating systems. Hence some evaluated items, like display settings, may be more dependent on the manufacturer than the OS. Details of the devices can be seen in Table 2. The reason for selecting these operating systems to the study was the different user interface design guideline ("iconographic" vs. "infographic"). The different UI designs look different, but the interesting question is what consequences to the usability the design has. Physically Lumia 620 and Galaxy S III mini are almost the same size and also the size and quality of the display are almost the same.

Nokia Lumia 620		***Samsung Galaxy S III mini***	
	**Dimension**: 115.4 x 61.1 x 11 mm **Weight**: 127 g **Display:** • ClearBlack, IPS LCD • TrueColor (24-bit/16M) • 3.8 " • 480 x 800 (WVGA) **OS:** Windows Phone 8.0		**Dimension:** 121.55 x 63 x 9.9 mm **Weight:** 120g **Display:** • sAMOLED • 16M • 4.0" • 480 x 800 (WVGA) **OS:** Android, 4.1Jelly Bean

Table 2. Details of the devices used in the evaluation. [Nokia, 2013] [Samsung, 2013].

Primary focus of this study was on the evaluation of the user interface and not of the physical characteristics of the devices. This choice was made due to the fact that there are several models using the same operating system. Typically the different models have the same features and functionalities in software-wise, but there are differences in the hardware e.g. size, display resolution and camera technology. Hence users can choose the physical characteristics of the device based on their preferences. However, there are also physical similarities between the different models. For example buttons like power, volume control and home are typically located in the same positions between the different models of the same manufacturer. Therefore, items such as location and tangibility of the buttons can be evaluated as part of the physical user interface evaluation.

The devices used in the evaluation were targeted for the Finnish market. Therefore settings like language were changed before the evaluation. In addition, for example, settings related to the accessibility, the home screen and the display were modified during the evaluation in order to check if certain features or functions were supported.

4.2. Preparing the evaluation

The second phase of the process was to define items that will be evaluated. The scope of this evaluation was to concentrate on the requirements of the elderly persons. The original paper of Heo *et al.* [2009] does not include the complete checklists used in their study. The paper has examples and a skeleton of the multi-level hierarchy of the checklists. In addition, none of the existing checklists or heuristics represented in the previous chapter inspects usability specifically from the elderly persons' standpoint. The hierarchy of the checklists used in this study imitates the multi-level model of the usability evaluation framework by Heo *et al.* [2009]. However, the property level of the checklists was composed based on the several heuristic checklists and guidelines introduced in the different studies.

The checklist to evaluate accessibility of a smartphone by Mi *et al.* [2013] has common factors with the needs of the elderly. For example, the need for tactile and auditory feedback of the button press is a common requirement. The accessibility checklist was supplemented with the specific needs of the elderly users identified based on the literature review of this thesis. Also, design guidelines for the elderly persons defined by Al-Razgan *et al.* [2013] were taken into account as well as the touchscreen-based mobile device heuristics by Inostroza *et al.* [2012]. Hence, the checklists are in practice lists of questions that aim to reveal answers to those factors that are meaningful for the elderly users.

The usability evaluation framework does not take into account haptic or auditory aspects of the user interface as criteria. Therefore, items related to the haptic and auditory feedback were classified into the physical user interface (PUI) as they are related to the response the user gets when having the device in hand and pressing buttons. Items related to an auditory user interface, such as speech recognition, were aligned to the logical user interface (LUI) as they can be used as optional ways to perform a task or to get feedback.

Each item in the checklists was also classified according to the usability criterion and the usability indicator. Figure 4 describes the multi-level, hierarchical model of the checklists. Following sections explain the content of the task-dependent and task-independent checklists used in this study including references and classification.

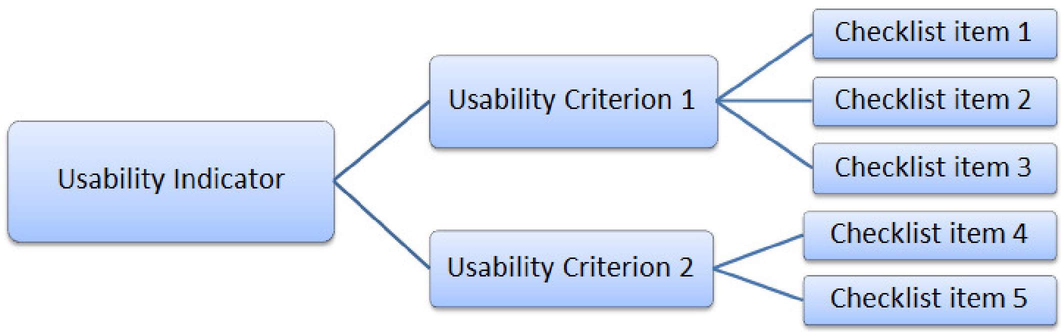


Figure 4. A multi-level hierarchy of the checklists.

4.2.1. Task-dependent checklist

This usability evaluation was targeted to the most important functions for the elderly users, and features that cause difficulties for the elderly users according to the previous studies. Based on the previous researches the most important tasks for the elderly users are making and receiving a call, setting an alarm, creating a calendar reminder, changing a ringing tone profile, adjusting the volume and sending and receiving text messages [Kurniawan, 2008]. Making and receiving a call, changing a ringing tone profile, setting a new alarm and creating a calendar reminder were selected as the tasks to be evaluated in this study. Text messaging was excluded due to its heavy dependency on the keypad usage that is hard to evaluate without the actual users. Adjusting volume was not evaluated as its own task but as part of the physical user interface evaluation.

Template for the task-dependent checklists was constructed on the basis of the common factors between the different tasks. The complete task-based checklist template including the criteria and indicator levels is available in Appendix 4. For each task the user must be able to access the function (entry), perform the task (use) and get confirmation on whether the operation was successful (exit). The task-based checklist template was constructed on the basis of these three steps. In each step the focus was on those topics that were identified to be meaningful to the elderly persons. The target was not to evaluate all functions, but instead to concentrate on the main requirements of the elderly users that are explained in the section 2.4.

The first step of the task is entry to the function. One of the main requirements of the elderly users was easy access to the most important functions. Preferably, these functions should be available directly from the home screen. The entry level task-based checklist concentrates specifically on the ease of access by checking whether the function is available on the home screen, whether it is easy to identify the function (unambiguous icon and terminology) and whether there are alternative ways to evoke the function like voice-activation.

The next step of the task is the actual use of the application. In this step the focus of the evaluation was on how well the application supports the needs of the elderly to have simplified and short menu paths, only relevant information available and understandable terminology. Also topics like error prevention and error correction were evaluated as part of the task performance.

Final step of the task performance is to get confirmation on the task completion. In this step the items that were evaluated were related to the unambiguity of icons and terminology and to the feedback about the operation status. Also the possibility to cancel the operation was evaluated.

In addition, there are some task specific items in the checklist. For example, related to the task of receiving a phone call the elderly mentioned that they would like to see an image of the caller. In addition in the accessibility checklist Mi *et al.* [2013] had a corresponding item that utilizes auditory channel "*Are there assignable or talking ringing tones that identify callers?*". These items were evaluated as part of the receiving a call task.

4.2.2. Task-independent checklists

Heo *et al.* [2009] listed topics like information architecture, wording and functional options to the LUI-based checklist. The logical user interface based checklist of my study study focuses on the specific concerns of the elderly persons such as the multi-layered menu structure, terminology, keys that do not have a self-explanatory label, different modes (e.g. idle, edit) and the lack of feedback like audio sound of button press. However, in my study the menu structure was evaluated only on a level that indicated if there was an easy access to the most important functions. The complete LUI-based checklist can be found from Appendix 5.

Meaning and aesthetics of the icons, font type and size, as well as display style and color were in the checklist of graphical user interface by Heo *et al.* [2009]. The main concerns of the elderly persons were small size of icons, fonts and text. The elderly also raised contrast and brightness of the display as an issue, as well as the possibility to adjust the time for how long the display stays active. The GUI-based checklist of this study was established based on these findings. The complete set of GUI-based questions is in Appendix 6.

In the physical user interface perspective Heo *et al.* [2009] listed ergonomic consideration of buttons, grip and accessory, and contextual consideration of position and manipulation. Most of the ergonomic issues the elderly persons listed were related to buttons. Buttons were too small, too close to each other, too sensitive and not tangible enough. Based on these findings the PUI-based checklist of my study utilizes the accessibility checklist by Mi *et al.* [2013]. The questions aimed to reveal how easily buttons can be recognized and whether there is any feedback of the button press available. Also the sensitivity of the touchscreen was part of the evaluation.

4.3. Conducting the usability evaluation

In the usability evaluation phase both devices were evaluated based on the task-dependent and the task-independent checklists. The evaluation was conducted by going through all the questions of all the checklists with both devices. Comments were added to those items that led to interesting observations regarding usability. Based on the comments the severity of the problems and examples of good and bad design were easier to find.

According to the usability evaluation framework, the severity of each usability finding had to be defined and converted into a numerical value. Hence all findings were at first fitted into the five point semantic scale: severe usability issue, major usability issue, minor usability issue, no usability issue, highly usable. The severity was decided based on the assumed importance of the finding from the elderly persons' perspective. For example sensitivity of the touch-screen can be adjusted in both of the evaluated devices. However, interpretation of the sensitivity settings differs between the devices: in the Nokia device sensitivity means that touch-screen can be used with gloves, whereas in the Samsung device it adjusts the tap and hold delay. In the elderly users' point of view the tap and hold delay is more important, even though in some conditions ability to use the touch-screen with gloves might be useful.

After the severity grading each value was transformed into the corresponding quantified value. Heo *et al.* [2009] used range from -6 to 6 and then simply sum the values. The focus of the study of Heo *et al.* [2009] was not in the usability quantification as such [Ham, 2013]. One problem of calculating the sum is that the results are not easily comparable if the amount of items changes in the checklists. Therefore, the quantification method was modified in my study. In my study a range from 0 (severe usability problem) to 4 (highly usable) was used instead of range from -6 to 6 (see Table 3). Average was calculated for each usability indicator instead of summing the values, and the single usability score is an average of all the evaluated items. Even though it is not generally speaking recommended to calculate an average for an ordinal scale data, it can be done in order to illustrate data [Holopainen & Pulkkinen, 1997].

Usability level	*Quantified value*
Severe usability issues	0
Major usability issues	1
Minor usability issues	2
No usability issues	3
Highly usable	4

Table 3. Usability quantification scale used in this study.

4.4. Analyzing the results and making a proposal for improvements

The aim of the last phase was to analyze the results and to make a proposal for how the design could be improved. Heo *et al.* [2009] emphasized that even if two devices end up with the same final score it does not mean that the devices are similar. Overall usability must be compared in the usability indicator level to see what areas of the design need to be improved. For example, if the final score of usability is the same for two devices there can be differences in the indicator level (see Figure 5). Therefore, a comparison of the final usability score does not offer enough details about the issues found.

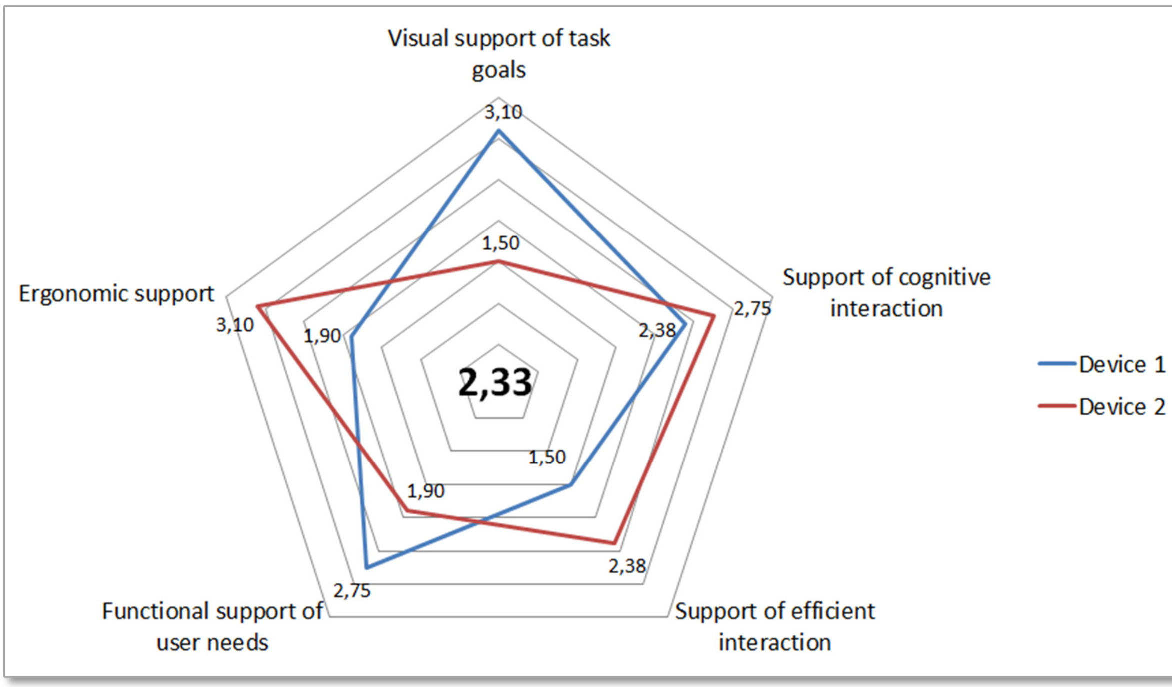


Figure 5. Example of differences in the indicator levels of the devices having the same overall usability score.

5. The evaluation of the Windows Phone and the Android user interfaces

The results of the evaluation are presented in this chapter. The first section focuses on the overall evaluation results. The following sections discuss the most important findings in detail on the usability indicator level.

5.1. Overview of the evaluation results

The overall score of usability was defined for both of the devices by calculating the average of all evaluated items. Based on the averages Windows Phone 8.0 (Nokia Lumia 620) got slightly better overall usability score than Android 4.1 Jelly Bean (Samsung Galaxy S III mini). The scores of the evaluated items of LUI-, GUI- and PUI-based checklist can be found in Appendices 5, 6 and 7. The task-based scores are available in Appendix 8. Figure 6 illustrates the overall results and the usability scores of Windows Phone (2.90) and Android (2.43). The difference in the usability scores is mainly derived from the differences in two indicators: visual support of task goals and functional support of user needs. There are no major differences between the scores in support for cognitive interaction, support of efficient interaction, or ergonomic support levels. However, the findings vary between the devices within the same indicator.

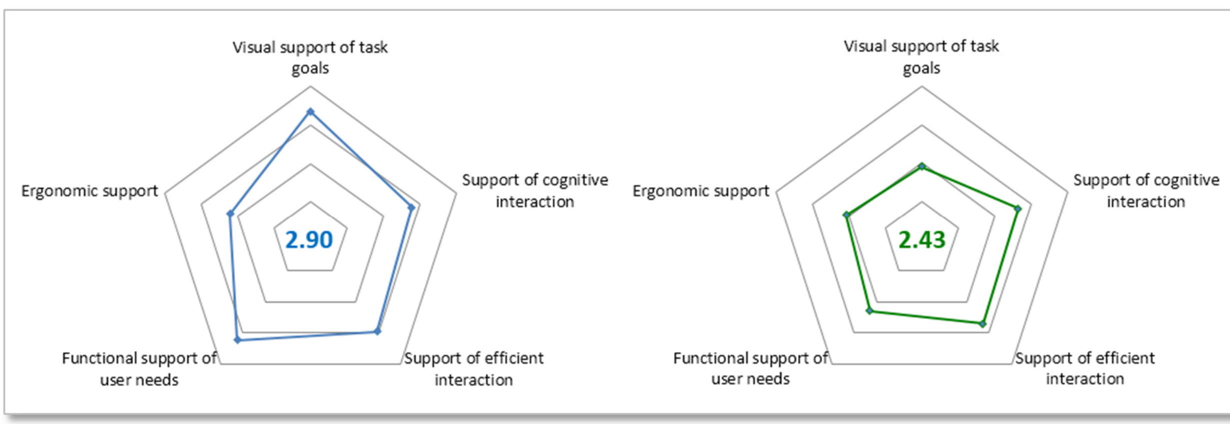


Figure 6. The overall usability score of Windows Phone 8.0 on the left side and Android 4.1 Jelly Bean on the right side.

In general simplicity, minimalistic design and fewer functions and features of Windows Phone 8.0 reflect better the requirements of the elderly users. Android 4.1 Jelly Bean offers vast amount features that can be attractive for the experienced elderly users. However, according to Sayago *et al.* [2011] the vast amount of features has a negative impact specifically on the learnability. Like stated in the literature review, simplicity and ease of use are the key factors to encourage the elderly persons to adopt technology.

5.2. Visual support of task goals

In the visual support of task goals –category the main focus of the evaluation was in the identification of the visual cues like icons and accessibility to the applications. In this category the difference between the user interfaces was the most evident. Windows Phone got 3.36 as an average while Android got 1.91 (see Figure 7). Questions in the checklist were related to the accessibility and how definite the visual cues, like icons, are. The accessibility was evaluated by questions like "*would the users think that they can achieve the task by using the device*" [Heo, et al., 2009].

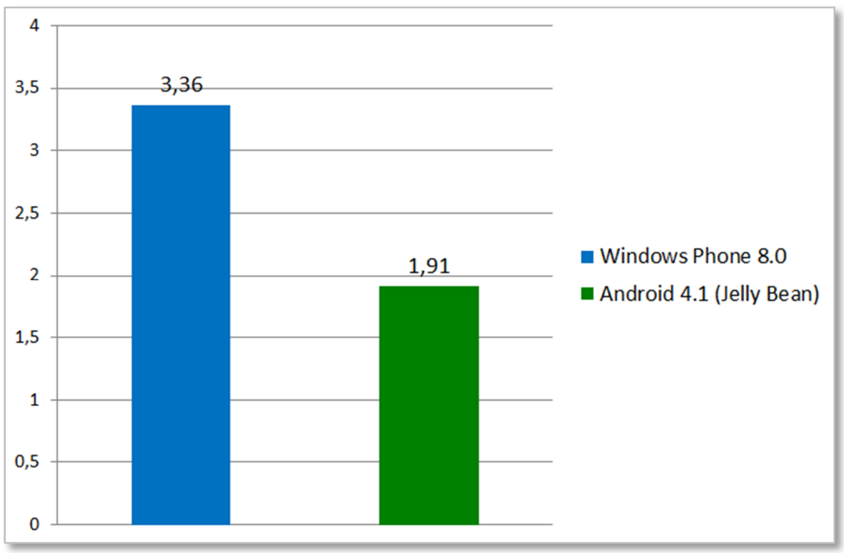


Figure 7. The results of the visual support of user needs -indicator.

The main reason for the difference in the results in this category lies with the size and the simplicity of the icons especially on the home screen. The home screen of the Windows Phone utilizes icons even though the user interface is called "infographic". Figure 8 illustrates the home screens of Windows Phone and Android. Windows Phone gained better results due to the option to change size of the icons, also known as tiles, on the home screen. The size of the tiles can be switched between small, medium and large. Hence even on a small display the size of the target area can be increased. According to Kobayashi *et al.* [2011] and Holzinger *et al.* [2007] a large target area on the touchscreen-based mobile devices improves the hit rate. The option to enlarge the icons and clear contrast may reduce need to wear glasses or use awkward features like zooming [Sayago, et al., 2011]. Figure 8 also illustrates the more simplified icons of Windows Phone in comparison to Android. However, the animated live tiles such as people (contacts) in Windows Phone may distract users' attention. The advantage of Android is the different shape and colors of the icons.

Figure 8. Home screen of Windows Phone on the left and the basic mode home screen of Android on the right.

Users can select the applications that are pinned to the home screen on both devices. Hence there is an access to the most important applications on the home screen as proposed by Kurniawan [2008]. The main difference is that for the Windows Phone the user can pin for example the alarm clock and the contacts to the home screen without need to configure settings. Android allows adding the contacts and the alarm clock on the home screen only if the user changes the home screen mode from basic to the easy mode from the settings (see Figure 9). In the easy mode the applications are divided to several screens and the user does not have full freedom to choose in which screen to pin the applications or contacts. For example contacts and alarm clock cannot be on the same screen. Enabling the easy mode requires that the user knows about the existence of the option and also knows how to enable it (Apps/Settings/Home screen mode). As discussed in the literature review the so called hidden features are often not used due to lack of knowledge.

Figure 9. Android's home screen in the easy mode.

Both user interfaces have a textual label of the application available in addition to the icon. In Android the appearance of the applications is similar on the home screen and on the applications list. The applications list of Windows Phone highlights the textual cues while the icons are small. Sometimes the visual cue of the icon may not correspond to a real world object or the impression that the elderly users have. For example, Android has an image of the globe as the icon for the Internet. The icon may remind the elderly user of an atlas rather than the web browser. Hence having a large textual label can facilitate the identification of the application. Figure 10 illustrates how the textual information, the “infographic” design, is emphasized in Windows Phone. A plain background and a large font size make it also easier to read the textual labels in Windows Phone.

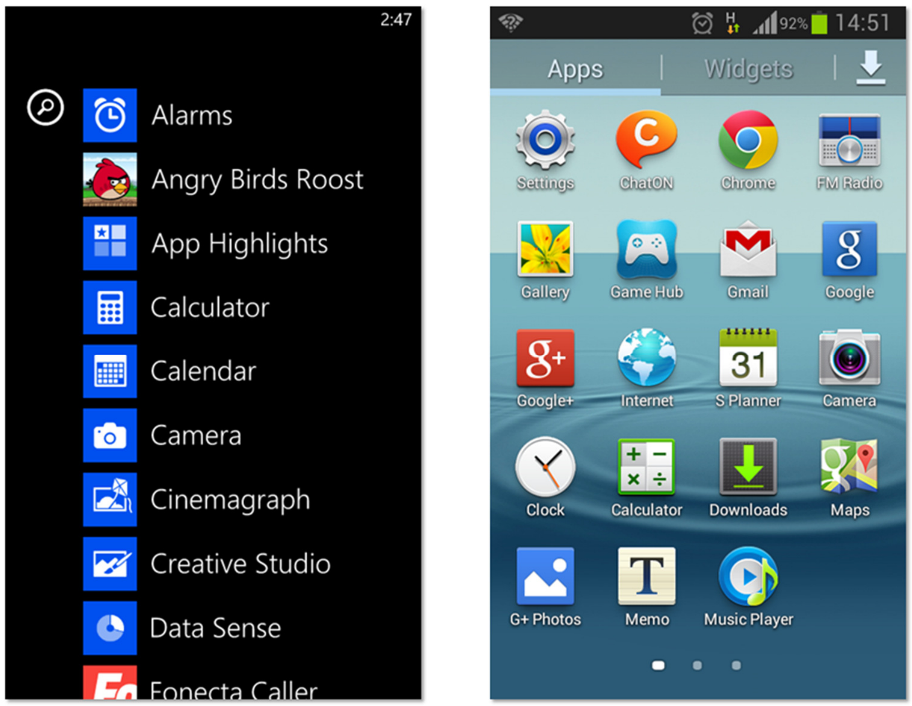


Figure 10. Applications list of Windows Phone on the left and Android on the right.

The main usability issue of Windows Phone in this category is related to the size of the soft keys such as Save and Edit inside the applications that makes it difficult to distinguish and point at the keys. In many cases the soft keys are very small. Figure 11 illustrates the difference in the soft keys between Windows Phone and Android in the phone application. In case that call history is the first view when the user opens the phone application then the keypad must be selected by using the soft keys. Even though in Windows Phone the icons have good contrast and they are simplified it may be still difficult to distinguish the small icons from each other. In general the soft keys are bigger in Android and the label text is also visible, whereas in Windows Phone the label text of the soft keys can be seen only by pressing the three dots icon on the bottom right corner of the display. However, both user interfaces have also different kinds of soft keys depending on the application.

Figure 11. Keypad -soft key in the phone application, example of Windows Phone on the left and Android on the right side.

5.3. Functional support of user needs

In the functional support of user needs –category the main focus of the evaluation was in the relevance and amount of features and data in the applications. Windows Phone got 3.23 as an average while Android got 2.31 (see Figure 12). The main questions in the checklist covered following topics: do the functionalities reflect the requirements of the user group, whether the functions are designed in consideration of the task context, and are there additional data not relevant for the task execution.

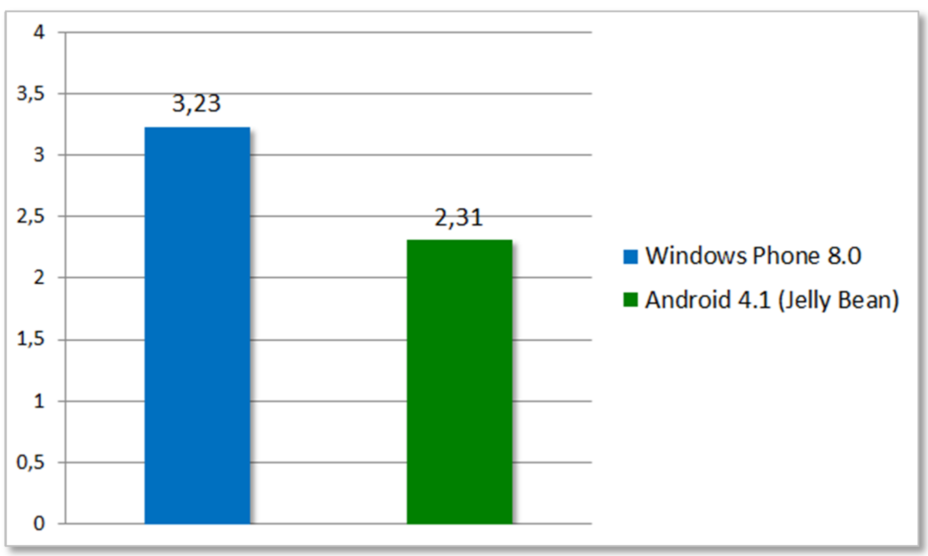


Figure 12. Results of functional support of user needs -indicator.

The main reason for the difference in the results was caused by the amount of features and data. As found in the literature review section, the vast amount of functions and a complicated menu structure impair the usability. Android offers more features and options to the users compared to the Windows Phone. The vast amount of different input fields and functions in the applications may hamper the elderly users' attention and distract the task execution. In Android all data is available to the users right away, whereas in Windows Phone the features that are presumable not so commonly used are typically hidden by default. Figure 13 illustrates the difference in the calendar application.

The calendar application of Windows Phone shows only the basic fields: subject, location, calendar, date, time and duration. The rest of the fields like reminder and repeat are hidden behind “More details” -button. Android shows all options within one screen and a lot of options such as “Quick add”, “Add event” and “Add task”. As well as information that may not be that relevant for the elderly users like the time zone. In addition the keypad is opened automatically hiding some of the input fields when starting the calendar application in Android.

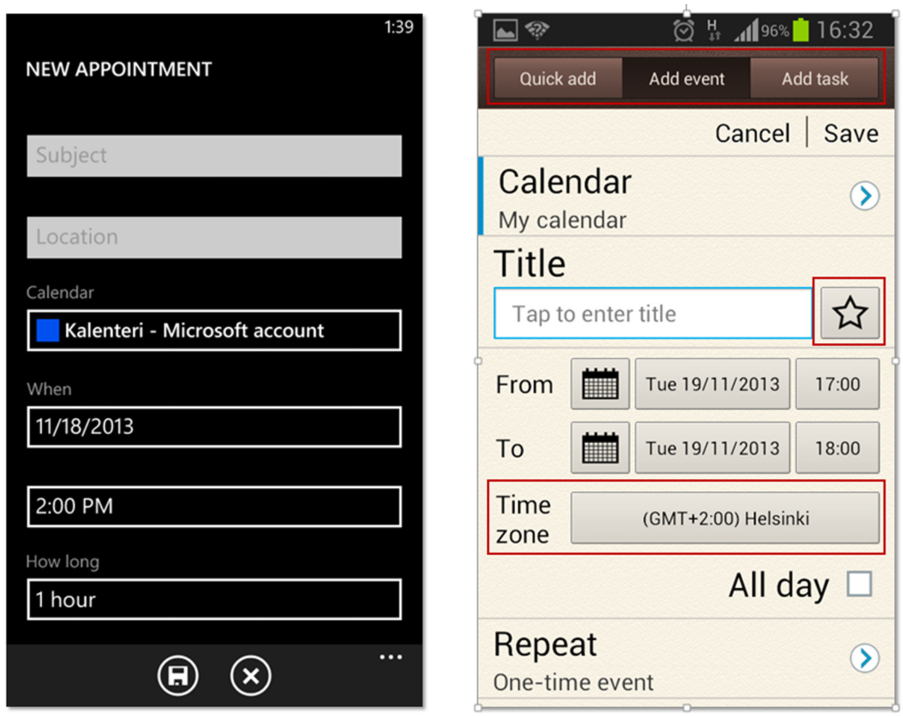


Figure 13. The calendar application as an example of simplified design of Windows Phone on the left, and Android providing more options and entry fields on the right.

The ringing tone profile is a good example of a feature that may be even too simplified in Windows Phone. In both user interfaces there is a shortcut to change the ringing tone profile (see Figure 14). In Android all options are available at the same time, whereas in Windows Phone the user can see only the active profile. In Android there are several options where the profile can be changed: notification panel, volume buttons, and power button. Menu and power button offer three options: sound, vibration and mute. The user is able to change the selection easily between these three. In Windows Phone the profile can only be changed by pressing the volume button. In addition there are only two options available at a time. If the user has the vibration enabled then the profile can be changed only between sound (ring) and vibrate, and vibrate only. Hence disabling the vibration is not possible. The same applies to Android if the profile is changed by using volume button. For Windows Phone vibration must be at first disabled from the settings, and only after that mute option is available in the volume panel. Then options in the volume panel are sound (ring) or mute. This is again example of that the user is expected to know that the mute feature is available as well as to know how to enable it (Apps/Settings/ringtones+sounds). However, the vibration could help to detect the incoming calls. Hence the elderly users may want to have the vibration enabled. To improve usability Windows Phone should also provide the mute option even if vibration is enabled. Also in this example the size of the soft keys and their label text is relatively small in Windows Phone.

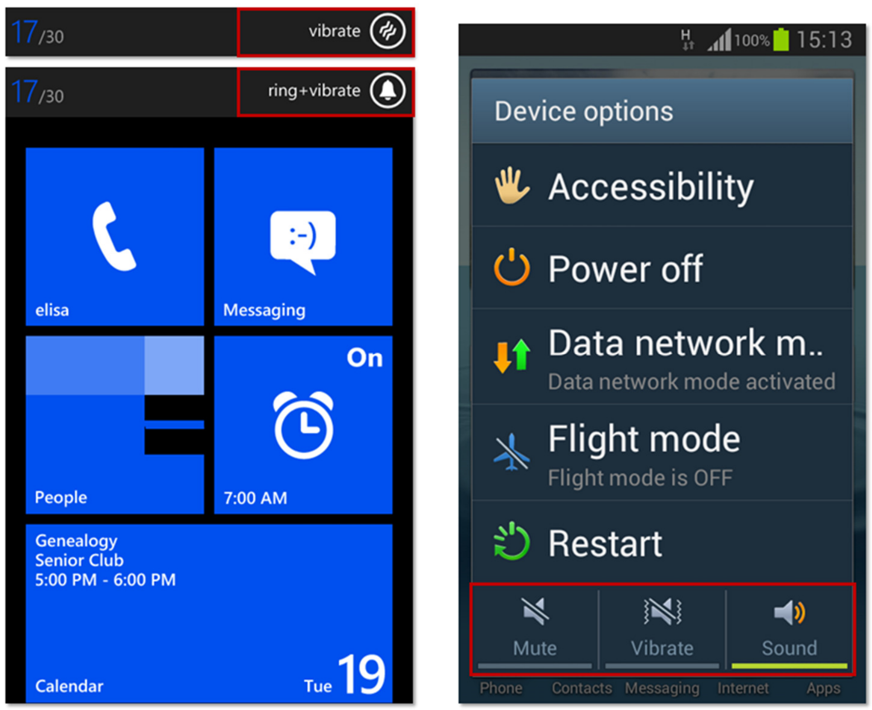
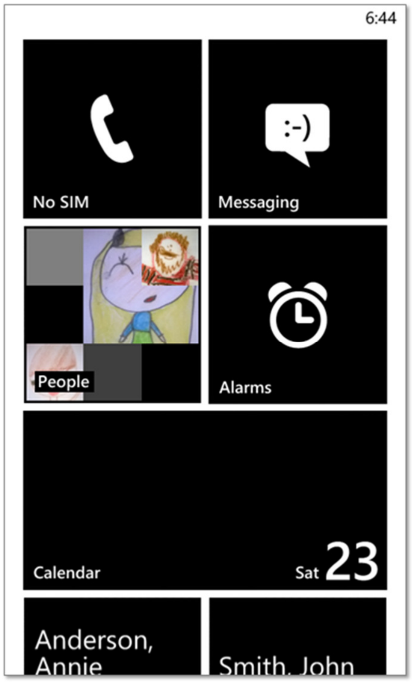


Figure 14. Changing the ringing tone profile can be done by tapping the icon. Windows Phone on the left with only one option visible at a time and Android on the right side showing all options.

According to the previous research the elderly persons prefer to have a clear contrast, a brightly illuminated keypad and an option to adjust the time of how long the display stays active [Kurniawan, 2008]. These requirements were evaluated as part of the functional support of the users' needs as they reflect how the users' needs have been taken into account in the designed functions. Both user interfaces have options to adjust the display's brightness and the display timeout. In Windows Phone the contrast can be improved by changing the background color and the theme color. In addition there is an option to enable high contrast. Similar high contrast mode is not available in Android. However, the easy mode of the home screen sets background of the home screen partially plain which makes it is easier to distinguish the content of the home screen. Figure 15 illustrates the high contrast mode of Windows Phone and the easy mode of Android.



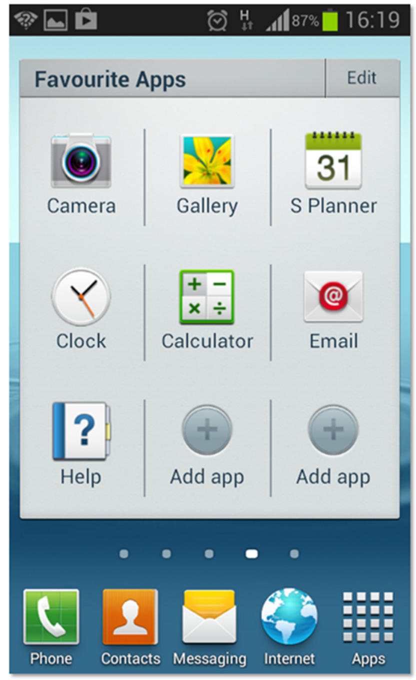


Figure 15. Examples of the high contrast mode of Windows Phone on the left, and the easy mode of Android home screen on the right.

5.4. Support of cognitive interaction

Support of cognitive interaction –category focused to evaluate consistency of the user interface and how well the user interface guides the user. Results of the evaluation are almost the same: Windows Phone got 2.78 as an average and Android got 2.64 (see Figure 16). However, there is a difference in the consistency of the user interface design. The consistency is especially important to the novice users as it facilitates learning. The main questions in the checklist aimed to reveal whether the visual cues were shown effectively and whether the information relevant to task execution was provided at right time.

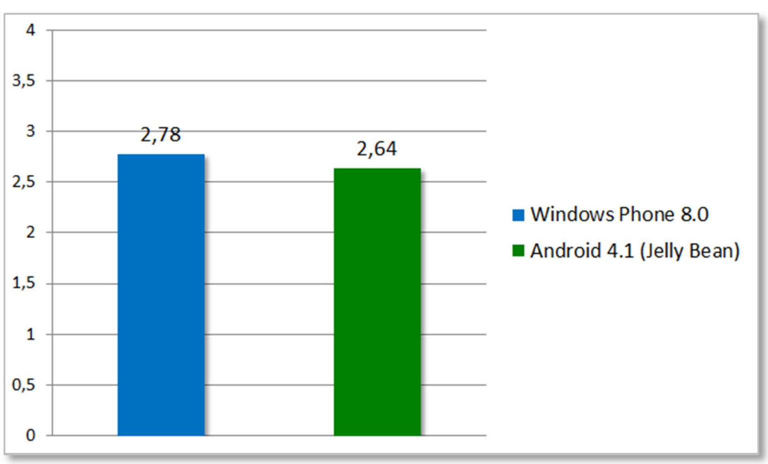


Figure 16. Results of support for cognitive interaction.

One of the questions in the task-based checklist was “Is the cue for starting the task clear?”. Answering to an incoming call was one of the tasks that were evaluated. The elderly users had requirements related to answering incoming calls like showing the picture of the caller and having an assignable ringing tone. Both Windows Phone and Android support these requirements. Figure 17 illustrates that the picture of the caller is rather large compared to the size of the whole display. It is also possible to have dedicated ringing tones for the contacts. Hence the user interfaces fulfill the needs of the elderly users with regards to identify the caller. Also cues to answer or reject the incoming call are quite clear, although in this case the handset icon of Android is perhaps more informative than the plain textual information of Windows Phone. Both user interfaces utilize gestures to accomplish the task. Al-Razgan *et al.* [2012] gave a recommendation to avoid gestures that require a combination of tap and slide. Windows Phone requires slide gesture to activate the device if it has been in the standby mode. This gesture enables answer and reject -soft keys. Android requires combined tap and slide gesture to answer or reject the call. Even though cues on how to accomplish the task are quite clear, it might require some practice to use the combined tap and slide gestures. However, Android offers also an option to answer to the incoming call by pressing the home key, and the power button can be used to end or reject the call. These optional ways to answer and reject the calls must be enabled from the settings.

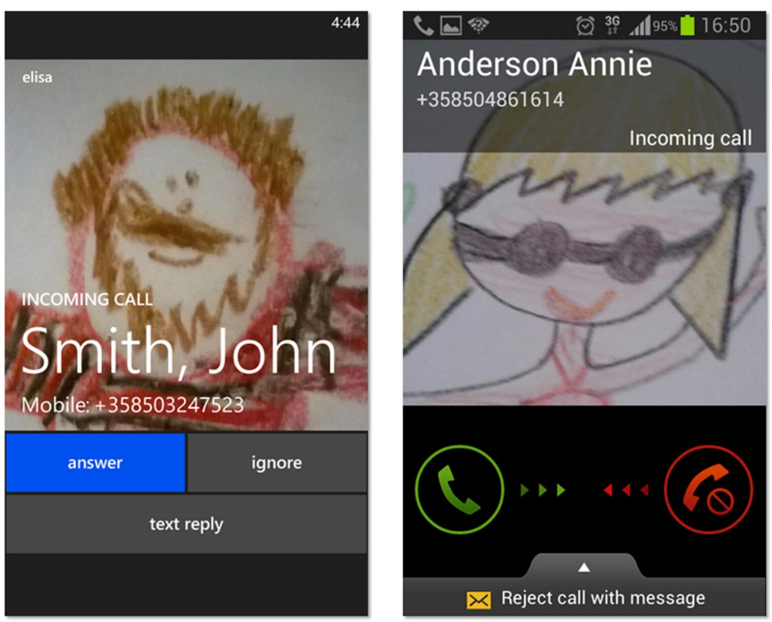


Figure 17. Both user interfaces, Windows phone on the right and Android on the left, show the picture of the caller as well as cues of the answering options.

In general both devices offer cues for how to start and complete the tasks and prevent users from entering invalid values. Typically Android has more options and features available. The reason why Android got slightly lower result is mainly due to inconsistency of the visual cues and functionalities. See Figure 18 as an example of how the same icon can have two different meanings. On the home screen the icon refers to the phone application, whereas on the contact view the same icon refers to the joined contacts.

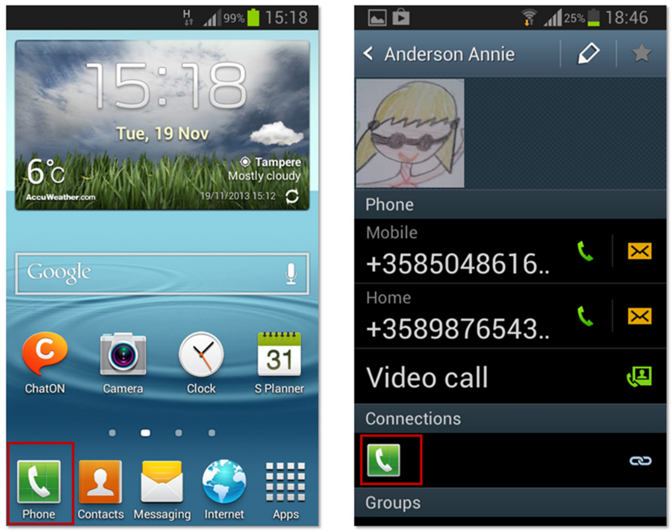


Figure 18. The inconsistent meaning of an icon in Android.

Figure 19 illustrates the variation of the same functionality. In the contacts list a view that opens after tapping the contact depends on where the user taps. If the user taps on the picture of the contact, information is shown on a pop-up dialog. If the user taps the name of the contact, information is opened in its own view. Inconsistency of the user interface causes confusion especially in the learning phase.

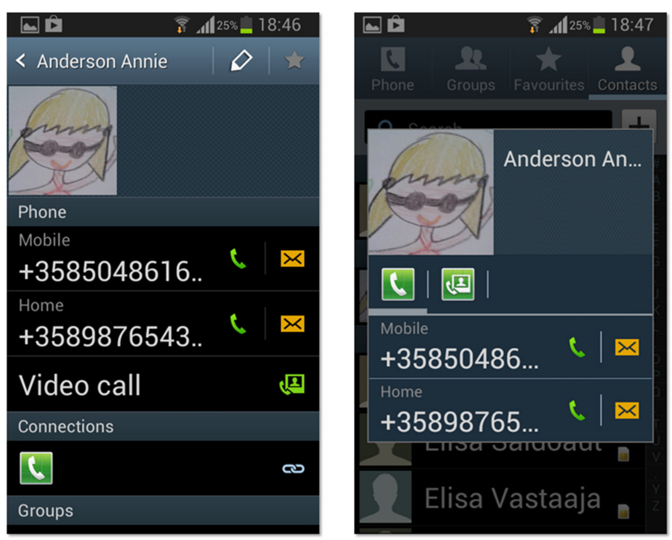


Figure 19. Different views of the same contact in Android.

5.5. Support of efficient interaction

The support of efficient interaction –category focused on evaluating error prevention as well as alternative ways to perform tasks. Evaluated items reflected topics such as is it easy to perceive functions designed to support effective interaction and is it easy to recover from errors. Results of the evaluation were almost the same; Windows Phone got 2.96 as an average and Android got 2.72 (see Figure 20).

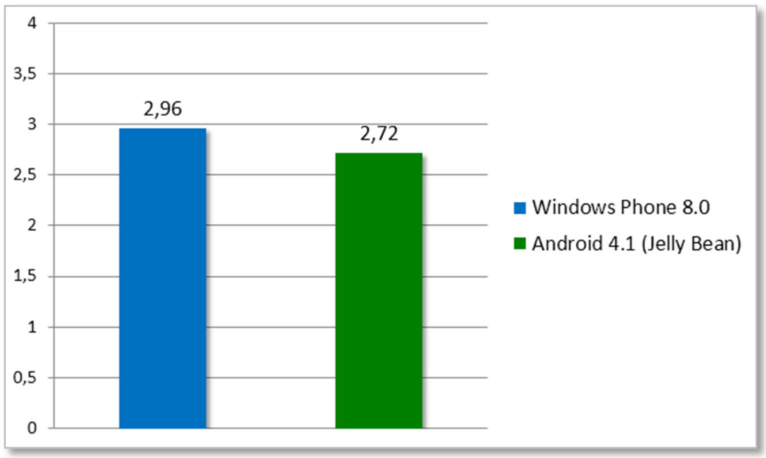


Figure 20. Results of support of efficient interaction -indicator.

One of the requirements of the elderly users is an option for controlling the device with voice commands [Kurniawan, 2008]. Both Windows Phone and Android supports voice commands for limited purposes. Android supports voice commands for example to dictate a text message and to make a Google search. Windows Phone supports options to open applications, to make a call, to search from the Internet and to dictate a text message. The voice command functionality of the Windows Phone can be activated with a long press of the Windows button (home button) and saying for example “Call John Smith” or “Open Calendar”. In the messaging application there is a microphone icon to indicate that the user can dictate the text message. In Android a voice command can be activated in all cases by pressing the microphone icon. Figure 21 illustrates how the user interface looks like when the user is dictating a message. Speech recognition seems to be rather reliable in both devices at least in quiet environment. However, the voice command functionality is not supported for all languages (e.g. Finnish). The microphone icon in Android indicates voice command option, but for example in the Windows Phone the user must know that the voice commands can be activated with a long press of the Windows button. Hence, it can be challenging to find these features and like Gelderblom *et al.* [2010] stated, the so called hidden features are often not used due to lack of knowledge of their existence.

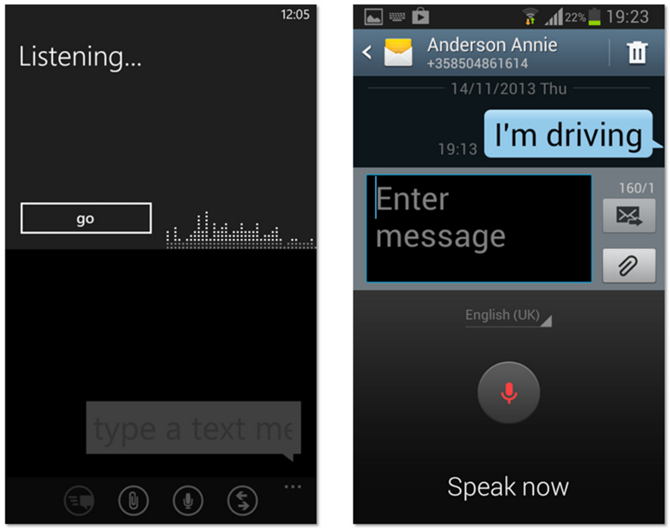


Figure 21. Dictating a text message -view of Windows Phone on the left and Android on the right.

In general both Windows Phone and Android try to prevent errors by offering only relevant data to the users. For example date and time are displayed as selection lists (see Figure 22). However, there are cases like entering the phone number when the user may need to make a correction. According to the research one of the challenges the elderly persons have is recognition of the keys that do not have a textual label (e.g. backspace) [Kobayashi, et al., 2011]. In the numeric keypad the users must make corrections by using the backspace key. In both user interfaces backspace behaves differently depending on the length of the key press; a short press removes digits one by one and a long press removes all the digits at once. For the inexperienced user this kind of a mode change can be confusing.

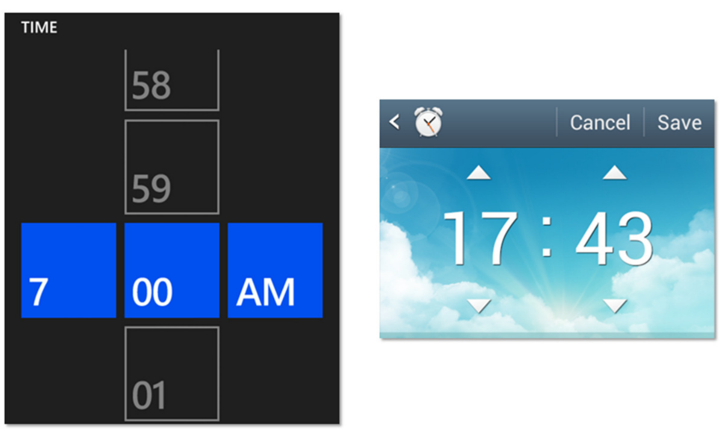


Figure 22. Examples of the time selection -fields of the alarm clock application that prevent users from entering invalid data, Windows Phone on the left and Android on the right.

5.6. Ergonomic support

In the ergonomic support –category the focus was to evaluate whether the physical manipulation of the user interface was comfortable. Tactile and audio feedbacks of the buttons and soft keys, as well as the sensitivity of the touch screen, were also a part of the evaluation. Results of the evaluation are almost the same; Windows Phone got 2.20 as an average and Android got 2.07 (see Figure 23). The slightly lower average for Android in the ergonomic category was caused by the invisibility of the menu and back buttons, issues with the volume buttons and the lack of haptic feedback.

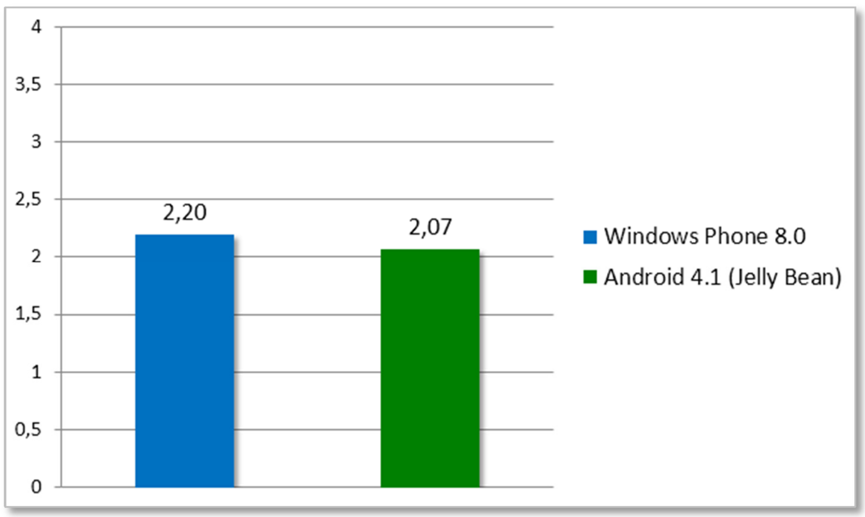


Figure 23. Results of the ergonomic support -indicator.

In the ergonomic point of view the main usability problem in both devices are the buttons that are embedded into the surface. Figure 24 illustrates these buttons below the display. There are no tactile markers on the surface. In Windows Phone there are visible icons, but in Android the back and the menu buttons are not even visible unless they are touched. Hence the user may accidently press these buttons without even realizing it. However, the home button is tangible in Android unlike in Windows Phone.

The volume buttons have been located differently in the devices. In Nokia Lumia all the buttons are located on the right edge of the device, whereas in Samsung Galaxy the power button is on the right side and volume button is on the left. Even though the accessibility to the volume control is good in both devices, in practice the user may easily press the power and the volume buttons at the same time when they are on the opposite edges in Galaxy.

Figure 24. Back, Windows (home) and search buttons of Windows Phone on the left. In the middle Android when the menu and back buttons are not active, and on the right menu and back buttons are activated [Nokia, 2013] [Samsung, 2013].

Android does not provide audio or haptic feedback by default. The audio feedback of keytones, touch sound and screen lock can be separately enabled from the settings. The audio feedback of the different buttons and soft keys is the same. For example pressing the back button sounds exactly the same as pressing a number soft key in the numeric keypad. Therefore, it is not possible to recognize the action only based on the audio feedback. Windows Phone does not support audio feedback to the same extent. For example opening the application from the home screen or applications list does not play any sound. However, there is haptic feedback available for the "back", "Windows" and "search" buttons by default. In addition audio feedback can be enabled for the key presses and for the display lock and unlock functions. The difference compared to Android is that the audio feedback varies depending on the action. For example the sound of the audio feedback of the numeric keypad is similar than the sound of the key press of the landline telephones. Hence the audio feedback resembles the previous experience of the elderly persons. Also locking and unlocking the display plays a different kind of sounds that makes it easier to connect the audio feedback to the action.

Sensitivity of the touchscreen, like described earlier, is adjustable in the both devices. However, the impact is different: in Android the tap and hold delay can be adjusted, whereas in Windows Phone the sensitivity setting allows using the device with gloves. In both devices the touch was recorded only when the user releases the key. For example, when writing a text message a long press of a letter key does not cause the repetition of the letter in the text. Although in some cases a long press may invoke different action; the short press of the backspace key means delete one character while the long press of the backspace key is interpreted as delete all.

6. Discussion

The motivation for this Master's thesis emerges mainly from the attempt to find a way to evaluate usability in a certain context. In this case the context was to evaluate how the selected smartphone user interfaces fulfill the needs of the elderly users. The prerequisite of the evaluation was to identify the needs and desires of the target group. Based on the literature review it became evident that there is a lot of research on the information and communication technology and the elderly users. Material about the mobile phones use of the elderly is also available. However, research focusing on the smartphone usage in the context of the elderly users is limited. Part of the findings on the feature phone use can be applied to smartphone use. However, all such findings may not be directly applicable. For example, the elderly persons who belong to the active daily users group are presumably more likely using smartphones than those who use mobile phone only occasionally. The active users may also have different preferences. These differences were not emphasized in the research of Kurniawan [2008] or van Dyk *et al.* [2012]. Therefore, also my study relied on the general findings on the design preferences of the elderly users.

Based on the recent publications such as Inostroza *et al.* [2013] the need to have fast and affordable tools to evaluate usability of smartphones has grown. It has been realized that the criteria of evaluation developed for PC applications and web pages is not directly applicable to the touchscreen-based mobile devices. Smartphones are also available to a wider audience due to the low-priced models. Hence there is a demand to fulfill the needs of varied user groups. Often it is more cost-efficient to evaluate the user interface against the dedicated checklists such as the accessibility checklist by Mi *et al.* [2013] instead of involving the real users in the design process.

A checklist development seems to follow the same pattern in different studies: study existing material, create a checklist based on the previous findings and verify the checklist with real users [Heo, et al., 2009] [Inostroza, et al., 2012] [Ji, et al., 2006] [Mi, et al., 2013]. This thesis followed the same approach excluding the verification of the checklist with real users. The original target of the thesis was not to develop a heuristic checklist. However, the checklist was required in order to conduct the evaluation by following the usability framework and the process defined by Heo *et al.* [2009]. Now that the checklist exists, it obviously needs to be validated. Validation work, however, is beyond the scope of this thesis.

A checklist for evaluating from the elderly users' point of view could not be found in prior work. There are studies suggesting design guidelines concentrating on the elderly needs such as Al-Razgan *et al.* [2012] and Kurniawan [2008]. The checklists like TMD do not cover the special needs of a certain user group. For example requirements related to the haptic and auditory feedback were covered in the accessibility checklist. But the accessibility checklist does not cover some topics that were essential to the elderly users. Therefore, checklists used in this study were composed based on the information from different sources. Disadvantage of the checklists is the lack of possibility to evaluate items that are heavily dependent on the actual users. For example, text messaging was excluded from the evaluation because of this. Another challenging topic to evalute without the involvement of the actual users is how well the user interface components like icons resemble the impressions the users have. In some cases the original division of the usability properties by Heo *et al.* [2009] did not correspond the specific requirements of this study. For example haptic or auditory feedback is not mentioned at all by Heo *et al.* [2009].

The usability framework does not restrict the methods that can be used for the evaluation. For example findings of a usability test can be classified based on the multi-level and hierarchical model of the usability framework. In practice finding a representative sample of the elderly smartphone users turned out to be challenging. As explained in the literature review both demographic characteristics as well as previous experience of the technology have impact on the empirical research. Applying the expert evaluation method in this thesis reduces the noise in the results caused by the diversity of the user group. On the other hand the idea of the expert evaluation is to combine opinions from several experts instead of making the evaluation only based on the opinion of one evaluator. Especially when evaluating the severity of the findings there can be different opinions. On the other hand the idea of this study was to compare two different user interface designs. In this case the comparison was done based on the same set of criteria and severity rating for both user interface designs.

During the evaluation it became obvious that those questions on the checklists that were unambiguous and could be simply answered yes or no, were easier to rate than those which did not have a clear answer. For example the item "*Can the size of the icons be changed?*" can be easily evaluated without input from the real users, whereas questions like "*Is the terminology clear?"* is something that only the real users can give the final answer to. The severity of the findings depends also on the case being evaluated e.g. additional information in the applications, like the time zone selection in the Android's calendar application, may distract user or then not. This is a good example of the situation where usability issue can be identified based on the heuristic evaluation, but the severity is hard to rate without input from the real users. The rating depends also on the standpoint: is the evaluation done by considering the novice users or the experienced users. In this study the approach was closer to the novice users' viewpoint. Based on the experiences of this evaluation it can be said that in order to make the checklists suitable for the expert evaluation they require some fine-tuning, such as focusing on the clear yes/no type of questions. In addition, the multi-level hierarchical framework appears to be rather laborious procedure for evaluating usability, if there is no a specific need to make high level comparison between the devices or design solutions.

The checklist based expert evaluation aims to reveal design flaws that impair the usability and the final outcome of the evaluation is typically a proposal how to fix the flaws. Hence the biggest benefit of the evaluation is gained during the development phase when proposed changes to the user interface can be done. In this study the emphasis was to identify favorable and unfavorable design solutions from the existing user interface designs and offer examples of those classified based on the usability indicators. The usability evaluation framework by Heo *et al.* [2009] opens up a possibility to compare products or design solutions in high level. However, the high abstraction level may make the presentation of the actual findings abstract and difficult to understand. Hence, the overall usability score and the scores of the indicators alone do not lead to concrete actions without knowledge of what kind of criteria and checklists have been used in the evaluation. The usability framework offers tools to quantify and visualize usability which is especially useful for the comparison purpose.

This study may not reflect the actual opinions of the elderly users. In order to improve the validity of the research, the items inspected based on the checklists should be evaluated with real users. However, the diversity of the user group makes it challenging to have a generic checklist specifically aimed for the elderly persons. A more appropriate approach could be to have separate checklists for novice users or users with the diminished sense of sight, for example. The age as such is not the determining factor. Although, diminished sense of sight is a typical symptom of aging, it can occur in younger users as well. Likewise, novice users can be found in all age groups. An interesting topic to investigate in the future would be how to make the smartphones easy to personalize to better fulfill the needs of different kinds of users as well as how to make the personalization attractive without making the users feel that they have somehow abnormal requirements.

7. Conclusions

The potentiality of the elderly persons as smartphone users seem to be recognized. For example, the Danish hearing-aid manufacturer GN Store Nord cooperates with Apple in order to launch an iPhone compatible hearing-aid that does not look like a traditional hearing-aid. Their aim is to attract the aging population with the accessory that can be used as a headset as well as the hearing-aid. Also other hearing-aid manufacturers have awoken to investigate possibilities that the new technologies bring along. [Sanoma News Oy, 2013].

Based on the results of this thesis the smartphone operating systems already support many features that make the use of the devices comfortable for the elderly users. The challenge is how to enable these features. Especially Android has many accessibility features that can be enabled from the settings. Accessibility settings are one menu item in the settings, but still, for example, the easy mode is not part of the accessibility settings. In Windows Phone many features that make the device easier to use for the elderly are enabled or even built in to the system by default. For example, the option to change the size of the tiles on the home screen and the plain colors to enhance vision. However, some features must be enabled from the settings like in Android.

The overall issue with Android is that it supports a wide scale of features, such as time zone selection in the calendar, that are not relevant to most of the elderly users. Showing a lot of additional data hampers users' attention and loads the cognitive capacity. Many options complicate the learning process and make it hard to recall how to perform tasks. The advantage of Windows Phone over Android is simplicity from both user interface design and features perspective. In the context of the novice elderly users it can be said that less is more. Plain and minimalistic user interface design combined with the textual information supports better the requirement of simple and easy to use device. The major disadvantage of the Windows Phone user interface is the small soft keys inside applications. In many applications the most important features have large soft keys like "call" but less frequently used features can be accessed only through small soft keys.

The elderly woman who just wanted a beautiful phone, which happened to be Samsung Galaxy S III mini, is an concrete example proving that the elderly persons are potential users of the smartphones, and that they may have some special needs. The woman eventually searched assistance on how to use the device from peer-tutors and got written step-by-step instructions including illustrative UI drawings on how to answer and make a phone call with her new phone. In addition her phone was customized to have a larger font size and a longer delay time than it originally had.

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Appendices

Appendix 1

Usability checklist for mobile phone user interface [Ji, et al., 2006].

Usability Principle
Cognitive Support
Predictability
Learnability
Structure principle
Consistency
Memorability
Familiarity
Information support
Recognition
Visibility
Simplicity
Subsitutivity
Interaction support
Feedback
Error indication
Synthesizability
Responsiveness
User support
Recoverability
Flexibility
User control
Customizability
Performance support
Effectiveness
Efficiency
Effort

Appendix 2

The touchscreen-based mobile devices heuristics compared to the Nielsen’s heuristics [Inostroza, et al., 2012].

Touchscreen-based mobile devices heuristics		*Nielsen’s heuristics*	
ID	***Name***	***ID***	***Name***
TMD1	Visibility of system status	H1	Visibility of system status
TMD2	Match between system and the real world	H2	Match between system and the real world
TMD3	User control and freedom	H3	User control and freedom
TMD4	Consistency and standards	H4	Consistency and standards
TMD5	Error prevention	H5	Error prevention
TMD6	Minimize the user's memory load	H6	Minimize the user's memory load
TMD7	Customization and shortcuts	H7	Flexibility and efficiency of use
TMD8	Aesthetic and minimalist design	H8	Aesthetic and minimalist design
TMD9	Help users recognize, diagnose, and recover from errors	H9	Help users recognize, diagnose, and recover from errors
TMD10	Help and documentation	H10	Help and documentation
TMD11	Physical interaction and ergonomics		

Appendix 3

A heuristic checklist for an accessible smartphone interface design [Mi, et al., 2013].

Checklist item
1. Is the phone shaped easily to fit into users' hands?
2. Can the phone withstand drops and scratches?
3. Do the keys prevent slipping?
4. Are the edges easily detectable to help users locate buttons?
5. Are commonly used buttons (such as home, volume, power) placed in obvious or intuitive locations?
6. Are the buttons uniquely shaped, large, and spaced to support quick identification of location and function?
7. Are there tactile markers on the phone surface for primary feedback?
8. Do the controls and keys not require tight grasping, pinching, or twisting of the wrist?
9. Are the buttons highlighted when pressed?
10. Are the screen and menus easy to explore without excessive searching?
11. Is there a high-resolution display?
12. Is there no glare or reflection from the touch screen?
13. Is voice activation available to enable users to determine system status?
14. Does the phone have voice-activated dialing and text entry?
15. Are there assignable or talking ringtones that identify callers?
16. Is there easy access to voice mail without long key sequences?
17. Are users notified of errors?
18. Are commonly used menu items grouped together?
19. Can the screen reader technology be easily accessed?
20. Does the phone have message reader software?
21. Is speed or shortcut dialing available?
22. Can calls be answered by pressing any key?
23. Can the touchscreen be started by touching in any position?
24. Is there an indicator of ringing or vibrating mode?
25. Can selections be cancelled?
26. Does the phone confirm every completed function?
27. Does the phone allow for error correction?
28. Can gliding gestures be used for direct manipulation to make selections?
29. Is there an adjustable delay of button response to ensure that multiple touches can be treated as one touch?
30. Are reusable commands and gestures used to ensure consistent interactions across applications and functions?
31. Is feedback accurately presented upon request?
32. Does the phone allow up to 2 s of holding a key before the action will repeat?
33. Can the name of a character that is being entered be heard?
34. Are the names of items on the screen heard as they are touched?
35. Is there a brief, distinct sound when an item is selected?
36. Are menu lists divided into morphemic units (broken into pieces) to make it easier to read back to the user?
37. Can sound feedback be stopped at any time to move to the next function?
38. Is it possible to turn off sound feedback?

39. Does the phone have volume control?
40. Are there auditory indicators of battery status, signal strength, and roaming?
41. Is vibration feedback localized to the hand or touching/activation finger rather than vibrating the entire device?
42. Are small high-speed displacements used as feedback to provide strong and easily detectable sensation (above threshold)?
43. Is the phone's layout consistent and familiar?
44. Is there visual and touch or sound feedback to identify the status of locking or toggle controls or keys?

Appendix 4

Template of the task-dependent evaluation checklist

Task step	Usability indicator	Usability criteria	Corresponding area	Related phone component	#	Checking question	Reference	
Step 1 (entry)	Visual support of task goals	Do the users think that they can achieve a task using the mobile phone?	LUI	homescreen, menu	1	Is there an easy access to application?	[Mi et al., 2013][Inostroza et al., 2012][Ji et al. 2006][Kurniawan, 2008][Lim, 2010]	10. Are the screens and menus easy to explore without extensive searching? TMD7 User support See chapter 2.4.2.
	Support of efficient interaction	Does the mobile phone provide functions to making users achieve a task more efficiently?	LUI	homescreen, menu	2	Are there alternative options to open application?	[Mi et al., 2013][Inostroza et al., 2012][Ji at al., 2006]	14. Are there voice-activated dialing and text entry? TMD7 Customization and shortcuts Performance support
	Support of cognitive interaction	Are visual cues shown effectively?	GUI	icon, label text, highlight	3	Is the cue for the application clear?	[Inostroza et al. 2012] [Ji et al. 2006]	TMD2 Match between system and the real world Cognitive support
Step 2 (use)	Support of cognitive interaction	Are visual cues shown effectively?	GUI	icon, label text, menu	4	Is the cue for starting the task clear?	[Inostroza et al. 2012] [Ji et al. 2006]	TMD2 Match between system and the real world Information support
	Support of cognitive interaction	Is the information relevant to task execution provided at right time?	LUI	input field, label text, cursor, highlight	5	Are the most important information in the beginning?	[Inostroza et al., 2012] [Ji et al. 2006]	TMD4 Consistency and standards Cognitive support
	Functional support of user needs	Are the users' needs reflected in the designed functionalities?	LUI	input field, highlight	6	Is it easy to enter data?	[Inostroza et al., 2012] [Ji et al. 2006]	TMD5 Error prevention Interaction support

	Functional support of user needs	Are the function designed in consideration of task context?	LUI	input field, highlight	7	Is there additional data not relevant for the task execution?	[Inostroza et al. 2012] [Ji et al. 2006]	TDM6 Minimize user's memory load Cognitive support
	Functional support of user needs	Are the function designed in consideration of task context?	LUI	input field, icons, highlight	8	Are there several focusing points within a screen, which can hamper users' attention?	[Inostroza et al. 2012] [Ji et al. 2006]	TDM6 Minimize user's memory load Cognitive support
	Support of cognitive interaction	Are there any measures to for preventing error occurrence?	LUI	input field, highlight	9	Is format of input fields allowing only entering valid data?	[Inostroza et al., 2012] [Ji et al. 2006]	TMD5 Error prevention Interaction support
	Support of efficient interaction	When the users make a mistake, can they recover easily from it?	LUI	soft key, cursor, highlight	10	When user has entered wrong data is it easy to make correction?	[Mi et al., 2013][Instroza et al., 2012] [Ji et al., 2006]	25. Can selections be cancelled? TMD9 Help users recognize, diagnose and recover from errors Interaction support
	Support of efficient interaction	Can the user easily perceive the functions designed to support efficient interaction?	LUI	icons, label text	11	Are there alternative options to complete a task?	[Inostroza et al., 2012] [Ji et al., 2006]	TMD7 Flexibility and efficiency of use Performance support
	Ergonomic support	Is the physical manipulation of PUI comfortable?	PUI	soft key, menu, buttons	12	Are commonly used components placed in obvious or intuitive locations?	[Mi et al. 2013][Inostroza et al, 2012] [Ji et al. 2006]	5. Are commonly used buttons (such as home, volume, power) placed in obvious or intuitive locations? TMD2 Match between system and real world Cognitive support
	Ergonomic support	Is the physical manipulation of PUI comfortable?	PUI	vibration, sound	13	Is there tactile/audio feedback to support interaction?	[Mi et al., 2013][Ji et al. 2006][Kurniawan, 2008][van Dyk et. Al., 2012]	44. Is there visual and touch or sound feedback to identify the status of locking

								or toggle controls or keys? User support See chapter 2.4.3
Step 3 (exit)	Support of cognitive interactio n	Are visual cues shown effectively?	GUI	icon, label text, menu	14	Is the cue for completing the task clear?	[Inostroza et al. 2012][Ji et al. 2006]	TMD1 Visibility of system status Interaction support
	Support of efficient interactio n	When the users make a mistake, can they recover easily from it?	LUI	soft key, cursor, highlight	15	Is it easy to cancel a task?	[Mi et al., 2013][Instroza et al., 2012][Ji et al., 2006]	25. Can selections be cancelled? TMD9 Help users recognize, diagnose and recover from errors User support

Appendix 5

LUI-based checklist

Usability indicator	Usability criteria	Related phone component	Checking question	Reference	Windows Phone	Android
Visual support of task goals	Do the users think that they can achieve a task using the mobile phone?	home screen, icons, label text	Is there easy access from home screen to the most relevant applications (phone, contacts alarm, calendar, SMS)?	[Mi et al., 2013]: 5. Are commonly used menu items grouped together? [Lim, 2010]: Direct access and low-level interaction structure (chapter 2.4.2)	4	1
Visual support of task goals	Can the user understand the meaning of the cues exactly?	icons	Do the icons correspond to the real world?	[Inostroza et al. 2012]: TMD2 [Ji et al., 2006]: Cognitive support	3	2
Support of cognitive interaction	Can the user assess the current state of operation or get feedback on task progress?	icons, label text, highlight	Are mode (e.g. Edit mode) changes obvious to the user?	[Kobayashi et al., 2011]: see chapter 2.4.2 [Inostroza et al., 2012]: TMD1 [Ji et al. 2006]: Information support	3	2
Functional support of user needs	Are the users' needs reflected in the designed functionalities?	input field, highlight	Is there a separate SW keypad for text and numbers?	[van Dyk et al., 2012]: see chapter 2.4.2 [Ji et al., 2006]: Information support	3	3
Support of cognitive interaction	Can the user understand the meaning of the cues exactly?	label text	Are there textual labels for backspace and shift keys in software keypad?	[Kobayashi et al., 2011]: see chapter 2.4.2	2	2
Functional support of user needs	Are the users' needs reflected in the designed functionalities?	label text	Is the terminology clear?	[Kurniawan, 2008][van Dyk et al., 2012] see chapter 2.4.2 [Ji et al., 2006]: Cognitive support	3	2
Functional support of user needs	Are users' needs reflected in the designed functionalities?	buttons, soft keys, key pad	Is there audio feedback available?	[Kurniawan, 2008][van Dyk et al., 2012] see chapter 2.4.3, 2.4.4	2	2
Functional support of user needs	Are users' needs reflected in the designed functionalities?	microphone, loudspeaker	Are there possibilities to control device via voice and audio?	[Kurniawan, 2008][van Dyk et al., 2012] see chapter 2.4.3, 2.4.4 [Ji et al., 2006]: User support	4	3

Appendix 6

GUI-based checklist

Usability indicator	Usability criteria	Related phone component	Checking question	Reference	Windows Phone	Android
Support of cognitive interaction	Are visual cues shown effectively?	screen, keypad, label text	Can the size of font in screen, keypad and buttons (soft keys) be changed?	[Kurniawan, 2008][van Dyk et al., 2012] [Inostroza et al., 2012]: TMD3 [Ji et al., 2006]: User support	3	3
Visual support of task goals	Are visual cues shown effectively?	icons	Can the size of icons be changed?	[Kurniawan, 2008][van Dyk et al., 2012] [Inostroza et al., 2012]: TMD7 [Ji et al., 2006]: User support	4	0
Visual support of task goals	Are visual cues shown effectively?	softkeys, buttons	Can the size of softkeys be changed?	[Kurniawan, 2008][van Dyk et al., 2012] [Inostroza et al., 2012]: TMD7 [Ji et al., 2006]: User support	2	2
Support of cognitive interaction	Are visual cues shown effectively?	display, icons	Can the size of text changed (e.g. SMS)?	[Kurniawan, 2008][van Dyk et al., 2012] [Inostroza et al., 2012]: TMD7 [Ji et al., 2006]: User support	3	3
Functional support of user needs	Are the users' needs reflected in the designed functionalities?	display	Can the contrast of the display customized?	[Kurniawan, 2008][van Dyk et al., 2012] [Inostroza et al., 2012]: TMD7 [Ji et al., 2006]: User support	4	2
Functional support of user needs	Are the users' needs reflected in the designed functionalities?	display	Can the brightness of the display be customized?	[Kurniawan, 2008][van Dyk et al., 2012] [Inostroza et al., 2012]: TMD7 [Ji et al., 2006]: User support	4	4
Functional support of user needs	Are the users' needs reflected in the designed functionalities?	display	Can screen timeout be changed?	[Kurniawan, 2008][van Dyk et al., 2012] [Inostroza et al., 2012]: TMD7 [Ji et al., 2006]: User support	4	4

Appendix 7

PUI-based checklist

Usability indicator	Usability criteria	Related phone component	Checking question	Reference	Windows Phone	Android
Ergonomic support	Is the physical manipulation of PUI comfortable?	buttons, soft keys	6. Are the buttons uniquely shaped, large, and spaced to support quick identification of location and functions?	[Kurniawan, 2008][van Dyk et al., 2012] see chapter 2.4.3, [Mi et al., 2013] [Inostroza et al., 2012]: TMD11	1	2
Ergonomic support	Is the physical manipulation of PUI comfortable?	buttons, soft keys	7. Are there tactile markers on the phone surface for primary feedback?	[Kurniawan, 2008][van Dyk et al., 2012] see chapter 2.4.3, [Mi et al., 2013] [Inostroza et al., 2012]: TMD11	1	1
Functional support of user needs	Are users' needs reflected in the designed functionalities?	buttons, loudspeaker	Are volume keys easy to access?	[Kurniawan, 2008][van Dyk et al., 2012] see chapter 2.4.3, 2.4.4 [Inostroza et al., 2012]: TMD11	3	3
Ergonomic support	Is the physical manipulation of PUI comfortable?	buttons, soft keys, key pad	Can sensitivity of touch changed?	[Kurniawan, 2008][van Dyk et al., 2012] see chapter 2.4.3, [Mi et al., 2013] [Inostroza et al., 2012]: TMD7	0	4

Appendix 8

Results of the task-based evaluations

	MAKING A CALL FROM CONTACTS		MAKING A CALL FROM KEYPAD		RECEIVING A CALL		SETTING A NEW ALARM	
*)	Windows Phone	Android	Windows Phone	Android	Windows Phone	Android	Windows Phone	Android
1	4	4	4	2	3	3	4	1
2	3	1	3	3	3	3	4	2
3	4	3	4	3	3	3	4	2
4	3	3	1	3	4	4	4	3
5	3	3	3	3	4	4	3	3
6	1	2	4	4	3	3	3	2
7	3	3	3	3	3	3	3	3
8	3	1	4	2	3	2	4	3
9	3	0	3	3	3	3	4	3
10	3	3	2	2	3	3	3	3
11	3	2	4	2	3	2	3	2
12	4	1	3	2	3	3	3	3
13	3	1	4	1	2	4	2	2
14	1	1	2	4	2	4	3	1
15	1	4	2	3	3	3	3	3

*) Number of the task-based checklist item in Appendix 4

MAKING A CALENDAR REMINDER			CHANGE RINGING TONE PROFILE	
*)	Windows Phone	Android	Windows Phone	Android
1	4	1	2	2
2	4	2	3	3
3	2	2	2	2
4	3	2	3	3
5	2	0	4	3
6	3	1	1	3
7	3	0	4	2
8	3	0	4	2
9	3	3	1	4
10	2	3	3	3
11	3	4	3	3
12	3	1	2	2
13	2	2	2	3
14	3	1	1	2
15	3	1	3	3