Smartphone Evaluation Heuristics for Older Adults

by

Piotr Calak

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SMARTPHONE EVALUATION HEURISTICS FOR OLDER ADULTS

Piotr Calak
Advisor: Dr. Blair Nonnecke
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Age-related physical and cognitive changes hinder the ability of older adults to operate smartphones. While many user interface (UI) heuristics exist today, there is a need for an updated set designed specifically to assess the usability of mobile devices for an older audience. Smartphone evaluation heuristics for older adults based on age-related changes in vision, hearing, attention, memory and motor control were developed in this thesis by analyzing literature on age-related physical and cognitive changes impacting smartphone usability. Support for heuristics was found by gathering information on how older adults use cell phones through interviews and an online survey. It was demonstrated that strength of support for some heuristics increases with age. The evaluated heuristics provide usability practitioners and designers with a framework for evaluating the usability of smartphones for older adults.
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1 Introduction

Mobile devices include mobile PCs, PDAs and smartphones as well as personal media players such as the iPod. In this sector, smartphones represent the fastest growing category and shipments of smartphones have already surpassed shipments of PC’s (Canalys, 2012). Smartphones include basic services such as telephone and email, and increasingly allow users to browse the internet, connect to social networks, participate in community discussions and allow users to stay connected at all times.

Current mobile devices and mobile application designs don’t address the needs and expectations of older adults (Kurniawan, 2008; Ziefle, 2010) and often cater to the needs of the most prevalent market group, young adults (Pattison & Stedmon, 2006). 18 to 34 year old adult males are the largest group that uses mobile technologies (Horrigan, 2009), although they only make up roughly 30% of the world’s population (United Nations, 2005). In contrast, older adults are one of the fastest growing consumer segments for the use of mobile technology and they will require customized and accessible smartphones.

Older adults are commonly defined by gerontologists as persons aged 60 years and older (Hinrichsen & Molinari, 1998). Age-related changes have negative effects on vision, hearing, attention, memory and motor control. Many age-related changes are experienced as early as the age of 50 and get progressively worse. They include lowered contrast sensitivity (Pattison & Stedmon, 2006; Scialfa, C., & Kline, 2007), decreased ability to focus on objects nearby (Goldstein, 2006, p. 550) and loss of auditory sensitivity at higher frequencies (Goldstein, 2006, p. 568). Age-related changes in information processing efficiency have a negative effect on memory (S. Smith, Norris, & Peebles, 2000) and a reduction in information processing speed adversely affects attention (McDowd & Shaw, 2000). Older adults experience impairments in motor control, muscular coordination, strength and tactile sensitivity (Spirduso, Francis, & MacRae, 2005). Older adults also experience slower feedback regarding the position of the limb with
respect to the target (Donkelaar & Franks, 1991). These factors negatively affect the abilities of older adults to use and operate mobile devices (Pattison & Stedmon, 2006; Ziefle & Bay, 2005). For the purpose of this thesis, older adults are defined as anyone over the age of 50.

Approximately 10.4% of world’s population is over 60 years old (United Nations, 2005). By 2050 the proportion of older adults is projected to double to 21.7% and is expected to outnumber people under the age of 15 (United Nations, 2005). Substantial increases in the population of older adults combined with the fact that people's healthy active lives extend over the age of 70 in developed countries (Mikkonen, Väyrynen, Ikonen, & Heikkila, 2002) will make older adults one of most powerful consumer groups.

Little research has been done to understand those with special needs, and in particular to assist people with cognitive impairments (Dawe, 2007). Enhanced accessibility of products can make them easier to use for all consumers (Vanderheiden & Vanderheiden, 1991). Graf et. al (2005) have called for the development of UI design guidelines based in age-related changes in sensory, perceptual, cognitive and motor control functions across the adult lifespan. Research suggests that older adults prefer mobile phones with large screens, large buttons, loud volume, simplified menus and large text (Kurniawan, 2006; Mallenius, Rossi, & Tuunainen, 2007; Plos & Buisine, 2006).

For the purpose of this thesis, heuristics are defined as rules of thumb to reduce the search for solutions in the domain of smartphone design for older adults. Compared to formal structures such as algorithms, "heuristics do not guarantee optimal, or even feasible, solutions and are often used with no theoretical guarantee" (Interaction Design Foundation, 2006).

The intended audience for the heuristics are usability practitioners, who can use the developed heuristics to evaluate the usability of smartphone design for older adults.
Thesis Statement

Are smartphone evaluation heuristics based on age-related physical and cognitive changes supported by experiences of older adults and is there stronger evidence with increasing age?

In this thesis, age-related changes impacting smartphone usability for older adults are discussed and synthesized into a set of smartphone evaluation heuristics. Literature on smartphone usage by older adults, heuristic development, adaptation and evaluation are analyzed. Mobile design guidelines and usability heuristics are evaluated for evidence of age-related support. The developed smartphone evaluation heuristics are then evaluated through interviews and an online survey.
2 Literature Review

This chapter reviews the following:

- Smartphone design, context of use, usability and possible uses for older adults (Section 2.1)
- Heuristic usage, adaptation and evaluation (Section 2.2)
- Simulation of age-related impairments (Section 2.3)

Based on the review of literature related to the topics outlined above, a set of heuristics will be created to address age-related changes in vision, hearing, attention, memory and motor control. Mobile design guidelines will be analyzed for issues related to ageing addressed by the heuristics.

2.1 What is a Smartphone?

A smartphone is a device, which combines the functionality of a mobile phone with features commonly found on a personal computer (PC). The core functionality of voice communication found in a mobile phone is often complimented by features such as email, instant messaging, calendar, and internet browser. Smartphone users also have the ability to download and install a multitude of applications. Downloadable smartphone applications allow users to perform a variety of tasks in a mobile context. Users are often required to become familiar with new interaction paradigms in downloaded apps.

As technology advances, mobile devices are becoming smaller in size and contain increasingly more features. Constant miniaturization of smartphones leads to inherent limitations that include a limited display size and a difficulty of data input (Moll, 2007). Users are required to dedicate considerable attentional resources to perform increasingly complex tasks on miniature devices.

2.1.1 Context of Use for Smartphones

The contexts in which smartphones are used are much more dynamic and unpredictable than desktop PC’s (Tamminen, Oulasvirta, Toiskallio, & Kankainen, 2004). Context, defined as the “circumstances and conditions that surround a place, thing, or event” (Moll, 2007) is one of the most important factors related to smartphone usability. Smartphone users often interact with their devices with one hand
in cognitively demanding environments, such as while walking and paying constant attention to surroundings. Multitasking results in decreased attention resources available with a smartphone (Tamminen et al., 2004). Mobile users dedicate a large portion of their attention resources to monitoring the environment for landmarks and checking whether they are proceeding in the correct direction towards their destination (Tamminen et al., 2004). Limitations related to smartphone usage with scarce attentional resources in cognitively demanding environments should be addressed in design.

2.1.2 Smartphone Usability
The two most important determinants for the popularity of mobile phones are usability and user friendliness (Duh, Tan, & Chen, 2006). Usability is defined by how easy to learn, efficient to use and easy to remember a system is (Nielsen & Mack, 1994). A usable system should also have a low error rate and should be pleasant to use (Nielsen & Mack, 1994). Duh, Tan and Chen (2006) state that good mobile phone design can lead to increased sales, reduced mental and physical stress as well as a decreased learning curve. These factors are applicable to smartphones, which are often even more complex than mobile phones. Usability of technology is especially important for older adults, who experience a range of physical and/or cognitive disabilities (Boulos, Anastasiou, Bekiaris, & Panou, 2011).

2.1.3 Smartphones and Older Adults
Older adults selectively make use of new technologies, but often encounter more trouble than younger adults in acquiring devices, becoming competent users and troubleshooting (Czaja et al., 2006). Huber and Watson (2011) found that the older a person is the more likely they are to seek help with operating a new technology. Graf et. al (2005) reports that in a digital camera usability study, younger adults did not request any help when learning to operate a new device, while older adults did not begin the task without guidance.

Aging is associated with a general slowing of physical and cognitive abilities that are required to learn new technologies (Huber & Watson, 2011). Doctors and psychologists often encourage older adults to
“learn new things, because it can be beneficial for their brain, help prevent illnesses such as Alzheimer’s and allow them to gain new skills for a job” (Borges, Conceição, Lima, & Reategui, 2012).

Common problems that older adults experience while using mobile phones include; small screens and UI’s that are hard to see, miniaturized buttons and keypads with tiny inscriptions, poor sound quality and a large number of functions (Borges et al., 2012; Pattison & Stedmon, 2006). Older adults often find it challenging to accomplish tasks within pre-defined time limits (Mitchell & Chesters, 2004). The problems experienced by older mobile phone users are further exaggerated in smartphones, because of an increased functionality set often found in smartphones.

Researchers have proposed UI’s and mobile devices designed specifically towards increasing the usability and accessibility for older adults (eg. Olwal, Lachanas, & Zacharouli, 2011; Pattison & Stedmon, 2006; Sulaiman & Sohaimi, 2010). Olwal et al. (2011) evaluated the potential for a customizable cell phone UI framework for older adults by comparing three mobile devices: generic cell phone, generic cell phone with OldGen UI, cell phone for seniors. User observation sessions and informal test sessions with older adults (63-74 years old) were conducted to determine the performance of a UI adapted for older adults. Based on preliminary observations and observations with older adults, Olwal et al. (2011) determined that it is possible to address age-related accessibility issues on generic cell phone UI’s.

### 2.1.4 Smartphones in Healthcare

As smartphones become pervasive, they have potential to transform healthcare (Boulos, Wheeler, Tavares, & Jones, 2011). Smartphones are embedded with a multitude of sensors often including an accelerometer, digital compass, gyroscope, GPS, microphone, proximity sensor, ambient light sensor and camera, which are fostering the creation of a new field called mobile phone sensing (Lane et al., 2010). Sensors embedded in mobile phones are finding applications in many fields including healthcare (Consolvo et al., 2008). Boulos et al. (2011) suggests that body-worn and ambient sensors can assist with home monitoring. Mellone et al. (2012) demonstrated that sensors embedded in mobile phones can be
almost as effective as professional equipment in movement analysis, which can in turn result in enhanced balanced and mobility support for older adults. Mobile technologies can serve as portable aids and assistive devices for older adults (Graf et al., 2005).

Technology can help older adults remain independent and lead productive lives at a lower cost than long term care (Armstrong, Nugent, Moore, & Finlay, 2010; Huber & Watson, 2011; Siek, Rogers, & Connelly, 2005). Smartphones have been used to support people with many age-related diseases often experienced by older adults including diabetes (Rao, Hou, Golnik, Flaherty, & Vu, 2010), Alzheimer’s (Armstrong et al., 2010), Parkinson’s (Chang, Chu, Chen, & Wang, 2008; Nolan et al., 2012) and amnesia (Svoboda & Richards, 2009).

**Diabetes**

Rao et. al. (2010) conducted a survey of iPhone apps and observed diabetes patients as they used three apps to manually record their blood glucose levels. Rao et al. (2010) found that younger participants were quicker at completing a recording task and were more proficient at learning or navigating an app interface than older participants and hypothesized that better performance of younger smartphone users could have been related to their prior experience with smartphones. Rao et al. (2010) suggest that a glucose level meter, which communicates directly with the iPhone is likely to benefit older diabetes patients.

**Alzheimer’s Disease**

Alzheimer’s disease affects older adults at an increasing rate over the age of 65 (Seshadri & Wolf, 2007) and it has been seen to affect women at a greater rate than men (see Table 2.1).
<table>
<thead>
<tr>
<th>Age</th>
<th>Lifetime Risk - Women</th>
<th>Lifetime Risk - Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>17.2%</td>
<td>9.1%</td>
</tr>
<tr>
<td>75</td>
<td>18.5%</td>
<td>10.2%</td>
</tr>
<tr>
<td>85</td>
<td>20.3%</td>
<td>12.1%</td>
</tr>
</tbody>
</table>

Table 2.1 - Lifetime risk estimates for Alzheimer’s disease at 65 years, 75 years, and 85 years, adapted from Seshadri & Wolf (2007)

Armstrong et al. (2010) report that although many technologies to assist people with Alzheimer’s disease are available, no single product or solution covers the top unmet needs outlined by Lauriks et al. (2007):

- obtaining generalized and personal information
- coping with symptoms of dementia
- maintaining social contact and company
- enhancing (feelings of) safety

Armstrong et al. (2010) argue that smartphones have the potential to assist people with Alzheimer’s disease and proposes a set of apps that include an activity of daily living reminder, picture-dialing phone, geo-fencing and a one-hour reminder system.

**Parkinson’s disease**

Parkinson’s disease affects adults over the age of 50 at an increasing rate (Elbaz et al., 2002) and it has been observed that men have a higher risk of developing parkinsonism than women (see Table 2.2).

Parkinsonism is defined as “the presence of at least two of four cardinal signs: rest tremor, bradykinesia, rigidity, and impaired postural reflexes” (Elbaz et al., 2002). Approximately 70% of people with Parkinson’s disease are affected by speech impairments (Logemann, Fisher, Boshes, & Blonsky, 1978).

Nolan et al. (2012) demonstrated that smartphones can assist people with Parkinson’s disease. He developed a smartphone-based speech therapy application to aid older adults with Parkinson’s disease by providing a visual volume cue (Nolan et al., 2012). Chang et. al (2008) demonstrated that smartphones can assist cognitively impaired patients including those with Parkinson’s disease. His
system was shown to be effective at assisting with navigating the environment by prompting spatial photos at the right time and place (Chang et al., 2008).

<table>
<thead>
<tr>
<th>Age</th>
<th>Risk to age, years (%) - men</th>
<th>Risk to age, years (%) - women</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
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</tr>
<tr>
<td>90</td>
<td>3.5</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Table 2.2 - Risk of developing parkinsonism, adapted from Elbaz et al. (2002)

Amnesia
Research suggests that patients with mild memory impairments, who are provided with structured on-device training, can successfully use mobile technologies to enhance their independence (Gentry, Wallace, Kvarfordt, & Lynch, 2008; Svoboda & Richards, 2009). In an experiment with an older adult affected by amnesia, Svoboda and Richards (2009), demonstrated that a commercially available smartphone can assist an individual with mild to severe memory impairments and positively influence objective and qualitative measures of memory functioning.

With the increasing number of applications of smartphones in healthcare and a growing number of mobile apps, which tap into sensors embedded on mobile phones, it will become increasingly important to design smartphones and user interfaces catered to the needs of older adults. Otherwise, as mobile technology becomes pervasive in everyday life, older adults might become disadvantaged in healthcare (Czaja et al., 2006).

2.2 Heuristic Evaluation
Heuristic evaluation is a UI evaluation method proposed by Nielsen and Molich (1990) in the early 1990's. The goal of heuristic evaluation is to find usability problems in an existing UI design, so they can be fixed (Nielsen, 1992). Heuristic evaluation is performed by usability professionals, who evaluate a UI design against a set of accepted usability principles called evaluation heuristics (Nielsen & Molich, 1990).
The severity and location of each problem is noted and evaluators provide their opinions on how to improve the UI. Nielsen and Molich argued that heuristic evaluation was an inexpensive and effective alternative to formal empirical user testing (Nielsen & Molich, 1990; Nielsen & Phillips, 1993; Nielsen, 1992).

2.2.1 Usability Heuristics
Usability heuristics are; rules of thumb that describe common properties of usable UI’s (Nielsen, 2005). They summarize best usability practices for UI design (Nielsen & Mack, 1994) and help evaluators focus on aspects of a UI that are often trouble spots, simplifying the detection of usability problems (Baker, Greenberg, & Gutwin, 2002). Heuristics often serve as classifiers that help evaluators make sense of a set of problems.

In contrast, design guidelines contain a prescriptive set of rules that have to be followed in the design process by product designers and developers (Nielsen & Molich, 1990). Guidelines often have over a thousand rules to follow and are often seen as intimidating (Nielsen & Molich, 1990).

Primary users of heuristics are usability practitioners and product designers. In 1989, Nielsen and Molich developed a list of 9 UI evaluation heuristics. Their heuristics explained a large proportion of problems found in telephone-based and computer UI’s. Although their heuristics explained problems found in telephone-based and early text-based computer UI’s, they are still useful in explaining problems found in today’s advanced UI’s. However, with the miniaturization of computer devices, ubiquitous computing, and the introduction of touch screen UI's there is a need to update their usability heuristics for mobile devices.

Five years after publishing the initial heuristics, Nielsen (1994), revised them to enhance their exploratory power. He compared 7 sets of published usability heuristics with a database of 249 usability...
problems found in 11 software projects. Two of the evaluated projects had character-based UI’s, 6 had graphical UI’s, and 3 had telephone-operated UI’s (Nielsen, 1994).

After evaluating the usability problems in his study, Nielsen (1994), classified heuristics that explained the majority of usability problems into 7 groups. He gave each group a descriptive name that summarized the underlying usability phenomenon covered by the heuristics in that grouping. The groupings proposed by Nielsen were as follows:

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use

Nielsen also argued that two important heuristics should be added as the 8th and 9th evaluation heuristics (Nielsen, 1994):

8. Aesthetic and minimalist design
9. Help users recognize, diagnose and recover from errors

Nielsen later proposed a tenth UI usability heuristic in his book titled Usability Inspection Methods (Nielsen & Mack, 1994):

10. Help and documentation

Nielsen’s heuristics are one of the most widely used in the field of UI design (Usability.gov, n.d.). One of the limitations of Nielsen’s heuristics was their basis on usability problems identified in only eleven software projects. It is very likely that if a different set of projects were chosen, the heuristics would have been different. An analysis of positive aspects and limitations of heuristic evaluation follows.
2.2.2 Positive Aspects of Heuristic Evaluation

Heuristic evaluation is popular with researchers as well as usability practitioners (Baker et al., 2002). Some of the major benefits of heuristic evaluation include the speed at which it can be performed and the fact that no actual users are required to perform it. The heuristic evaluation technique is well documented and even non-practitioners can perform it with some degree of success (Baker et al., 2002).

Nielsen found that aggregating the results of heuristic evaluations independently, performed by five evaluators, identified approximately two-thirds of usability problems in a UI (Nielsen & Molich, 1990). He recommended that evaluators should inspect UI’s independently to prevent them from influencing and biasing each other’s findings. Nielsen established that aggregating the results of independent evaluations resulted in uncovering a greater variety of errors in comparison to those found by a group of evaluators working together.

A study by Jeffries, Miller, Wharton and Uyeda (1991) showed that heuristic evaluation found more problems than empirical usability testing, cognitive walkthroughs and guidelines evaluation. Heuristic evaluation was reported to find the largest number of problems including the most serious ones at the lowest cost compared to any other evaluation technique. Usability testing was found to reveal more severe usability problems, but at a substantially higher cost. Another study by Desurvire, Kondziela and Atwood (1992) found that heuristic evaluation revealed more usability problems than cognitive walkthroughs, but only when expert evaluators performed the evaluations.

2.2.3 Negative Aspects of Heuristic Evaluation

One of the major limitations of heuristic evaluation is the fact the quality of the results based on an evaluation largely depend on the expertise of the evaluators. To guarantee that all of the major usability problems are identified in a heuristic evaluation, a set of domain experts in a particular field is required. Practitioners performing heuristic evaluations need to be experienced with this technique to provide high quality results.
Nielsen found that usability specialists were more efficient than non-experts at finding usability problems by performing heuristic evaluations (Nielsen, 1992). This finding was sustained by Desurvire, Kondziela and Atwood (1992), who found that evaluators with less knowledgeable performed poorly.

Another limitation of the heuristic evaluation method is the fact that multiple evaluators with knowledge and experience using the technique are required. Jeffries et al. (1991) found that heuristic evaluation uncovered many specific, one-time and low priority problems.

In the same study, Jeffries et al. (1991), found that usability testing revealed more severe, recurring and global problems than heuristic evaluation. Nielsen (1992) came to a different conclusion and found that major usability problems have a higher probability of being found by heuristic evaluation than minor problems.

Desurvire et al. (1992) found another limitation of heuristic evaluation. Their study showed that a heuristic evaluation performed by single evaluator was consistently the least powerful technique when compared to other usability techniques. Results of multiple evaluations by a group of experts have to be aggregated to uncover a large number of usability problems.

The last limitation of the heuristic evaluation method is the fact that evaluators are required to have concrete data on how users will interact with the system being evaluated. User education, context of use, frequency and common usage scenarios have to be well documented and understood by evaluators in order for heuristic evaluation to yield relevant results.

**2.2.4 Heuristic Adaptation and Evaluation**

Nielsen's original heuristics have been adapted to many fields. There are many examples of successful adaptations of heuristics and a few of the most well documented heuristic adaptations are described below.
Web Usability Heuristics
Adaptations of heuristics for website usability evaluation are found in "Usability Heuristics for the Web" (Instone, 1997) and "Designing Web Sites for Older Adults: Expert Review of Usability for Older Adults at 50 Web Sites" (Chisnell & Redish, 2005).

Instone (1997) adapted Nielsen's original usability heuristics to evaluate website usability. The heuristics proposed by Instone (1997) address issues specifically related to website design. Instone's (1997) adaptation of Nielsen's original heuristics serves as a great example of how heuristics can change over time.

Another adaptation of heuristics for website usability was demonstrated by Chisnell and Redish (2005). Their heuristics "focused on usability and performance issues that older adults often have when using websites" (Chisnell & Redish, 2005). Chisnell and Redish (2005) derived their heuristics from a review of research on website design and older adults. The four main disciplines that their heuristics covered were interaction and navigation, information architecture, presentation or visual design, and information design.

Game Playability Heuristics
Adaptations of heuristics for game playability evaluation are discussed in "Using Heuristics to Improve the Playability of Games" (Desurvire, Caplan, & Toth, 2004) and "Do usability expert evaluation and test provide novel and useful data for game development?" (Laitinen, 2006).

Desurvire et al. (2004) studied the validity of heuristic evaluation in game design. Their study compared game playability heuristics to standard user testing methodologies. Desurvire et al. (2004) concluded that game playability heuristics proved to be effective in uncovering problems early in the game design stages prior to building out expensive prototypes.
The methodology used in Desurvire et al.’s (2004) study involved evaluating a game prototype by several playability experts and game designers. Evaluators noted how each heuristic was supported or violated in the prototype and defined the playability issues encountered. Alternative solutions for resolving playability issues were proposed by both evaluators and game designers.

The number of playability issues uncovered by heuristic evaluation and user testing were compared and their usefulness was analyzed. Heuristics were found to be effective at revealing playability issues and uncovered more problems than traditional user testing. There was much overlap between the problems that were identified by heuristic evaluation and user testing.

Laitinen (2006) described the heuristic process that was used to evaluate the usability of games. The process begins by usability specialists evaluating the product independent of each other. Evaluators note usability issues and present their findings to an evaluation leader. The underlying reasons behind the problems, their severity and possible solutions are discussed. Next the evaluation leader aggregates the findings into a single list. Similar problems found by evaluators are grouped into predefined categories and they are summarized in a final usability report by the evaluation leader. The final report lists all problems, detailed descriptions, severity classifications and suggests solutions to uncovered problems. In the last step of the process, the evaluation leader usually presents the final report to developers and discusses key findings. Laitinen (2006) concluded that usability evaluation and testing can provide both novel and useful data. He found that 43% of all the usability problems were new to game developers (Laitinen, 2006).

**Computer Supported Collaborative Work (CSCW) Heuristics**

Baker et al. (2002) demonstrated that it is possible to develop a set of heuristics for identifying teamwork-oriented usability problems related to real-time collaboration within a shared workspace. Their motivation for developing teamwork software evaluation heuristics was the lack of practical and inexpensive groupware evaluation methodologies. Baker et al. (2002) found that a large number of
teamwork software problems were uncovered using the heuristic evaluation method. They also found that there was much overlap between the problems found by different evaluators and that only a few evaluators are needed to uncover a good number of teamwork problems.

The heuristic adaptations described, show that it is possible to create domain-specific heuristics with great explanatory power. A summary of best practices for adapting heuristics to specific domains follows.

2.2.5 Best Practices for Making Heuristics

Based on the review of heuristics, a few general points about creating a set of heuristics can be made:

- Heuristics are rules of thumb that summarize common properties of usable UI’s (Nielsen, 2005)
- Provide feedback for usability practitioners and product designers
- Compile best usability practices for UI design (Nielsen & Mack, 1994)
- Often based on findings of usability testing (Nielsen, 1994)
- Help evaluators focus on aspects of a UI that are often trouble spots (Baker et al., 2002)
- Simplify the detection of usability problems (Baker et al., 2002)

Heuristics are short, easy to understand rules of thumb that summarize common properties of usable UI’s (Nielsen, 2005). They are often composed of approximately ten principles and are meant to be easy to follow by evaluators (Nielsen & Molich, 1990).

Heuristics summarize the best practices and guidelines in a given field. Nielsen based his original set of UI usability heuristics on personal experience and widely known usability principles (Molich & Nielsen, 1990). He then refined his original heuristics by analyzing 249 usability problems and evaluating how well known heuristics and guidelines explained these problems (Nielsen, 1994). Other usability professionals have also based their heuristics on guidelines and widely known principles (Baker et al., 2002; Desurvire et al., 2004).
Heuristics are often tested by comparing the number of problems found to standard user testing methodologies such as usability testing (Desurvire et al., 1992). Their efficiency increases exponentially when the results of multiple evaluations are grouped together (Baker et al., 2002; Nielsen, 1994).

2.3 Simulation of Age-Related Barriers

Simulating age-related issues related to mobile device usage can help evaluators and designers understand the barriers imposed on older adults by mobile device designs. Holzinger, Searle, and Nischelwitzer (2007) proposed a way to simulate some physical and perceptual impairments by use of an Age Simulator. They used a special suit, AgeSim, to stimulate physical restrictions of different groups of people. Under arms and leg joints of the suit are webbed and designed to restrict joint movements. Weights designed to simulate arthritic joints, and a decreased sense of touch, are fitted into the suit pockets. A helmet, which restricts head movement, can be outfitted with a number of accessories that simulate various disabilities including:

- exchangeable visors to simulate eye disorders
- headset to simulate hardness of hearing
- mountable camera to record what the user sees during usability tests

Holzinger et al. (2007) conducted a usability study of a mobile device with a fully capable engineer, who was fitted with an AgeSim suit. His sense of touch was restricted with the use of gloves, his vision was reduced by more than half and his hearing was altered with the use of a helmet. When the user tried interacting with a mobile device, he found it impossible to use a stylus to navigate the mobile device UI. The reduced vision made it hard to see the numbers on the keypad and the user couldn't compensate the reduced hearing with increasing the volume on the device. Holzinger et al. (2007) propose that mobile device designers and developers should experience the limitations in fine motor skills and movement, visual impairments and auditory limitations simulated by the AgeSim suit to understand the challenges experienced by older mobile device users.
3 Methodology

This chapter describes the method used to create and evaluate a set of smartphone evaluation heuristics for older adults. It also outlines the method to determine whether the strength of support for the proposed heuristics increases with age.

3.1 Research Design

In this project, a set of smartphone evaluation heuristics based on age-related physical and cognitive changes was created. Support for heuristics was assessed in mobile user experience and accessibility guidelines. Heuristics were evaluated by gathering information on how older adults use cell phones through interviews and an online survey.

Researchers have used various techniques to study mobile phone usage by older adults. Most studies followed a two-step process; expert interviews or focus groups to document the issues and a survey or questionnaire to validate the findings with a larger population. The methods used in these studies are described in Table 3.1.
<table>
<thead>
<tr>
<th>Research Topic</th>
<th>Author, Title &amp; Date</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issues related to use of mobile phones by 60+ year olds</td>
<td>Kurniawan (2008). Older people and mobile phones: A multi-method investigation.</td>
<td>• Focus group discussions&lt;br&gt;• Online survey</td>
</tr>
<tr>
<td>Characteristics of an ageing-friendly mobile phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived context-related benefits of mobile phones for older persons</td>
<td>Melenhorst, Rogers and Caylor (2001). The Use of Communication Technologies by Older Adults: Exploring the Benefits from the Users Perspective.</td>
<td>• Focus group discussions</td>
</tr>
<tr>
<td>Mobile device and service design issues for older people aged 56 years old and over in Malaysia</td>
<td>Hassan and Nasir (2008). The use of mobile phones by older adults: a Malaysian study.</td>
<td>• Online survey</td>
</tr>
<tr>
<td>Evaluating customizable mobile phone UI framework for older adults</td>
<td>Olwal, Lachanas and Zacharouli (2011). OldGen: Mobile Phone Personalization for Older Adults.</td>
<td>• Questionnaire&lt;br&gt;• User observation sessions</td>
</tr>
<tr>
<td>Identifying necessary mobile phone features for older adults</td>
<td>Sulaiman and Sohaimi (2010). An Investigation to Obtain a Simple Mobile Phone Interface for Older Adults.</td>
<td>• User interviews&lt;br&gt;• Survey</td>
</tr>
</tbody>
</table>

Table 3.1 - Methods used to study mobile phone usage by older adults

Common techniques used by researchers to study issues related to mobile phone usage by older adults included interviews, focus groups, surveys, and user observation sessions. The values and limitations of these techniques are listed in Table 3.2.
<table>
<thead>
<tr>
<th>Method</th>
<th>Value</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>User interviews</td>
<td>• Inexpensive way to gauge mobile phone usage patterns and problem areas for older adults</td>
<td>• Time consuming to organize one-to-one meetings with participants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Interview participants recruited in a small geographical area</td>
</tr>
<tr>
<td>Focus group discussions</td>
<td>• Inexpensive method of collecting feedback from larger groups of users</td>
<td>• Difficult to recruit and bring together a group of older users</td>
</tr>
<tr>
<td></td>
<td>• Ability for moderator to adjust questions on the fly</td>
<td>• Participants can influence each other’s answers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Artificial environment</td>
</tr>
<tr>
<td>Surveys</td>
<td>• Quick way to collect information</td>
<td>• Respondents can answer artificially if there are too many questions</td>
</tr>
<tr>
<td></td>
<td>• Standardized questions lead to standardized responses, which can be quantified</td>
<td>• Open-ended questions can generate large amounts of data</td>
</tr>
<tr>
<td></td>
<td>• Can be distributed online</td>
<td>• Users must have access to the internet to participate in online surveys</td>
</tr>
<tr>
<td></td>
<td>• Inexpensive way of verifying results with a large, geographically dispersed population</td>
<td>• Multiple submissions in online surveys</td>
</tr>
<tr>
<td>User observation sessions</td>
<td>• Methodological way of uncovering usability issues</td>
<td>• Costly lab time and expensive usability testing equipment</td>
</tr>
<tr>
<td></td>
<td>• Full control over experiment</td>
<td>• Mobile context and environment not reflected</td>
</tr>
</tbody>
</table>

Table 3.2 - Values and limitations of methods used to study mobile phone use by older adults

Many different methods of gathering data from older adults exist (Malik & Edwards, 2008). There are positive and negative aspects of using each method; a discussion of the values and limitations of user interviews, focus group discussions, surveys and user observation sessions follows.

**User Interviews**

User interviews are widely used to collect qualitative usability data (Martin & Weiss, 2006; Väätäjä, 2010) without the need to use a usability lab or specialized usability testing equipment. This method has been used by researchers to gather information on mobile phone usage by older adults (Inglis et al., 2003; Kurniawan, 2008; Sulaiman & Sohaimi, 2010). Interviews are often used in early stages of research with older adults to uncover problems and concerns as well as desired and unwanted features (Sulaiman & Sohaimi, 2010). There are two challenges with conducting user interviews: finding eligible participants and recruiting from a small geographical area.
Focus Group Discussions
Researchers have found focus group discussions valuable when conducting studies with older adults (Inglis et al., 2003), but issues with handling more than 3 older adults during a focus group have been observed. These issues can be attributed to hearing impairments, problems with attention and the inability for older participants to follow a discussion (Malik & Edwards, 2008).

Surveys
Surveys have been conducted by researchers to study mobile phone usage amongst older adults (Hassan & Nasir, 2008; Sulaiman & Sohaimi, 2010). Dale and Schulz (2011) have successfully used an online survey to gather data on older adult use of mobile phones, the difficulties they experience during use, expectations and additional functionality. Depending on the characteristics of the population, online surveys can result in sample sizes larger than mail and telephone surveys (Kraut et al., 2004). They can also facilitate access to a large number of demographically diverse and hard to reach participants (Reips, 2002; Wright, 2006). Thanks to cost effectiveness of online surveys compared to other techniques, it is possible to obtain large sample sizes (Bachmann & Elfrink, 1996; Reips, 2002) and thus increase statistical power to detect an effect (Borenstein, 1997). Online surveys enable automatic storage of responses, preventing transcription errors (Andrews, Nonnecke, & Preece, 2003).

The main challenge with online surveys is the fact that the data is self-reported and the accuracy of demographic or characteristic information cannot be validated (Wright, 2006). Other considerations include sufficient representation of the target audience (Andrews et al., 2003; Matsuo, McIntyre, Tomazic, & Katz, 2004), dropout rate and multiple submissions of survey answers (Reips, 2002).

User Observation Sessions
Laboratory-based user observation sessions are often used to study usability of mobile devices (eg. Duh et al., 2006; Waterson, Landay, & Matthews, 2002). One of the advantages of lab-based user observation sessions is the ability of the researcher to control the experiment by outlining the
instructions to participants and ensuring that they are followed (Zhang & Adipat, 2005). Other advantages include direct control over external variables, ability to measure usability criteria and interpret results (Zhang & Adipat, 2005).

One of the major challenges with observing users in a lab environment is the fact that the mobile context is largely ignored. The impact of unreliable data networks and a distracting environment cannot be replicated in a lab setting (Zhang & Adipat, 2005). Another challenge is the fact that lab-based usability testing can be costly (Waterson et al., 2002).

3.2 Evaluation Methods Used in this Study

Two methods were chosen to gather information on how older adults use smartphones: user interviews and an online survey. Interviews deemed to be the least expensive and the easiest method to solicit data from older adults in a timely manner and surveys were selected to validate interview results with a larger population at a low cost.

Qualified interview participants were recruited from a pool of Computer Club members in a seniors' centre. To validate the interview findings with a larger, geographically dispersed population of older adults, an online survey was conducted. This method was best suited to mitigate the risk of recruiting participants with similar experiences and health issues from a small geographical area.

3.2.1 A Two Phased Approach

The study consisted of two phases (see Figure 3.1). In Phase 1, user interviews with a group of older mobile phone users were conducted to explore whether there is support for the proposed heuristics. This was done by examining age-related cell phone usability issues, documenting usage patterns such as commonly used features, and exploring areas for improvement in physical design and operation of cell phones for older adults.
In Phase 2, the findings from Phase 1 were explored with a larger population via an online survey (see Appendix D for a summary of the key interview findings and the corresponding survey questions designed to validate whether there was support for the heuristics in a larger population). For simplicity, Phase 1 interviewees are referred to as “interviewees” and Phase 2 online survey respondents are referred to as “respondents”.

![Figure 3.1 - Evaluation strategy](image)

### 3.3 Creating Heuristics

Researchers have suggested developing category-specific heuristics applicable to a specific class of products and supplementing general usability heuristics (eg. Nielsen and Mack, 1994). Dykstra (1993) proposes a way of building a supplementary list of category-specific heuristics by performing a competitive analysis and user testing of existing products in a given category. He suggests abstracting principles to explain usability problems that are found (Dykstra, 1993).

The stylistic and structural formatting of smartphone evaluation heuristics developed in this thesis will be modeled on prior heuristics (eg. Baker et al., 2002; Nielsen, 1994; Pinelle, Wong, Stach, & Gutwin, 2009), but our heuristics will be grounded in age-related physical and cognitive issues. There will be no
relationship with prior heuristics, other than stylistic and structural formatting. Our proposed smartphone evaluation heuristics for older adults will be based on a set of age-related issues found in literature on age-related physical and cognitive changes experienced by older adults.

The smartphone evaluation heuristics proposed in this paper are intended for use by usability practitioners and mobile device designers to identify and prevent common age-related usability problems in smartphone design. They serve as general principles for the design of usable and accessible smartphones for older adults.

3.4 Evaluating Heuristics

Researchers have used many techniques to evaluate heuristics. Nielsen (1994) evaluated heuristics by calculating which ones best explained 249 usability problems found in 11 projects. Tan, Liu and Bishu (2009) evaluated Nielsen’s heuristics by comparing the efficiency and effectiveness between heuristic evaluation and user testing of 4 websites. Jeffries et al. (1991) evaluated the effectiveness of the heuristic evaluation process by comparing how many usability problems were found using this technique in comparison to usability testing, software guidelines and cognitive walkthroughs. Chisnell and Redish (2005) evaluated their heuristics for evaluating web design for older adults by performing a set of tasks through older adult personas with different disabilities across 50 web sites. Pinelle, Wong, Stach, and Gutwin (2009) evaluated their set of heuristics for multiplayer games by comparing to groupware usability heuristics by Baker et al. (2002). Baker et al. (2002) evaluated their proposed heuristics using a methodology similar to the one used by (Nielsen, 1992). Baker et al. (2002) identified three main goals for evaluating proposed heuristics: 1) determine whether different evaluators perform similarly using heuristics, 2) determine whether evaluator performance varies across separate evaluations, 3) determine whether a small number of evaluators can find a large proportion of usability problems.
Smartphone evaluation heuristics for older adults developed in this thesis will be evaluated by gathering information on how older adults use cell phones through interviews and an online survey. An analysis of mobile user experience and accessibility guidelines for age-related factors will be conducted (see Appendix A) to determine support for smartphone evaluation heuristics.

The next section reviews literature that focuses on factors related to smartphone usability for older adults. It covers age-related changes in vision, hearing, attention, memory and motor control and proposes heuristics that practitioners can use to evaluate smartphone usability for older adults.

### 3.5 Smartphone Evaluation Heuristics for Older adults

The impact of age-related changes on the usability of mobile devices for older adults will be examined and evaluation heuristics will be proposed to address these changes. Mobile user experience and accessibility guidelines will be analyzed for support. Age-related changes in the following areas will be reviewed:

- Vision
- Hearing
- Attention
- Memory
- Motor control

Each proposed heuristic in this section is identified by the following nomenclature:

- Proposed heuristic [area][heuristic number]
- Eg. VIS1 [vision][heuristic #1]

The implications of each heuristic for software and/or hardware design will be discussed in the corresponding sections.

User experience and accessibility guidelines from the most prominent smartphone/operating system developers were reviewed, along with guidelines from AT&T, a major service provider the USA. The following are the specific guidelines reviewed: iOS Human Interface Guidelines (Apple, 2012), Android
Accessibility Guidelines (Android Open Source Project, 2012) and Microsoft User Experience Design Guidelines for Windows Phone (Microsoft, 2012) and AT&T’s uXd Style Guide (AT&T Mobility, 2008). When support for an age-related factor was found, it was noted in the development of the related heuristic(s) in the following section.

### 3.5.1 Vision

Aging has a negative impact on the visual system. Older adults find it more difficult to perform everyday visual tasks, especially in challenging viewing conditions such as dim lighting or low contrast (Scialfa, C., & Kline, 2007). Age-related changes in the visual system and the proposed heuristics to address them are outlined in this section.

#### Light Accommodation

Older adults experience a decreased ability to focus on objects nearby due to a reduction in the strength of the ciliary muscles (presbyopia) (Scialfa, C., & Kline, 2007). The ability to focus on near and far objects decreases by 50-55% between the ages of 8 and 50 (Pattison & Stedmon, 2006). Decreased lens elasticity experienced by older adults results in a diminished ability to accommodate (Haigh, 1993; Pattison & Stedmon, 2006). An average 50 year old has a near point of 50cm, compared to a near point of 12.5cm for an average 30 year old (Haigh, 1993; Pattison & Stedmon, 2006). To address a lowered ability to focus on near objects, smartphone screen size should be expanded.

Proposed heuristic:

**VIS1 - Expand screen size**

Implications for software and hardware design:

**Software** - Mobile UI's should utilize the entire available screen

**Hardware** - Physical screen size should be sufficient for older adults to see comfortably
**Decreased Visual Acuity**

The ability to distinguish detail diminishes after the age of 50 (Haigh, 1993; Pattison & Stedmon, 2006; Steenbekkers, Dirken, & Beijsterveldt, 1997). On average, an adult over the age of 60 requires on average three times more light than a 20 year old to see the same level of detail (Haigh, 1993). Low light vision is also negatively impacted by a reduced number of rods in the eye related to aging (Scialfa, C., & Kline, 2007). Older adults often find it difficult to see detail in low lighting conditions.

Decreased visual acuity of older adults is a factor that should be addressed in the design of mobile devices for an older audience. Poor visual acuity is associated with difficulties in conditions that require good resolution and adaptation to changing light conditions (Fozard & Gordon-Salant, 2001). Due to lowered light accommodation and decreased visual acuity experienced by older adults, the size of text and UI elements such as icons and images should be expanded for older adults.

Support for this heuristic was found in 3 guidelines:

1. AT&T uXds Style Guide states that; “increasing the font size is essential for some users”. It also states that; “interfaces using big fonts [...] ease the use of mobile phones.
2. Android Accessibility Guidelines state that; “low vision users benefit from [...] large visuals”.

Proposed heuristic:

VIS2 - Expand size of text and UI elements

Implications for software and hardware design:

Software - On-screen text and UI components such as buttons and icons should be large enough for users to see comfortably

Hardware - Screen size should be large enough to accommodate large text and UI components
Lowered Contrast Sensitivity

Older adults are less sensitive to contrast under low lighting conditions due to lower retinal illuminance (Scialfa, C., & Kline, 2007). Contrast sensitivity, or the ability to distinguish between light and dark affects the ability to see the outlines of objects (Haigh, 1993). It diminishes between the ages of 20 to 80 years with a notable decline starting around the age of 40 (Pattison & Stedmon, 2006). Contrast sensitivity decreases even further after the age of 65 - it declines at the rate of 28% per decade (Fozard & Gordon-Salant, 2001).

A study showed that older adults prefer higher contrast text on handheld devices. Due to lower contrast sensitivity, text and image contrast should be increased on smartphone UI’s for older adults.

Support for this heuristic was found in 2 guidelines:

1. AT&T uXd Style Guide suggests that; “interfaces using high contrast [...] ease the use of mobile phones”.
2. Android Accessibility Guidelines state that; “low vision users benefit from [...] high contrast”

Proposed heuristic:

VIS3 - Increase text and image contrast

Implications for software and hardware design:

Software - High contrast graphics should be used for text and icons

Hardware - Screens should allow for high contrast ratios to be displayed

Glare

Adults over the age of 40 often experience a discomfort, or disability in the form of glare (Haigh, 1993). It arises from increased lens opacity of an old eye, which results in light scatter. The eye can use light most effectively when it enters the eye from the front (Haigh, 1993). Light that enters the eye from the side can scatter and result in a blurred image (Voike, 1981). Increasing the amount of illumination for
adults over the age of 60, who often need as much as three times more light than 20-year olds, can lead to an intolerable level of glare (Haigh, 1993).

Due to lower contrast sensitivity and higher susceptibility to glare, the ability to fine-tune mobile device screen brightness and contrast should be available in devices catered to older adults. A night viewing mode with a reversed colour scheme could be utilized to reduce glare and increase contrast in low-light environments.

Proposed heuristic:

VIS4 - Allow users to fine-tune screen brightness and contrast

Implications for software and hardware design:

Software - Users should be permitted to adjust brightness and contrast in all apps. A reverse colour scheme for low-light environments and a high contrast colour scheme for sunny conditions should be available

Hardware - Screens should facilitate adjustment of brightness and contrast

**Loss of Colour Sensitivity**

Darkening and yellowing of lens in the eye results in age-related loss of colour sensitivity and colour discrimination errors. Older adults often find it hard to distinguish between colours that contain traces of blue or yellow, especially under dim lighting (Scialfa, C., & Kline, 2007).

The use of colours to display information should be minimized to address the needs of older users with loss of colour vision. Older adults often experience a decreased ability to perceive short-wavelength colours (blues, yellows). If the use of colors cannot be avoided, mid to high wavelength colours should be used.
Proposed heuristic:

**VIS5** - Avoid the use of colour to relay information

Implications for software and hardware design:

Software - UI components should not utilize short-wavelength colours

Hardware - Screens should allow for high contrast ratios to be displayed

**Decreased Efficiency of Visual System**

Studies show that unnecessary information details and useless information such as decorated text and animation negatively impact task completion rates in older adults (Curzon, Wilson, & Whitney, 2005; Kosnik, Winslow, Kline, Rasinski, & Sekuler, 1988). Decreased efficiency of the visual transmission system in older adults should be addressed by avoiding animation and fast-moving objects (Hawthorn, 2000), especially on small-screen device UI’s.

Proposed heuristic:

**VIS6** - Avoid the use of animation and fast-moving objects

Implications for software and hardware design:

Software - Avoid the use of animations

Hardware - No implications
3.5.2 Vision Heuristics

The proposed vision heuristics are summarized in Table 3.3.

<table>
<thead>
<tr>
<th>Proposed Heuristic</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS1 - Expand screen size</td>
<td>Diminished ability to accommodate and focus on near objects</td>
</tr>
<tr>
<td>VIS2 - Expand size of text and UI elements</td>
<td>Decreased visual acuity, especially in low lighting conditions</td>
</tr>
<tr>
<td>VIS3 - Increase text and image contrast</td>
<td>Lowered contrast sensitivity under low lighting conditions</td>
</tr>
<tr>
<td>VIS4 - Allow users to fine-tune screen brightness and contrast</td>
<td>Higher susceptibility to glare</td>
</tr>
<tr>
<td>VIS5 - Avoid the use of colour to relay information</td>
<td>Loss of colour sensitivity and colour discrimination errors</td>
</tr>
<tr>
<td>VIS6 - Avoid the use of animation and fast-moving objects</td>
<td>Decreased efficiency of the visual transmission system</td>
</tr>
</tbody>
</table>

Table 3.3 - Evaluation heuristics focused on age-related changes in the visual system

3.5.3 Hearing

Sensitivity of the auditory system decreases with age (Goldstein, 2010), especially at high frequencies. Older individuals often find it hard to communicate in noisy environments. Hearing loss is affected by factors such as exposure to noisy work environments, diet and genetic factors (Pattison & Stedmon, 2006). These factors usually result in hearing loss that causes impairment by the age of 50 (Takeda et al., 1992).

Loss of High-Frequency Hearing

Older adults often experience a decrease in ability to discriminate sounds, especially at higher frequencies (Takeda et al., 1992). This results from a loss of inner hair cells in the cochlea, which reduces the transmission of high-frequency sounds. Decreased number of cochlear hair cells results in hearing loss, limited frequency selectivity and a reduced frequency range (Fozard & Gordon-Salant, 2001).

Sharashenidze et. al (2007) observed that 30-39, 40-49 and 50-59 year old females had better hearing acuity than males at higher frequencies (12.5 kHz, 14 kHz and 16 kHz). The differences between 60-69 and 70-79 year old males and females were significantly smaller and almost equal to each other. At
lower frequencies 0.125-2 kHz, hearing loss was smaller than at higher frequencies. At lower frequencies hearing-loss characteristics between males and females were similar across all age groups (Sharashenidze et al., 2007).

Age-related auditory system deficiencies can be addressed by avoiding the use of high frequencies to convey information. Lower frequencies could be used to convey auditory cues such as confirmation tones and alerts to older adults in order to mitigate age-related loss of hearing at higher frequencies and to ensure that both older males and females can hear their cell phone sounds.

Proposed heuristic:

AUD1 - Use lower frequencies to convey auditory cues such as confirmation tones and alerts

Implications for software and hardware design:

Software - Auditory cues such as ringtones and message notification sounds should use lower frequencies

Hardware - Speakers should allow for low auditory cues

**Age-related Hearing Diseases**

One of the main age-related diseases of the auditory system is *presbycusis* (Fozard & Gordon-Salant, 2001). It is defined as an inevitable deterioration in hearing ability that occurs with age (Gates & Mills, 2005). Presbycusis results in a gradual loss of hearing caused by noise exposure. An estimated 30-35% of older adults between the ages of 65 and 75 years and 40-50% of older adults 75 and experience loss of hearing (National Institute on Deafness and Other Communication Disorders, 1997). Presbycusis causes a hearing loss that is gradual, with patients often not being aware of their diminishing auditory capabilities. Some of the symptoms of presbycusis include loss of sound clarity and volume, which result in an impaired ability to understand conversations and distinguish human speech with the presence of
background noise. High pitched sounds such as “s” and “th” are difficult to hear and differentiate and certain sounds seem annoying or overly loud. Tinnitus, a ringing, roaring or hissing sound may also be present in one or both ears of older individuals.

Amplitude of auditory cues for older adults should be easily adjusted to accommodate for age-related hearing loss and easily adjustable to a level that users are comfortable with.

Proposed heuristic:

AUD2 - Allow users to fine-tune volume level of auditory cues

Implications for software and hardware design:

Software - No implications

Hardware - Speaker volume should be adjustable

### 3.5.4 Auditory Heuristics

The proposed auditory heuristics are summarized in Table 3.4.

<table>
<thead>
<tr>
<th>Proposed Heuristic</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUD1 - Use lower frequencies to convey auditory such as confirmation tones and alerts</td>
<td>Decreased sensitivity of the auditory system at high frequencies</td>
</tr>
<tr>
<td>AUD2 - Allow users to fine-tune volume level of auditory cues</td>
<td>Age-related hearing clarity and sound volume loss</td>
</tr>
</tbody>
</table>

**Table 3.4 - Evaluation heuristics focused on age-related changes in the auditory system**

### 3.5.5 Attention

Older adults often experience age-related changes in attention. These changes can be attributed to an overall decline in cognitive functioning due to a reduction in the speed of processing (McDowd & Shaw, 2000).
Dual Task Processing and Inhibitory Deficiencies

Dual task processing, which is defined as the ability to concurrently perform two different tasks (Kramer & Kray, 2006), is negatively affected by reduced selective attention resources and inhibitory deficiencies (McDowd & Craik, 1988). Older adults often experience a narrow attentional focus, or the ability to change attention between different spatial locations (McDowd & Shaw, 2000). (Trick and Enns (1998) found that older adults were less able than younger adults to shift attention voluntarily between items.

To address age-related changes in dual task processing, the need to switch between tasks should be minimized. Interaction should be limited to a single task at a time and alerts such as new message notification should be disabled while executing complex tasks. The costs of inhibiting distracting stimuli such as a constant blinking light while trying to execute another task could prove to be very high for older users.

Support for this heuristic was found in iOS Human Interface Guidelines, which encourage designers to “focus on the primary task” and only present information that is crucial in a given context.

Proposed heuristic:

ATT1 - Minimize the need to actively monitor two or more tasks

Implications for software and hardware design:

Software - Avoid multi-tasking

Hardware - No implications

Distraction

Older adults are easily distracted by extraneous detail and background noise (Hawthorn, 2000). Aging can also be attributed to a negative impact of inhibition of non-target information in visual search tasks
(Madden, Pierce, & Allen, 1996). Smartphone UI clutter and extraneous details should be minimized to address the increased attention costs of inhibiting unnecessary information.

Support for this heuristic was found in 2 guidelines:

1. iOS Human Interface Guidelines encourage designers to be succinct and present only the most important information concisely and prominently.
2. Microsoft User Experience Design Guidelines for Windows Phone states that; “simplicity of the interactive experience is essential”. It also states that designers should; “strive to keep each screen as focused as possible [,] eliminate any extra clutter [and] present the user with only what is absolutely necessary. Microsoft’s guidelines also note that; “clutter is never good and leads to confused users”.

Proposed heuristic:

ATT2 – Minimize UI clutter and avoid extraneous details

Implications for software and hardware design:

Software - Avoid unnecessary UI decorations

Hardware - No implications

Visual Search

Lowered visual search capabilities can be observed in older adults. Kang & Yoon (2008) suggest that unavailable menus and icons should be clearly distinguished from the background to prevent selection of inactive or disabled functions on small-screen devices by older adults.

Proposed heuristic:

ATT3 - Disable inactive UI objects

Implications for software and hardware design:

Software - Remove inactive components from the UI
3.5.6 Attention Heuristics

The proposed attention heuristics are summarized in Table 3.5.

<table>
<thead>
<tr>
<th>Proposed Heuristic</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATT1 - Minimize the need to actively monitor two or more tasks</td>
<td>Reduction in dual task processing and inhibitory deficiencies</td>
</tr>
<tr>
<td>ATT2 - Minimize UI clutter and avoid extraneous details</td>
<td>Distraction by extraneous detail</td>
</tr>
<tr>
<td>ATT3 - Disable inactive UI objects</td>
<td>Lowered visual search capabilities</td>
</tr>
</tbody>
</table>

Table 3.5 - Evaluation heuristics focusing on age-related changes in attention

3.5.7 Memory

Older adults experience negative changes in memory. The storage capacity of working memory does not decline with age, but processing efficiency has been observed to decline with time (S. Smith et al., 2000).

Working memory impairments, especially in situations requiring a high information load can be observed in older populations (Chen, Hale, & Myerson, 2003).

Working Memory Decline

Older adults experience a decline in their ability to allocate working memory capacity to more than one task at a time (Cavanaugh & Blanchard-Fields, 2006). Performing new tasks can be problematic for older adults (Pattison & Stedmon, 2006), especially if these tasks are complex. Due to the fact that older adults experience a decline in their ability to allocate working memory capacity to more than one task, single task interaction should be used instead of multitasking. Task status should be clearly visible at all times to decrease the amount of information that has to be stored in working memory.

Proposed heuristics:

MEM1 - Use single task interaction instead of multitasking whenever possible
MEM2 - Clearly present task status at all times

Implications for software and hardware design:

Software - Avoid multi-tasking and display task status in each UI screen

Hardware - No implications

Learning

Older adults maintain neural plasticity and the ability to learn, but the process of learning can take more time, especially when complex material is involved (Kandel, Schwartz, & Jessell, 2000). This factor could explain technophobia or the avoidance of new technologies (Brosnan, 1998). Older adults often find it difficult to learn how to use new technologies, which do not support their mental models (Pattison & Stedmon, 2006). Mental models familiar to older adults such as lists should be used to minimize the amount of learning required.

Support for his heuristic was found in 4 evaluated guidelines:

1. AT&T uXd Style Guide states that; “people relate new models to experience and existing models”.
2. iOS Human Interface Guidelines suggest; “making usage easy and obvious” and encourage mobile app designers to; “make it easy for people to use [their] app by reinforcing their experience”.
3. Android Accessibility Guidelines encourage designers to provide users with an; “information hierarchy [and] architecture that makes sense”.
4. Microsoft User Experience Design Guidelines for Windows Phone encourage designers to; “be consistent” and suggest that leveraging consistent interactions could lead to increased user satisfaction and productivity.

Proposed heuristic:

MEM3 - Leverage mental models familiar to older adults

Implications for software and hardware design:

Software - Use interaction paradigms familiar to older adults
Remembering Pictorial Stimuli

Older adults have been observed to perform worse than young adults in remembering pictorial stimuli (A. D. Smith & Park, 1990). This finding might be related to deficiencies in working memory related to aging. Complex pictorial stimuli such as icons and animations, which older adults often find hard to remember (A. D. Smith & Park, 1990) should be substituted with readable text.

Proposed heuristic:

MEM4 - Use clear text instead of pictorial stimuli to relay information

Implications for software and hardware design:

Software - Use text instead of icons in UI screens

Hardware - No implications

3.5.8 Memory Heuristics

The proposed memory heuristics are summarized in Table 3.6.

<table>
<thead>
<tr>
<th>Proposed Heuristic</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEM1 - Use single task interaction instead of multitasking whenever possible</td>
<td>Decline in working memory capacity</td>
</tr>
<tr>
<td>MEM2 - Clearly present task status at all times</td>
<td>Decline in working memory capacity</td>
</tr>
<tr>
<td>MEM3 - Leverage mental models familiar to older adults</td>
<td>Slower learning of new technologies</td>
</tr>
<tr>
<td>MEM4 - Use clear text instead of pictorial stimuli to relay information</td>
<td>Decreased performance in remembering pictorial stimuli</td>
</tr>
</tbody>
</table>

Table 3.6 - Evaluation heuristics focusing on age-related changes in memory

3.5.9 Motor Control

Deficiencies in motor control, muscular coordination and strength are some of the factors related to aging. Tactile sensitivity and sensory feedback also decrease with age. These factors should be addressed in smartphone UI designs for older adults.
Motor Functions, Coordination and Strength

Older adults experience decreased grip strength related to forearm and spine density (Spirduso et al., 2005). General slowing of motor functions, propagation and loss of synchronization between neural impulses due to neurobiological slowing can also be observed with aging (Donkelaar & Franks, 1991). These factors might make it difficult for older adults to interact with small targets that require precise interaction.

Motor speed and eye-hand coordination has been observed to vary between the sexes with age. Ruff and Parker (1993) conducted two types of tests to determine the differences in motor speed and eye-hand coordination between men and women across age. On the Finger Tapping Test, a motor speed test, women were observed to perform slower than men. Women were also observed to perform increasingly slower with age. In contrast, men of increasing age did not perform increasingly poorly. On the Grooved Pegboard Test, an eye-hand coordination measure, women performed substantially faster than men. Decreased performance with age of similar magnitude was observed in both sexes.

Impairments in motor control, muscular coordination, strength and tactile sensitivity, which often affect older smartphone users, should be considered in UI design. Sufficiently large buttons and keyboards should be used to allow comfortable physical interaction. Buttons and keys should also be raised whenever possible to clearly distinguish them from the smartphone case. Target areas should be enlarged to simplify interaction.

Support for his heuristic was found in 3 evaluated guidelines:

1. iOS Human Interface Guidelines encourages designers to “make targets fingertip-size”.
2. Android Accessibility Guidelines encourage using “recommended touch target sizes”, which are determined to be 48dp.
3. Microsoft User Experience Design Guidelines for Windows Phone suggests presenting users with “touch targets of ample size”. Based on user testing, it was determined that the preferred target size is a 9 mm square on touch devices. Microsoft’s General Design Principles also state that designers should make “provisions for clumsy fingers” and should not “test the user’s capacity for making frequent, precise taps”.

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Proposed heuristic:

MOT1 - Enlarge the size of keyboards, physical buttons and target areas

Implications for software and hardware design:

Software - Virtual keyboard keys and virtual UI buttons should be sufficiently large for older adults

Hardware - Physical keyboard keys and physical buttons should be sufficiently large for older adults to engage them with ease

Overall motor slowing that can be observed in older adults should be addressed by avoiding the use of time-sensitive interaction paradigms such as; short timeout limits to execute an action.

Support for this heuristic was found in 1 evaluated guideline. Android Accessibility Guidelines suggests providing "alternatives to affordances that time out". For high priority task flows, designers are not encouraged to rely on controls that disappear after a period of time.

Proposed heuristic:

MOT2 - Avoid the use of interaction timeouts

Implications of gender differences:

Since women have been observed to have slower motor speed than men and they tend to experience decreased performance with age (Ruff & Parker, 1993), interaction timeouts should be adjusted for female users.

Implications for software and hardware design:

Software - Avoid time-sensitive UI messages

Hardware - No implications
**Sensory Feedback**

Sensory feedback regarding the position of the limb with respect to the target is slower in older adults (Donkelaar & Franks, 1991) and a greater proportion of older adults’ movements are performed under feedback control (Pratt, Chasteen, & Abrams, 1994). To address these issues, UI’s should allow users to adjust the position of their limbs before executing an action.

Proposed heuristic:

**MOT3 - Allow user to adjust the position of limb before executing an action**

Implications of gender differences:

Since men have been observed to have worse eye-hand coordination than women and both sexes decreased their performance with age (Ruff & Parker, 1993), UI’s should be adjusted for male users.

Implications for software and hardware design:

**Software** - Virtual keyboards and buttons should provide users with a visual cue regarding the position of user's limb on the touchscreen

**Hardware** - Provide bumps on keys and shape them to facilitate easy interaction in all conditions

Users should be provided with a strong tactile feedback regarding the position of their finger relative to the keyboard or touch-screen. Older adults require a two to tenfold increase in the vibrational threshold to detect the sensation of touch (Perret & Regli, 1970). A strong vibration should be present whenever an older user interacts with a smartphone UI to provide feedback upon executing an action. Combining
visual, auditory and tactile feedback in a large touch-screen UI might prove to be especially beneficial for older adults.

Support for his heuristic was found in 2 evaluated guidelines:

1. Microsoft User Experience Design Guidelines for Windows Phone suggest that “users should get feedback that their taps have operated controls and allowed them to make progress in [an] app.
2. Android Accessibility Guidelines state that “most users benefit from visual and haptic feedback during their navigation”.

Proposed heuristic:

MOT4 - Provide strong tactile and auditory feedback upon executing an operation

Implications for software and hardware design:

Software - Virtual keyboard keys and virtual UI buttons should trigger vibrational and auditory feedback once the user engages them

Hardware - Physical keyboard keys and physical buttons should trigger auditory feedback once the user engages them

3. Motor Control Heuristics

The proposed motor control heuristics are summarized in Table 3.7.

<table>
<thead>
<tr>
<th>Proposed Heuristic</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOT1 - Enlarge the size of keyboards, physical buttons and target areas</td>
<td>Impairments in motor control, muscular coordination, strength and tactile sensitivity</td>
</tr>
<tr>
<td>MOT2 - Avoid the use of interaction timeouts</td>
<td>Motor slowing</td>
</tr>
<tr>
<td>MOT3 - Allow user to adjust the position of limb before executing an action</td>
<td>Slowed sensory feedback</td>
</tr>
<tr>
<td>MOT4 - Provide strong tactile and auditory feedback upon executing an operation</td>
<td>Increased vibrational threshold required to detect the sensation of touch</td>
</tr>
</tbody>
</table>

Table 3.7 - Evaluation heuristics focusing on age-related changes in motor control
### 3.5.11 Smartphone Evaluation Heuristics for Older Adults - Summary

In this section all of the proposed smartphone evaluation heuristics for older adults are summarized.

Age-related factors and corresponding heuristics are listed in Table 3.8.

<table>
<thead>
<tr>
<th>Age-Related Factor</th>
<th>Proposed Heuristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vision</strong></td>
<td>VIS1 - Expand screen size</td>
</tr>
<tr>
<td></td>
<td>VIS2 - Expand size of text and UI elements</td>
</tr>
<tr>
<td></td>
<td>VIS3 - Increase text and image contrast</td>
</tr>
<tr>
<td></td>
<td>VIS4 - Allow users to fine-tune screen brightness and contrast</td>
</tr>
<tr>
<td></td>
<td>VIS5 - Avoid the use of colour to relay information</td>
</tr>
<tr>
<td></td>
<td>VIS6 - Avoid the use of animation and fast-moving objects</td>
</tr>
<tr>
<td><strong>Hearing</strong></td>
<td>AUD1 - Use lower frequencies to convey auditory such as confirmation tones and alerts</td>
</tr>
<tr>
<td></td>
<td>AUD2 - Allow users to fine-tune volume level of auditory cues</td>
</tr>
<tr>
<td><strong>Attention</strong></td>
<td>ATT1 - Minimize the need to actively monitor two or more tasks</td>
</tr>
<tr>
<td></td>
<td>ATT2 - Minimize UI clutter and avoid extraneous details</td>
</tr>
<tr>
<td></td>
<td>ATT3 - Disable inactive UI objects</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>MEM1 - Use single task interaction instead of multitasking whenever possible</td>
</tr>
<tr>
<td></td>
<td>MEM2 - Clearly present task status at all times</td>
</tr>
<tr>
<td></td>
<td>MEM3 - Leverage mental models familiar to older adults</td>
</tr>
<tr>
<td></td>
<td>MEM4 - Use clear text instead of pictorial stimuli to relay information</td>
</tr>
<tr>
<td><strong>Motor Control</strong></td>
<td>MOT1 - Enlarge the size of keyboards, physical buttons and target areas</td>
</tr>
<tr>
<td></td>
<td>MOT2 - Avoid the use of interaction timeouts</td>
</tr>
<tr>
<td></td>
<td>MOT3 - Allow user to adjust the position of limb before executing an action</td>
</tr>
<tr>
<td></td>
<td>MOT4 - Provide strong tactile and auditory feedback upon executing an operation</td>
</tr>
</tbody>
</table>

**Table 3.8 - Smartphone evaluation heuristics for older adults**
4 Results

4.1 Interviews

Interviews were conducted at a local seniors’ community centre and at the participants' homes to address decreased mobility of older adults. All interviewees were cell phone owners, either regular cell phone or smartphone. Older adults with age-related impairments such as presbyopia and moderate loss of hearing were allowed to participate in the study, but those with complete loss of vision or hearing were excluded. Only interviewees 50 years of age or older were allowed to participate as most adults experience obvious age-related perceptual changes at this age. Both male and female interviewees were recruited, though gender balancing was attempted due to the paucity of interviewees.

Interviewees were older adults from the Guelph, Kitchener and Waterloo area and were recruited through the Computer Club at the Evergreen Seniors Centre. This location was chosen due to its close proximity to the University of Guelph, to increase scheduling flexibility. As an incentive to participate, a presentation on smartphone design for older adults during a monthly Computer Club meeting was conducted. Members were asked to participate in interview sessions. In addition, they were encouraged to invite other potential candidates to participate in the study. This method of interviewee recruitment was chosen to compensate for the fact that many older mobile phone users are less technically savvy and would be less likely to respond to calls for recruitment through electronic means.

Interviewees were informed of their right to withdraw both orally and through a printed consent form. If an interviewee chose to withdraw during or after the interview, we concluded the interview and assured the interviewee that the provided answers would not be used in the study. At the end of the interviews, interviewees were informed that they had the option to receive the study results upon its conclusion. Survey interviewees were not compensated for taking part in the interviews. However, as a token of appreciation interviewees were given a T-Shirt.
Interviewees took part in a 30 minute structured interview. During the interview they were asked 38 short questions about their experiences with mobile phones. The interview questions were designed to uncover usability issues addressed by the proposed heuristics. The questions were also geared to document interviewee demographics, cell phone usage patterns and motivations, commonly used features and areas of improvement, physical design and commonly performed tasks (see Appendix C for a complete list of questions used in the interviews along with a mapping of the heuristics that they were designed to validate).

To establish common tasks that older adults found easy and tasks that they found hard to perform, interviewees were asked to perform four tasks on their mobile phones, which were observed and recorded. The reason for asking interviewees to perform interactive tasks on their phones was to understand the comfort level of older adults with various cell phone features and modes of operation.

After each interview the results were reviewed to establish whether new findings were uncovered. Once it was established that no new data was collected, no further interviews were conducted.

The interviewees were self-selected and most were in their late 70s and 80s. However, the interest lay in understanding whether the issues for this group were the same as the results for younger users between 50 and 70 years of age. For example, the majority of interviewees were retired, flip phone users, and used them infrequently, mostly for emergency communications.

In addition, interviewees didn’t use any of the advanced cell phone features such as texting, searching the web, or downloading content most likely due to the form factor of the phones. Interviewees had a good understanding of what their phones do at all times with regards to basic operation and did not use on-device help. Navigating phone menus proved to be a challenge with over half of the interviewees, indicating that they found them hard to use.
Results from Phase 1 interviews were further explored in the Phase 2 survey. For example, since over 60.0% of interviewees found it hard to navigate menus (Figure 4.11), survey respondents were asked to provide suggestions on how menus could be improved (Survey Q18) (see Appendix D for details of how the interviews influenced the survey).

The demographic highlights from the interviews are as follows:

- Age: 60.0% between the ages of 70 and 80 (Figure 4.1)
- Vocation: 90.0% retired (Figure 4.2)
- Phone Style: 90.0% flip phone (Figure 4.3)
- Weekly usage: 30.0% 1-2 times per week (Figure 4.4)
- Common uses: 90.0% communication in emergencies (Figure 4.5)
- Commonly used features: 40.0% address book and 30.0% texting, call history and speed dial (Figure 4.6)
- Features not commonly used: 50.0% internet (Figure 4.7)
- Texting frequency: 60.0% never texted (Figure 4.8)
- Searched the web for information on their cell phones: 90.0% did not search (Figure 4.9)
- Downloaded ringtones, wallpapers or games: 80.0% did not download (Figure 4.10)
- Menus easy to navigate: 60.0% did not find easy (Figure 4.11)
- Shortcut usage: 60.0% did not use (Figure 4.12)
- On-device help usage: 100.0% did not use (Figure 4.13)
- On-device help easy to find: 50.0% did not find easy (Figure 4.14)
- Understanding what cell phones does at all times: 70.0% understood, at least with regards to basic operation (Figure 4.15)
Figure 4.2 - Interviewee vocation

Figure 4.3 - Types of cell phones used by interviewees
Figure 4.4 - Interviewee cell phone usage intervals

Figure 4.5 - Common cell phone uses
Figure 4.6 - Commonly used features

Figure 4.7 - Features not commonly used by interviewees
Figure 4.8 - Texting frequency

Figure 4.9 - Interviewees who searched the web for information on their cell phones

Figure 4.10 - Interviewees who downloaded content on cell phones
Figure 4.11 - Interviewees who found the menus on their cell phones easy to navigate

Figure 4.12 - Interviewees who used shortcuts

Figure 4.13 - Interviewees who used on-device help
4.2 Online Survey

In Phase 2 of the study, an online survey with older cell phone users was conducted. This method was chosen due to the fact that a large portion of older adults are internet users. According to a recent study by Zickhur & Madden (2012), 77% of 50-64 year olds and 53% of 65+ year olds were online. It was determined that 76% of 50-64 year old and 70% of 65+ year old internet users go online on a typical day.

Survey questions were designed to determine whether the results from Phase 1 interviews were valid for a larger population and to validate the proposed heuristics.
For example, it was determined in Phase 1 that interviewees were not dissatisfied with the keyboard on their mobile phones. In Phase 2, respondents were asked more detailed questions related to the size and type of their phone as well as the type of keyboard to better understand the nature of their devices. Furthermore, suggestions for keyboard improvement from the interviews were summarized and suggestions were presented to Phase 2 respondents, who were not satisfied with the operation of their cell phones (Appendix E, Survey Q17). In Appendix E, Survey Q18, respondents were presented with the options below and asked to rank them in order of greatest improvement:

- Simplify the menus
- Use less icons and more text
- Use language that's easier to understand in menus
- Provide descriptive textual labels beside icons
- Provide a list of frequently used features
- Provide an alphabetical list of all features

See Appendix D for a summary of the key interview findings and the resulting survey questions.

The survey was composed of 27 short questions and took approximately 30 minutes to complete (see Appendix E for a list of questions used in the online survey along with their respective goals and expectations).

Online survey participants were recruited through professional networks, online forums and seniors’ centres in North America. 211 responses were collected. The results from 41 respondents (19.4%) were excluded from the final analysis. The reasons for respondent exclusion are listed in Table 4.1.

Survey Monkey, an online survey tool, was used to facilitate the online survey and collect responses. Respondents were not compensated for completing the survey. Before commencing surveys, respondents were presented with an online consent form and asked to accept its terms. Upon completing the survey, respondents were informed that they had an option to receive the results of the
survey from the researchers upon its conclusion. Those who chose to receive the results were asked to provide their email addresses.

Only English-speaking participants were recruited and were informed of their right to withdraw from the survey in the recruitment email. Since the survey was anonymous, researchers did not have the ability to connect survey data to the identities of respondents. Due to this fact, participants were informed that once they submitted their data, researchers could not delete their unique answers. Only completed surveys became part of the data set. Results submitted by respondents who did not complete the required demographics data or haven’t submitted at least 3 responses to feedback questions were discarded.

<table>
<thead>
<tr>
<th>Reason for exclusion</th>
<th>Number of respondents excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not meet the required participation criteria</td>
<td>21</td>
</tr>
<tr>
<td>Did not agree to participate in the survey</td>
<td>7</td>
</tr>
<tr>
<td>Younger than 50</td>
<td>8</td>
</tr>
<tr>
<td>Older than 75 - Not enough data to compare the results from this age group to results from younger age groups</td>
<td>4</td>
</tr>
<tr>
<td>Did not own a cell phone</td>
<td>2</td>
</tr>
<tr>
<td>Skipped at least one of the demographic question</td>
<td>13</td>
</tr>
<tr>
<td>Did not answer more than 3 feedback questions</td>
<td>7</td>
</tr>
<tr>
<td>Total excluded</td>
<td>41</td>
</tr>
</tbody>
</table>

Table 4.1 - Reasons for respondent exclusion from online survey results

Out of the 170 eligible respondents, the largest group were 50-54 years olds (30.0%). 60-64 year olds were the second largest group of respondents (25.9%), followed by 55-59 year olds (20.0%).

The smallest group of respondents were the oldest older adults with 15.9% identifying themselves as 65-69 year olds and 8.2% as 70-74 year olds (see Figure 4.16). In comparison with the interviewees from Phase 1, respondents from Phase 2 were younger (see Table 4.2).
<table>
<thead>
<tr>
<th>Age</th>
<th>Interviewees (%)</th>
<th>Respondents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=10</td>
<td>N=170</td>
</tr>
<tr>
<td>50-59</td>
<td>20.0</td>
<td>50.0</td>
</tr>
<tr>
<td>60-69</td>
<td>10.0</td>
<td>41.8</td>
</tr>
<tr>
<td>80-79</td>
<td>60.0</td>
<td>8.2</td>
</tr>
<tr>
<td>80-89</td>
<td>10.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 4.2 - Age group comparison of Phase 1 interviewees to Phase 2 respondents

The largest group of respondents reported owning their cell phones for a long time, with 40.0% reporting that they have owned their devices for over 3 years (see Figure 4.17). The second largest group indicated that they owned their current cell phones less than a year (24.7%), followed by 1 to less than 2 years (17.6%) and 2 to less than 3 years (17.6%).
A large portion of respondents used their cell phones less than an hour in a typical week (34.1%), followed by 31.2% of respondents reporting using their cell phones for 3 hours or more. 2.4% of respondents reported not using their cell phones at all (Figure 4.18).

Just over half of the respondents (50.6%) were smartphone owners while the rest indicated owning regular mobile phones (Figure 4.19).
74.1% of respondents owned cell phones with physical keyboards and 25.9% reported owning phones with virtual keyboards (Figure 4.20). Of those respondents who owned phones with physical keyboards, 44.4% had a QWERTY keyboard, 42.9% owned flip phones and 23.0% had slider phones (Table 4.3).
### Table 4.3 - Physical keyboard type used by respondents

<table>
<thead>
<tr>
<th>Type of physical keyboard</th>
<th>Respondents with physical keyboards (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QWERTY keyboard</td>
<td>44.4</td>
</tr>
<tr>
<td>Flip phone</td>
<td>42.9</td>
</tr>
<tr>
<td>Slider phone</td>
<td>23.0</td>
</tr>
</tbody>
</table>

#### 4.2.1 Phone Configurations and Age

Aging cell phone users experience visual and motor control changes that impair their ability to use certain phone factors comfortably. To determine the impact of age on phone configurations and usage patterns, interview results were re-grouped into two age groups; younger adults (less than 60 years old) and older adults (60-74 years old). Due to the fact that the populations of 50-59 year olds and 60-74 year olds were not equal, two nonparametric statistical tests were used to determine significance of age-related support for heuristics. Fisher’s exact test of independence with $a = .05$ was used to analyze the significance of age-related results with 2x2 matrices (see Appendix F for an example calculation). For questions with matrices larger than 2x2, Pearson’s Chi-Squared Test of Independence with $a = .05$ was used (see Appendix G for an example calculation). In addition, a finer level of analysis was performed (5 year spans starting at 50), but it was not statistically significant.

#### Keyboard Preference and Age

**Expectation:** It was expected that a higher percentage of younger adults would own cell phones with virtual keyboards. This expectation was based on Phase 1 results, in which the majority of older adults owned flip phones, with physical keyboards.

**Observation:** When asked whether respondents owned phones with physical keyboards, the difference was not statistically significant (Survey Q4, Fisher’s $(N=170)$, $p=0.861$).

**Discussion:** Lack of significance between younger and older adults could be related to a small sample size, or lack of difference in ownership between the two groups of older adults in the Phase 2 survey.
QWERTY Keyboard Ownership and Age

*Expectation:* It was expected that the usage of QWERTY keyboards would decrease with age. This expectation was based on Phase 1 results, in which older adults indicated that they find phone keyboards small and have trouble pressing the correct buttons. Mobile phones with QWERTY keyboards typically have smaller keys than those found on non-QWERTY phones.

*Observation:* When asked whether respondents owned cell phones with QWERTY keyboards, a higher percentage of younger adults (51.6%) indicated that they had phones with such keyboards in contrast to older adults (37.5%). As this difference approached significance (Fisher’s (N=126), p=0.151), it suggests that younger adults are more likely to own cell phones with QWERTY keyboards that older adults.

*Discussion:* Due to deficiencies in motor control and muscular coordination older adults often find it difficult to press small buttons on virtual and physical QWERTY keyboards. This finding was validated in with older adults in Phase 1, who indicated that they preferred to perform tasks that required the use of a keyboard, such as typing an email on a desktop computer instead of a smartphone.

Flip Phone Ownership and Age

*Expectation:* It was expected that flip phone usage would increase with age. This expectation was based on the fact that the majority of Phase 1 interviewees (90.0%) were older flip phone users.

*Observation:* When asked whether respondents were flip phone users, a higher percentage of older adults (53.1%) indicated that they were using cell phones with the flip form factor compared to younger adults (32.3%). According to Fisher’s exact test of independence, this difference was statistically significant (Fisher’s (N=126), p=.020). One can infer that older adults are more likely than younger adults to use flip phones.

*Discussion:* Flip phones are usually less complicated than phones in other form factors with the flip screen serving as a physical switch for answering and ending calls. The flip form factor also helps protect
the keyboard from accidentally dialling when not in use and hence older adults prefer to use mobile phones with this phone factor.

**Slider Phone Ownership and Age**

*Expectation:* It was expected that a slider phone ownership would decrease with age.

*Observation:* When asked whether respondents were slider phone users, a higher percentage of younger adults (50.0%) than older adults (26.7%) indicated that they owned phones with the slider form factor. As this difference approached significance (Fisher’s (N=72), *p*=.055), it suggests that younger adults are more likely to own slider phones.

*Discussion:* Slider phones are usually found to have physical keyboards used for typing text messages or emails and these features are thought to be complex and not frequently used by older adults on their cell phones. Based on Phase 1 interviews, older adults preferred to perform complex tasks such as checking their email on home PC’s.

**Touchscreen Ownership and Age**

*Expectation:* It was expected that touchscreen phone ownership would decrease with age. This expectation was based on the results of the interviews, in which older adults did not have much experience with touchscreens.

*Observation:* When asked whether respondents owned touchscreen cell phones, a higher percentage of younger adults (42.9%) than older adults (20.0%) indicated that they owned phones with touchscreens. According to Fisher’s exact test of independence, this difference was statistically significant (Fisher’s (N=72), *p*=.048). One can infer that younger adults are more likely than older adults to own touchscreen phones.

*Discussion:* Older adults might find touchscreen phones unfamiliar and hard to use due to lack of tactile feedback. Physical buttons might be a better option when designing mobile phones for older adults.
Mobile Phone Type and Age

**Expectation:** It was expected that smartphone ownership would decrease with age. This expectation was based on Phase 1 results, in which older adults indicated ownership of basic mobile phones.

**Observation:** When asked whether respondents owned smartphones or regular cell phones, a higher percentage of younger adults (61.2%) indicated that they owned smartphones than older adults (40.0%). According to Fisher’s exact test of independence, this difference was statistically significant, (Fisher’s (N=170), p=.009). One can infer that younger adults are more likely than older adults to own smartphones.

**Discussion:** Smartphones are thought to be more complex and expensive than regular cell phones. Older adults are often overwhelmed by lowered perceived smartphone usability and price, which often result in a preference for regular cell phones amongst this group.

4.2.2 Usage Patterns and Age

Differences in cell phone usage patterns can be observed between younger and older adults. These can be attributed to a variety of factors including employment status and activity levels. The section below summarizes differences in cell phone usage between older adults and their impact on the proposed heuristics and cell phone design.

Length of Ownership and Age

**Expectation:** It was expected that older adults keep their cell phones for longer periods of time than younger adults due to financial reasons and lack of need to own the latest technology.

**Observation:** When asked how long respondents owned their current cell phones, a higher percentage of younger adults (31.8%) than older adults (17.6%) indicated that they owned their cell phones less than 1 year. Moreover, a higher percentage of older adults were found to own their cell phones for more than 3 years (47.1%) in contrast to younger adults (32.9%). As this difference approached
significance (Pearson’s Chi-Squared \((N=170), p=.121\)), it suggests that younger adults are more likely than older adults to own their cell phones for less than 1 year. It also suggests older adults are more likely than younger adults to own their cell phone 3 years or longer (see Figure 4.21).

**Discussion:** Older adults are less likely to upgrade their cell phones to the latest models and they tend to hold on to them for longer than younger adults. Cell phones for older adults should be designed with durability in mind, to ensure that they can last as long as older adults expect them to.

![Figure 4.21 - Length of cell phone ownership comparison of younger vs. older adults](image)

**Weekly Usage and Age**

*Expectation:* Based on the results of the interviews in Phase 1, older adults were expected to use their cell phones infrequently on a weekly basis.

*Observation:* When asked for how long respondents use their cell phones in a typical week, a larger portion of older adults (42.3%) than younger adults (23.5%) use their cell phones for less than an hour. It was also observed that younger adults were more likely to use their cell phones 3 hours or more in a typical week (40.0%) than older adults (23.9%). According to Pearson’s Chi-Squared Test of Independence, these differences were statistically significant, (Pearson’s Chi-Squared \((N=170), p=.013\)).
The results infer that older adults are more likely than younger adults to use their cell phones for less than 1 hour per week and younger adults are more likely than older adults to use their cell phones for 3 hours or more per week (see Figure 4.22).

**Discussion:** The implication of this finding in cell phone design is such that due to the fact that older adults use their cell phones infrequently, they should be designed in a highly usable way that allows for frequent re-learning of operation.

![Weekly cell phone usage interval comparison of younger vs. older adults](image)

**Figure 4.22 - Weekly cell phone usage interval comparison of younger vs. older adults**

### 4.3 Evaluating Heuristics

This section presents results from Phase 1 interviews and the Phase 2 online survey and summarizes how support for each heuristic was determined. Online survey results were further analyzed to determine whether strength of support for heuristics increased with age. Two age divisions were compared; 50-59 and 60-74, with 85 survey participants in each group. A nonparametric statistical test was used to determine significance of age-related support for heuristics. Fisher’s exact test of independence with $\alpha = .05$ was used to analyze the significance of age-related results with 2x2 matrices. A finer level of analysis was performed (5 year spans starting at 50) and was not statistically significant.
Out of the 9 heuristics evaluated in this study, support for 8 heuristics was found. No clear support was found for the other heuristic. Summarized results are presented and grouped by heuristic type:

1) Vision (Section 4.3.3)
2) Hearing (Section 4.3.4)
3) Attention (Section 4.3.5)
4) Memory (Section 4.3.6)
5) Motor control (Section 4.3.7)

A brief overview of the results for each heuristic is followed by an analysis of interview, survey and age-related results. For a detailed breakdown of interview and online survey questions related to each heuristic, see Appendix C and Appendix E respectively. The criteria used for determining support are found in the following section.

### 4.3.1 Determining Support for Heuristics

The criteria used to determine whether data from the interviews and survey supported a heuristic varied for each heuristic. This is because the types of questions used to determine support varied (see Table 4.4 for the types of questions used in the Interviews). In the case of the interviews, there were Open-ended questions that often resulted in the interviewee describing anecdotes or scenarios of use that crossed several heuristics, e.g., Interview Q30 – How would you improve the screen on your mobile device? Response to this question could relate to any of the following heuristics:

- VIS1 - Expand screen size
- VIS3 - Increase text and image contrast
- VIS4 - Allow users to fine-tune screen brightness and contrast

If one or more anecdotes supported a heuristic then this was counted as support for the heuristic. Anecdotes not supporting the heuristic were also taken into account by cancelling out any positive account.
In contrast the interview script contained additional **Direct questions** related to a heuristic, e.g.,

Interview Q28. Do you find the text size large enough to read comfortably on your mobile phone? For these questions the criteria for showing support was set at greater than 50%, i.e., more than half of the interviewees had to have answered in favour.

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Example</th>
<th>Criteria for Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended</td>
<td>Interview Q30. How would you improve the screen on your mobile device?</td>
<td>Mention of change in line with the recommendation of a related heuristic</td>
</tr>
<tr>
<td>Direct</td>
<td>Interview Q28. Do you find the text size large enough to read comfortably on your mobile phone?</td>
<td>Over 50% disagreement</td>
</tr>
</tbody>
</table>

**Table 4.4 - Criteria for support from interview questions**

Four types of online survey questions were used (see Table 4.5). Answers to **True/False questions** were counted as support if over 50% of online survey respondents replied in favor of the corresponding heuristic. Responses from **Choose from a list questions** were counted as support if over 50% of respondents were in favor of an option related to a heuristic. In contrast **Rank order questions** were dependent on the number of possible options. For example, if respondents were asked to rank 5 items, and only one item was in support of a heuristic, then ranking that item in first place should on average happen 20% of the time. As a result, anything above 20% is suggests support for the heuristic. The last question type, **Likert**, was counted as supporting a heuristic if over 50% of the combined responses were "neutral", "unsatisfied", and "very unsatisfied".
<table>
<thead>
<tr>
<th>Question Type</th>
<th>Example</th>
<th>Criteria for Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>True/False</td>
<td>Survey Q20. Do you find it difficult to hear your cell phone sounds?</td>
<td>Over 50% agreement</td>
</tr>
</tbody>
</table>
| Choose from a list | Survey Q14. In order to use the phone comfortably, do you do any of the following:  
- Increase text size (+ 3 other options) | Over 50% of survey respondents in support of a related heuristic |
| Rank order    | Survey Q16. Which of the following would improve the screen on your cell phone? Rank the suggestions below in order of need of improvement:  
- Increase screen size (+ 4 other options) | Over 20% of respondents indicating a change in support of a particular heuristic as the most important improvement |
| Likert        | Survey Q15. How satisfied are you with the visibility of the screen on your cell phone?  
(very satisfied – very unsatisfied) | Over 50% not satisfied with characteristic related to a heuristic |

**Table 4.5 - Criteria for support from online survey results**

As will be seen in the following sections, overall support or lack of support for a heuristic was not a simple counting exercise.

### 4.3.2 Evaluated Heuristics

The evaluation methods used in this thesis were capable of evaluating 9 out of 19 proposed heuristics (see Table 4.6). The heuristics that were not suited for evaluation through interviews and surveys are listed in Appendix B.

Though outside of the bounds of this thesis, other methods could be used to validate the remaining heuristics. For example, heuristic MEM1 (Minimize the need to actively monitor two or more tasks) could be evaluated through observation. To validate this heuristic, older adult performance with single task interaction models could be compared to multitasking models in a usability lab. Similarly, the interaction of older adults with two working prototypes could be used to evaluate heuristic MOT4: Provide strong tactile and auditory feedback upon executing an operation.
<table>
<thead>
<tr>
<th>Age-Related Factor</th>
<th>Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>VIS1 - Expand screen size</td>
</tr>
<tr>
<td></td>
<td>VIS2 - Expand size of text and UI elements</td>
</tr>
<tr>
<td></td>
<td>VIS3 - Increase text and image contrast</td>
</tr>
<tr>
<td></td>
<td>VIS4 - Allow users to fine-tune screen brightness and contrast</td>
</tr>
<tr>
<td>Hearing</td>
<td>AUD1 - Use lower frequencies to convey auditory such as confirmation tones</td>
</tr>
<tr>
<td></td>
<td>and alerts</td>
</tr>
<tr>
<td></td>
<td>AUD2 - Allow users to fine-tune volume level of auditory cues</td>
</tr>
<tr>
<td>Memory</td>
<td>MEM3 - Leverage mental models familiar to older adults</td>
</tr>
<tr>
<td></td>
<td>MEM4 - Use clear text instead of pictorial stimuli to relay information</td>
</tr>
<tr>
<td>Motor control</td>
<td>MOT1 - Enlarge the size of keyboards, physical buttons and target areas</td>
</tr>
</tbody>
</table>

**Table 4.6 - List of evaluated heuristics**

In the presentation of the following results, interview participants are referred to as "interviewees" and online survey respondents are simply referred to as "respondents".

4.3.3 Support for Vision Heuristics

The heuristics in this section are related to the negative impact aging has on the visual system (See Section 2.4.1 for a full description of each vision heuristic). The support for the proposed vision heuristics found in Phase 1 and Phase 2 is summarized in Table 4.7, and the support for each of the heuristics is detailed in the following heuristic-named subsections.

<table>
<thead>
<tr>
<th>Vision Heuristic</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS1 - Expand screen size</td>
<td>+</td>
</tr>
<tr>
<td>VIS2 - Expand size of text and UI elements</td>
<td>+</td>
</tr>
<tr>
<td>VIS3 - Increase text and image contrast</td>
<td>+</td>
</tr>
<tr>
<td>VIS4 - Allow users to fine-tune screen brightness and contrast</td>
<td>+</td>
</tr>
</tbody>
</table>

**Table 4.7 - Summary of support for vision heuristics**

**VIS1 - Expand screen size**

*Overview:* Reasonably strong support for this heuristic was found in 2 anecdotes and 2 interview and survey questions.
Interviews: The majority of interviewees showed strong support for larger screens.

This heuristic was strongly supported in interview results with an overwhelming majority (80.0%) of interviewees indicating a strong preference for larger screens (Interview Q30). As a baseline, all but one interviewee had flip phones (Interview Q3, Figure 3.4), i.e., phones with small screens. Two supporting anecdotes were also found. One of the interviewees stated that; “if the phone was a bit bigger, then the screen would be bigger and that would be fine”. Another interviewee suggested eliminating a physical keyboard and “replacing it with a larger screen” instead. Both of these anecdotes suggest that older adults prefer mobile phones with larger screens.

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended</td>
<td>Interview Q30. How would you improve the screen on your mobile device?</td>
<td>One or more anecdotes in support of increasing mobile device screen size</td>
<td>80.0% of interviewees indicated preference for larger screens</td>
<td>+</td>
</tr>
<tr>
<td>Likert</td>
<td>Survey Q15. How satisfied are you with the visibility of the screen on your cell phone?</td>
<td>Mention of increasing screen size</td>
<td>Over 50% of interview participants not satisfied</td>
<td>-</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q16. Which of the following would improve the screen on your cell phone? Rank the suggestions below in order of need of improvement: - Increase screen size (+ 4 other options)</td>
<td>Over 20% of survey respondents indicating “increase screen size” as the most important improvement of cell phone screen</td>
<td>Over 20% of survey respondents indicating “increase screen size” as the most important improvement of cell phone screen</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4.8 - Summary of support for heuristic VIS1 - expand screen size
Survey: Over half of those dissatisfied with their screens said they would like larger ones.

It was expected that the majority of older adults would not be satisfied with the visibility of their cell phone screens. Surprisingly, 71.8% of respondents were satisfied with the visibility of the screen on their cell phones (Survey Q15). Of the respondents who were not satisfied with the visibility of screen on their mobile devices, 51.1% indicated that increasing screen size was the most important change that would improve the visibility (Survey Q16).

Age Related Analysis: It was expected that the older the respondent, the less they would be satisfied with the visibility of the screen. This was not found to be the case as the difference between 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q15, Fisher’s (N=170), p=.865). It was also expected that the older the respondent, the stronger their preference for a larger screen. This was not found to be the case as the difference between the answers of 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q16, Fisher’s (N=45), p=.556).

Discussion: The results of interviews and the survey strongly support the recommendation that smartphone screen size should be expanded to address lowered ability to focus on near objects. The unexpectedly high satisfaction rate with the visibility of the screen observed in the survey (Survey Q15) could be related to the fact that older adults don't have much experience with the latest smartphones, which tend to come with larger screen sizes. The majority of respondents owned their devices for over 3 years (see Figure 4.17).

VIS2 - Expand size of text and UI elements

Overview: Reasonably strong support for this heuristic was found in 6 anecdotes and 1 survey question.

Interviews: Support in interview results was mixed and contradictory, but 6 anecdotes supporting this heuristic were found.
70.0% of respondents found the text size to be large enough to read comfortably (Interview Q28). This contradicts our expectations, especially given that older adults were observed to use flip phones with small screens. This result could be related to the fact that older adults already had enlarged text on the cell phone UI’s, or they were unaware of the availability of phones with larger text.

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Interview Q28. Do you find the text size large enough to read comfortably on your mobile phone?</td>
<td>One or more anecdotes in support of expanding text or UI elements</td>
<td>6 supporting anecdotes</td>
<td>+</td>
</tr>
</tbody>
</table>

| Choose from a list | Survey Q14. In order to use the phone comfortably, do you do any of the following: - Increase text size (+ 3 other options) | Over 50% of survey respondents in support of a related heuristic                   | 30.0% of respondents didn’t find the text size to be large enough to read comfortably | -       |

| Rank order | Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank the suggestions below in order of greatest improvement: - Increase size of text (+8 other options) | Over 11.1% of survey respondents indicating “increase size of text” as the most important improvement in cell phone operation | 44.4% indicated increasing the size of text as the most important change that would improve cell phone operation | +       |

| Rank order | Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank the suggestions below in order of greatest improvement: - Increase size of icons (+8 other options) | Over 11.1% of survey respondents indicating “increase size of icons” as the most important improvement in cell phone operation | 20.6% indicated increasing the size of icons as the most important change that would improve cell phone operation | +       |

Table 4.9 - Summary of support for heuristic VIS2 - expand size of text and UI elements
Support for this heuristic did come in the form of two anecdotes described by interviewees stating that they were uncomfortable with text size:

1. “[they] have to use a magnifying glass” to read text comfortably (Interview Q28)
2. “sales representative at the carrier store enlarged the text size at time of purchase” (Interview Q28)

In addition, 4 interviewees responded to other questions with anecdotes indicating support for this heuristic:

1. Menus could be improved by increasing the text size beside icons (Interview Q16)
2. UI could be improved by increasing the text size (Interview Q32)
3. UI could be improved by increasing the text size beside icons (Interview Q32)
4. UI could be improved by increasing icon size (Interview Q32)

*Survey:* Close to a third of respondents increased text size and nearly half of those who were not satisfied with the operation of their cell phone indicated preference for larger text and icons.

31.2% of respondents indicated that they increased text size to use their cell phone comfortably (Survey Q14). This low number could be related to the fact that older adults were not familiar with cell phone options and unaware of the possibility to adjust the size of text.

Out of the 22.9% of respondents who were not satisfied with the operation of their cell phones, 44.4% indicated that increasing text size and 20.6% indicated increasing the size of icons were the most important changes that would improve the operation of their cell phone (Survey Q18).

**Age Related Analysis:** It was expected that the older the respondent, the more likely they would be to increase text size to use their cell phone comfortably. This was not found to be the case as the difference between 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q14, Fisher's (N=170), p=.508). The difference in preference for increased text size (Survey Q18, Fisher's (N=36), p=1.000) and icon size (Survey Q18, Fisher's (N=34), p=.681) as the most important improvement in cell phone operation were also not statistically significant between 50-59 year olds and 60-74 year olds who were not satisfied with the operation of their cell phones.
**Discussion**: The results of interviews and the survey support the recommendation that size of text and UI elements such as icons and images should be expanded to address lowered light accommodation and decreased visual acuity experienced by older adults. The wording of the interview question related to text size (Interview Q28) could have been stated improperly and thus 70.0% of respondents could have found indicated that they found text size large enough to read comfortably. The question could be improved by asking older adults whether they were able to see text and UI elements without glasses. Survey questions related to size of text and icons were preceded with a filter question about satisfaction with phone operation (Survey Q17), which could have been misleading. A more direct survey question gauging respondent satisfaction with size of text and UI elements could have resulted in stronger support for this heuristic.

**VIS3 – Increase text and image contrast**

*Overview*: Strong support for this heuristic was found in 6 anecdotes and 3 interview and survey questions.

*Interviews*: A third of interviewees indicated that increasing contrast would improve the screen on their cell phone. Over two thirds of interviewees found it hard to see the screen in certain environments and half had trouble in sunny environments. Six supporting anecdotes were found.

When older adults were asked whether they ever find it difficult to see the screen on their cell phone in certain environments (Interview Q29), 70.0% responded affirmatively. When asked how interviewees would improve the screen on their mobile device (Interview Q30), 30.0% suggested increasing contrast. 50.0% of interviewees indicated that they found it challenging to see the screen on their mobile devices in sunny conditions (Interview Q29). Six interviewees provided anecdotal support for this heuristic:

1. "Outside in the sun the screen can be difficult to see" (Interview Q29)
2. "When I’m using the phone as a passengers in a vehicle and the sun is shining I almost can’t see the screen at all” (Interview Q29)
3. “Sometimes trying to find a dark place outside” (Interview Q29)
4. “Can’t see the text on my screen during the day” (Interview Q29)
5. “In sunlight the screen just goes blank” (Interview Q29)
6. "Colours are too light in sunlight" (Interview Q29)

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Supp ort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Interview Q29. Did you ever find it difficult to see the screen on your mobile phone in certain environments?</td>
<td>Over 50% agreement</td>
<td>70% of interviewees found it difficult to see the screen in certain environments</td>
<td>+</td>
</tr>
<tr>
<td>Open-ended</td>
<td>Interview Q30. How would you improve the screen on your mobile device?</td>
<td>Mention of increasing text and image contrast</td>
<td>30% of interviewees mentioned increasing contrast</td>
<td>+</td>
</tr>
<tr>
<td>Likert</td>
<td>Survey Q15. How satisfied are you with the visibility of the screen on your cell phone?</td>
<td>Over 50% of interview participants not satisfied</td>
<td>28.2% of interviewees were &quot;neutral&quot;, &quot;not satisfied&quot;, and &quot;very unsatisfied&quot;</td>
<td>-</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q16. Which of the following would improve the screen on your cell phone? Rank suggestions in order of improvement: - Increase contrast (+ 4 other options)</td>
<td>Over 20% of survey respondents indicating “increase contrast” as the most important improvement of cell phone screen</td>
<td>32.5% indicated that increasing contrast was the most important improvement in cell phone screen</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q16. Which of the following would improve the screen on your cell phone? Rank suggestions in order of improvement: - Improve visibility in sunny conditions (+ 4 other options)</td>
<td>Over 20% of survey respondents indicating “improve visibility in sunny conditions” as the most important improvement of cell phone screen</td>
<td>64.4% indicated improving visibility in sunny conditions was the most important improvement in cell phone screen</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q16. Which of the following would improve the screen on your cell phone? Rank suggestions in order of improvement: - Improve visibility in low light conditions (+ 4 other options)</td>
<td>Over 20% of survey respondents indicating “improve visibility in low light conditions” as the most important improvement of cell phone screen</td>
<td>50.0% indicated improving visibility in low light conditions was the most important improvement in cell phone screen</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4.10 - Summary of support for heuristic VIS3 – increase text and image contrast
Survey: Close to a third of respondents were not satisfied with screen visibility. Nearly one third of those respondents indicated a preference for increased contrast, close to two thirds wanted improved visibility in sunny conditions and half in low light conditions.

71.8% of respondents indicated that they were satisfied with the visibility of their cell phone screen (Survey Q15). Out of the 28.2% of respondents who were not satisfied with screen visibility, 32.5% indicated that increasing contrast, 64.4% indicated improving visibility in sunny conditions and 50.0% indicated improving visibility in low light conditions were the most important changes that would improve the visibility of the screen on their cell phone (Survey Q16).

Age Related Analysis: It was expected that the older the respondent, the lower the satisfaction would be with the visibility of their cell phone screen. This was not found to be the case as the difference between 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q15, Fisher’s (N=170), p=.865). It was also expected that the preference for increased contrast and visibility in low lighting conditions would increase with age, but the difference was not statistically significant (Survey Q16, Fisher’s (N=40), p=1.000 and Fisher’s (N=40), p=0.354 respectively). A higher percentage of 60-74 year olds (77.3%) than 50-59 year olds (52.2%) indicated that improving visibility in sunny conditions as most important. As this difference approached significance (Survey Q16, Fisher’s (N=45), p=.120), it suggests that older adults are more likely to prefer improving screen visibility on their cell phones in sunny conditions when compared to young adults.

Discussion: The results of interviews and survey support the recommendation that text and image contrast should be increased to address lowered contrast sensitivity experienced by older adults. The challenges with viewing screens in sunny conditions uncovered in interviews were confirmed with a larger group of respondents. It was also determined that the older the respondent, the more likely they were to rank improving screen visibility in sunny conditions as most important. It was surprising that interviewees and respondents didn’t show stronger preference for improving screen visibility in low
lighting conditions, as the contrast sensitivity in low light decreases considerably with age. This could be related to the fact that older adults tend not to use their cell phones in low lighting conditions.

VIS4 – Allow users to fine-tune screen brightness and contrast

*Overview:* Support for this heuristic was found in 2 anecdotes and 2 interview questions.

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Interview Q29. Did you ever find it difficult to see the screen on your mobile phone in certain environments?</td>
<td>One or more anecdotes related to screen brightness or contrast</td>
<td>Two interviewees indicated that they did not like the screen brightness and they had trouble viewing screen in sunny conditions</td>
<td>+</td>
</tr>
<tr>
<td>Direct</td>
<td>Interview Q29. Did you ever find it difficult to see the screen on your mobile phone in certain environments?</td>
<td>Over 50% agreement</td>
<td>70% of interviewees indicated that they did not like the screen brightness and they had trouble viewing screen in sunny conditions</td>
<td>+</td>
</tr>
<tr>
<td>Open-ended question</td>
<td>Interview Q30. How would you improve the screen on your mobile device?</td>
<td>Mention of fine-tuning screen brightness and contrast</td>
<td>One interviewee suggested a reverse colour scheme for night time viewing</td>
<td>+</td>
</tr>
<tr>
<td>Choose from a list</td>
<td>Survey Q14. In order to use the phone comfortably, do you do any of the following: - Increase screen brightness (+ 3 other options)</td>
<td>Over 50% of survey respondents in support of a related heuristic</td>
<td>19.4% of respondents indicated that they increased screen brightness to use their cell phone comfortably</td>
<td>-</td>
</tr>
</tbody>
</table>

*Table 4.11 - Summary of support for heuristic VIS4 – allow users to fine-tune screen brightness and contrast*

*Interviews:* Over two thirds of interviewees found it hard to see the screen on their mobile phones in certain environments and a half had trouble in sunny environments. Anecdotal support for this heuristic was found in two interview questions.
When asked whether older adults ever find it difficult to see the screen in certain environments (Interview Q29), 70.0% responded affirmatively. Two interviewees responded to interview questions indicating support for the ability to fine-tune screen brightness and contrast:

1. One interviewee indicated that they did not like the screen brightness (Interview Q7)
2. One interviewee suggested a night time colour scheme to improve screen visibility in low lighting conditions (Interview Q30)

**Survey:** Nearly one fifth of respondents indicated that they increased screen brightness.

19.4% of respondents indicated that they increased screen brightness to use their cell phone comfortably (Survey Q14), but this result did not meet the required threshold to count as support for heuristic VIS4.

**Age Related Analysis:** It was expected that the older the respondent, the stronger their preference would be to increase screen brightness. This was not found to be the case as the difference between 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q14, Fisher's (N=170), p=1.000).

**Discussion:** Interview results support the recommendation that the ability to fine-tune mobile device screen brightness and contrast, as well as a night viewing mode should be available in mobile devices for older adults. These features would help mitigate negative effects of lower contrast sensitivity and higher susceptibility to glare experienced with age. The percentage of older adults who increased screen brightness (Survey Q14) could have been low, because the ability to fine-tune screen brightness could have been unavailable on their cell phones, or the interviewees did not know how to adjust this setting on their devices. Further support for this heuristic could have been gathered by asking respondents whether they increased contrast to use their cell phone comfortably (Survey Q14).

### 4.3.4 Support for Auditory Heuristics

The heuristics in this section are related to the negative impact aging has on hearing (See Section 3.5.4 for a full description of each auditory heuristic). The support for the proposed auditory heuristics found
in Phase 1 and Phase 2 is summarized in Table 4.12, and the support for each of the heuristics is detailed in the following heuristic-named subsections.

<table>
<thead>
<tr>
<th>Auditory Heuristic</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUD1 - Use lower frequencies to convey auditory such as confirmation tones and alerts</td>
<td>-</td>
</tr>
<tr>
<td>AUD2 - Allow users to fine-tune volume level of auditory cues</td>
<td>+</td>
</tr>
</tbody>
</table>

**Table 4.12 - Summary of support for auditory heuristics**

**AUD1 - Use lower frequencies to convey auditory cues such as confirmation tones and alerts**

**Overview:** No anecdotes or support in survey questions was found for this heuristic. Results of one interview question were mixed and contradictory.

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended</td>
<td>Interview Q34. How would you improve the sound on your mobile device?</td>
<td>Mention of using lower frequencies to convey auditory tones</td>
<td>One interviewee asked for lower pitched ringtones (support)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>One interviewee indicated preference for higher pitched ringtones (contradictory)</td>
<td>-</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q21. Select any of the following that would make it easier to hear the sounds on your cell phone. Rank your choices in order of greatest improvement: - Lower pitched ringtones (+ 3 other options)</td>
<td>Over 25% of survey respondents indicating “lower pitched ringtones” as the most important improvement of cell phone sound</td>
<td>3.5% indicated that lower pitched sounds were the most important changes that would make it easier to hear the sounds on their cell phones</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 4.13 - Summary of support for heuristic AUD1 - use lower frequencies to convey auditory cues such as confirmation tones and alerts**
**Interviews:** When asked how interviewees would improve the sounds on their cell phones (Interview Q34), the following answers were found:

- One interviewee asked for lower pitched ringtones, which serves as support for this heuristic
- One interviewee indicated preference for higher pitched ringtones, which contradicts the recommendation of this heuristic

**Survey:** No clear evidence in support of this heuristic was found in the interviews and survey.

24.1% of respondents indicated that they found it hard to hear their cell phone sounds (Survey Q20). Out of those respondents, 3.5% indicated that higher pitched sounds and 3.5% indicated that lower pitched sounds were the most important changes that would make it easier to hear the sounds on their cell phones (Survey Q21).

**Age Related: Analysis** It was expected that the older the respondent, the stronger their preference for lower pitched sounds. This was not found to be the case as the difference between 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q14, Fisher's (N=170), p=1.000).

**Discussion:** There is no clear evidence for this heuristic. There was one supporting finding and one contrary finding from one interview question. An equal percentage (3.5%) of respondents preferred higher pitched and lower pitched sounds in the survey. User testing could be used to determine the preferred frequency range of auditory cues to compensate for age-related hearing loss, limited frequency selectivity and a lower ability to discriminate high-pitched sounds.

**AUD2 - Allow users to fine-tune volume level of auditory cues**

**Overview:** Reasonably strong support for this heuristic was found in 3 anecdotes and 3 interview and survey questions.

**Interviews:** Majority of interviewees found it hard to hear cell phone sounds; nearly a third indicated setting volume levels at the highest levels and showed preference for louder ringtones. Six supporting anecdotes were found.
When asked whether respondents ever find it difficult to hear the sound on their cell phones (Interview Q33), over two thirds confirmed (70.0%). 30.0% of respondents found it challenging to hear their cell phone sounds in noisy environments and 30.0% of respondents indicated setting their volumes on the loudest setting and picking the loudest ringtones (Interview Q33). When asked how respondents would improve the sounds on their cell phones (Interview Q34), 30.0% indicated preference for louder ringtones. In addition, three interviewees provided anecdotal support for this heuristic:

1. One interviewee indicated a preference for “more control over volume” (Interview Q34)
2. One interviewee showed preference for “volume control with clear loudness status” (Interview Q34)
3. One interviewee indicated a preference for “more accessible volume control” (Interview Q34)

Survey: Nearly a quarter of respondents found it difficult to hear cell phone sounds and over half indicated strong preference for easy volume adjustments. More than a third increased volume to use their cell phones comfortably.

75.9% of respondents did not find it difficult to hear cell phone sounds (Survey Q20). Out of the remaining 24.1% of respondents who found it difficult, 60.5% indicated that making it easier to adjust the volume would be the most important improvement (Survey Q21). 35.9% of respondents indicated that they increased volume to use their phone comfortably (Survey Q14), but this result did not meet the required threshold to count as support for heuristic AUD2.

Age Related Analysis: It was expected that the older the respondent, the more likely they would be to increase volume to use their phone comfortably. This was not found to be the case as the difference between 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q14, Fisher’s (N=170), p=.523). It was also expected that the older the respondent, the harder it would be for them to hear cell phone sounds. Again, this was not found to be the case as the difference between the answers of 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q20, Fisher’s (N=170),
There was also no significance between 50-59 year olds’ and 60-74 year olds’ preference for easier volume adjustment (Survey Q21, Fisher’s (N=38), p=.741).

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Interview Q33. Did you ever find it difficult to hear the sound on your mobile device?</td>
<td>Over 50% agreement</td>
<td>70% of interviewees found it hard to hear sounds on their mobile devices</td>
<td>+</td>
</tr>
<tr>
<td>Open-ended</td>
<td>Interview Q34. How would you improve the sound on your mobile device?</td>
<td>Mention of features that would allow users to adjust sound volume in certain environments</td>
<td>30.0% of interviewees indicated preference for louder ringtones</td>
<td>+</td>
</tr>
<tr>
<td>True/false</td>
<td>Survey Q20. Do you find it difficult to hear your cell phone sounds?</td>
<td>Over 50% of interviewees indicating that they find it difficult to hear cell phone sounds</td>
<td>24.1% of interviewees found it hard to hear cell phone sounds</td>
<td>-</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q21. Select any of the following that would make it easier to hear the sounds on your cell phone. Rank your choices in order of greatest improvement: - Make it easier to adjust the volume (+ 3 other options)</td>
<td>Over 25% of survey respondents indicating “make it easier to adjust volume” as the most important improvement of cell phone sound</td>
<td>60.5% indicated that making it easier to adjust the volume would be the most important improvement</td>
<td>+</td>
</tr>
<tr>
<td>Choose from a list</td>
<td>Survey Q14. In order to use the phone comfortably, do you do any of the following: - Increase volume (+ 3 other options)</td>
<td>Over 50% of survey respondents indicating that they “increase volume” in order to use phone comfortably</td>
<td>35.9% of respondents indicated that they increased volume to use their phone comfortably</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4.14 - Summary of support for heuristic AUD2 - allow users to fine-tune volume level of auditory cues

Discussion: Age-related loss of sound clarity and volume is supported in the interview and survey results. This finding could be addressed by allowing users to adjust the level of auditory cues to a level
comfortable for older adults. 35.9% of respondents indicated that they increased volume to use their phone comfortably (Survey Q14). This low number could be related to the fact that older adults were not familiar with cell phone sound options or unaware of the possibility to adjust volume levels.

4.3.5 Support for Memory Heuristics

The heuristics in this section are related to the negative impact aging has on memory (see section 3.5.8 for a full description of each memory heuristic). The support for the proposed memory heuristics found in interviews and survey is summarized in Table 4.15, and the support for each heuristic is detailed in the following heuristic-named subsections.

<table>
<thead>
<tr>
<th>Memory Heuristic</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEM3 - Leverage mental models familiar to older adults</td>
<td>+</td>
</tr>
<tr>
<td>MEM4 - Use clear text instead of pictorial stimuli to relay information</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4.15 - Summary of support for memory heuristics

MEM3 - Leverage mental models familiar to older adults

*Overview*: Reasonably strong support for this heuristic was found in 2 anecdotes and 2 interview and survey questions.

*Interviews*: One fifth of interviewees wanted simpler menus and the same number wanted an alphabetical list of all features. Two supporting anecdotes were found.

When asked how older adults would improve menus in their mobile phones (Interview Q16), 20.0% of interviewees indicated that they would like to simplify the menus on their cell phones. 20.0% of interviewees suggested an alphabetical index of all features.

Two interviewees responded to an interview question with anecdotes in support of this heuristic:

1. One interviewee indicated that menus are “not self-explanatory and options are buried within sub-menus” (Interview Q16)
2. One interviewee stated that there is “a lot of jargon, many words that I don’t know the meaning of” in menus (Interview Q16)

<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Supp -ort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended</td>
<td>Interview Q16. How would you improve the menus in your mobile phone?</td>
<td>One or more anecdotes related to improving menus</td>
<td>2 supporting anecdotes</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mention of features that would leverage mental models familiar to older adults</td>
<td>- 20.0% wanted an alphabetical index of all features</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- 20% wanted simpler menus</td>
<td></td>
</tr>
<tr>
<td>Likert</td>
<td>Survey Q17. How satisfied are you with the operation of your cell phone?</td>
<td>Over 50% not satisfied with characteristic related to a heuristic</td>
<td>22.9% of respondents were &quot;neutral&quot;, &quot;not satisfied&quot;, and &quot;very unsatisfied&quot;</td>
<td>-</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank suggestions in order of greatest improvement: - Simplify the menus (+8 other options)</td>
<td>Over 11.1% of survey respondents indicating “simplified menus” as the most important improvement of cell phone operation</td>
<td>52.8% of respondents indicated that simplified menus were the most important change</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank suggestions in order of greatest improvement: - Use language that’s easier to understand in menus (+8 other options)</td>
<td>Over 11.1% of survey respondents indicating “using language that’s easier to understand in menus” as the most important improvement of cell phone operation</td>
<td>47.1% of respondents indicated language that's easier to understand in menus is the most important change</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank suggestions in order of greatest improvement: - Provide a list of frequently used features (+8 other options)</td>
<td>Over 11.1% of survey respondents indicating “providing a list of frequently used features” as the most important improvement of cell phone operation</td>
<td>34.4% of respondents selected list of frequently used features was the most important change</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank suggestions in order of greatest improvement: - Provide an alphabetical list of all features (+8 other options)</td>
<td>Over 11.1% of survey respondents indicating “providing an alphabetical list of features” as the most important improvement of cell phone operation</td>
<td>25.5% of respondents selected an alphabetical list of all features as the most important change</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4.16 - Summary of support for MEM3 - leverage mental models familiar to older adults
Survey: Over half of respondents who were not satisfied with the operation of their cell phone wanted simpler menus, two thirds showed preference for a list of frequently used features and a quarter for an alphabetical list of all features.

It was expected that the majority of older adults would not be satisfied with the operation of their cell phones. Surprisingly, 77.1% of respondents were satisfied (Survey Q17). Of the respondents who were not satisfied, 52.8% indicated that simplified menus were the most important change that would improve the operation of their cell phones (Survey Q18). 47.1% indicated preference for more understandable language in menus, 34.4% for a list of frequently used features and 25.5% for an alphabetical list of all features as the most important changes. These findings serve as support for heuristic MEM3 - leverage mental models familiar to older adults.

Age Related Analysis: It was expected that satisfaction with cell phone operation would decrease with age, but the difference was not statistically significant (Survey Q17, Fisher's (N=170), p=.716). The preference for simplified menus (Survey Q18, Fisher's (N=36), p=1.000), language that's easier to understand in menus (Survey Q18, Fisher's (N=34), p=0.300), list of frequently used features (Survey Q18, Fisher's (N=32), p=1.000) and alphabetical list of all features (Survey Q18, Fisher's (N=32), p=1.000) were also not statistically significant between 50-59 year olds and 60-74 year olds who were not satisfied with the operation of their cell phones.

Discussion: The results of interviews and the survey support the recommendation that mental models familiar to older adults should be leveraged to minimize the amount of learning required to use a cell phone. It was expected that older adults would indicate preference for simpler menus and that they would like them to be easier to learn, navigate and recall, as indicated by an earlier study of cell phone usage by older adults (Kurniawan, 2008). The survey questions related to menu simplification and two related features were preceded with a filter question about satisfaction with phone operation (Survey Q 17), which could have been misleading. More direct survey questions gauging respondent satisfaction
with menu operation and the ability to easily find frequently used features could have resulted in stronger support for this heuristic.

**MEM4 - Use clear text instead of pictorial stimuli to relay information**

*Overview:* Strong support for this heuristic was found in 4 anecdotes and 4 interview and survey questions.

*Interviews:* More than half of interviewees did not find their cell phone UI’s easy to use at all times and provided negative feedback concerning icons. 4 anecdotes related to confusing icons were also observed.

When asked whether interviewees find their cell phone UI’s easy to use (Interview Q31), 50.0% responded negatively and 10.0% of interviewees only found it sometimes easy to use. Four interviewees provided negative anecdotes related to UI icons:

- “Hard to understand what certain menu icons mean” (Interview Q31)
- “Hard to figure out the icons” (Interview Q31)
- “Don’t know what the icons mean” (Interview Q31)
- “[They don’t] have a clue what the icons stand for” (Interview Q31)

When asked how interviewees would improve the UI’s on their cell phones (Interview Q32), two provided feedback related to icons:

- “icons that are recognizable”
- “fewer icons”

When asked how older adults would improve menus in their mobile phones (Interview Q16), one interviewee indicated that they would find text descriptions beside icons helpful.
<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended</td>
<td>Interview Q16. How would you improve the menus in your mobile phone?</td>
<td>One or more anecdotes supporting the use of text instead of pictorial stimuli</td>
<td>4 anecdotes related to confusing icons</td>
<td>+</td>
</tr>
<tr>
<td>Direct</td>
<td>Interview Q31. Do you find the interface on your mobile phone easy to use?</td>
<td>Mention of replacing pictorial stimuli with text</td>
<td>One interviewee indicated that they would find text descriptions beside icons helpful</td>
<td>+</td>
</tr>
<tr>
<td>Open-ended</td>
<td>Interview Q32. How would you improve the interface on your mobile phone?</td>
<td>Mention of using less pictorial stimuli to relay information</td>
<td>- 10% of interviewees preferred “icons that are recognizable”</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank the suggestions below in order of greatest improvement: - Use less icons and more text (+8 other options)</td>
<td>Over 11.1% of survey respondents indicating “use less icons and more text” as the most important improvement</td>
<td>15.6% of respondents preferred less icons and more text as the most important improvement of cell phone operation</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q18. Select any of the following that would improve the operation of your cell phone. Rank the suggestions below in order of greatest improvement: - Provide descriptive textual labels beside icons (+8 other options)</td>
<td>Over 11.1% of survey respondents indicating “provide descriptive textual labels beside icons” as the most important improvement</td>
<td>11.8% of respondents indicated preference for descriptive textual labels beside icons as the most important improvement</td>
<td>+</td>
</tr>
</tbody>
</table>

**Table 4.17 - Summary of support for heuristic MEM4 - use clear text instead of pictorial stimuli to relay information**

Survey: Close to one in six respondents wanted less icons and more text and over one in ten showed preference for text beside icons.
Of the respondents who were not satisfied with the operation of their cell phone, 15.6% indicated preference for less icons and more text as the most important change (Survey Q18). 11.8%% indicated preference for descriptive textual labels beside icons (Survey Q18).

**Age Related Analysis:** It was expected that preference for less icons and more text would increase with age, but the difference was not statistically significant (Survey Q18, Fisher's ($N=32), p=1.000$). The preference for descriptive textual labels beside icons (Survey Q18, Fisher's ($N=34), p=1.000$) was also not statistically significant between 50-59 year olds and 60-74 year olds who were not satisfied with the operation of their cell phones.

**Discussion:** Based on the feedback from interviews and survey results, mobile phone designers can make UI’s more usable for older adults by proving text instead of pictorial stimuli such as icons to relay information. This change could help mitigate deficiencies in working memory related to remembering pictorial stimuli observed in older adults. To further validate this heuristic, usability testing could be used to determine whether task performance of older adults varies between icon-based UI’s and text-based UI’s.

### 4.3.6 Support for Motor Control Heuristics

The heuristics in this section are related to the negative impact aging has on motor control (see section 3.5.10 for a full description of each motor control heuristic). The support for the proposed motor control heuristics found in interviews and the survey is summarized in Table 4.18, and the support for each of the heuristics is detailed in the following heuristic-named subsections.

<table>
<thead>
<tr>
<th>Motor Control Heuristic</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOT1 - Enlarge the size of keyboards, physical buttons and target areas</td>
<td>+</td>
</tr>
</tbody>
</table>

*Table 4.18 - Summary of support for motor control heuristics*
MOT1 – Enlarge the size of keyboards, physical buttons and target areas

**Overview:** Strong support for this heuristic was found in 4 anecdotes and 4 interview and survey results.

**Interviews:** Over two thirds of interviewees didn’t find the keyboard easy to use and over a third mentioned increasing key size to improve the keyboard.

When interviewees were asked whether they found the keyboard on their mobile phone easy to use, 70.0% of the interviewees responded negatively (Interview Q23), with 40.0% suggesting enlarging key size to improve the keyboard (Interview Q24). Two anecdotes further support this observation:

- “If the keyboard was a little bigger, I would be able to manage it better” (Interview Q23)
- “I have to be really careful where I push my thumbs” (Interview Q23)

Two additional anecdotes were found when interviewees were asked what they disliked about their mobile phones; 20.0% found the keyboard too small (Interview Q7).
<table>
<thead>
<tr>
<th>Question Type</th>
<th>Question</th>
<th>Criteria for Support</th>
<th>Result</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Interview Q23. Do you find the keyboard on your mobile phone easy to use?</td>
<td>One or more anecdotes supporting increased size of keyboards, physical buttons and target areas</td>
<td>4 anecdotes related to small keyboard size</td>
<td>+</td>
</tr>
<tr>
<td>Open-ended</td>
<td>Interview Q24. How would you improve the keyboard on your mobile phone?</td>
<td>Over 50% disagreement</td>
<td>70.0% of the interviewees did not find the keyboard on their mobile phone easy to use</td>
<td>+</td>
</tr>
<tr>
<td>Likert</td>
<td>Survey Q22. If your cell phone has a physical keyboard, how satisfied are you with it?</td>
<td>Over 50% of interviewees indicating that they are not satisfied with the physical keyboard on their cell phones</td>
<td>54.7% of respondents were &quot;neutral&quot;, &quot;not satisfied&quot;, and &quot;very unsatisfied&quot; with the physical keyboard on their cell phone</td>
<td>+</td>
</tr>
<tr>
<td>Rank order</td>
<td>Survey Q23. How would you improve your current cell phone keyboard? Rank your choices in order of greatest improvement - Increase key size (+ 4 other options)</td>
<td>Over 20% of survey respondents indicating “Increase key size” as the most important improvement of cell phone keyboard</td>
<td>71.1% indicated that increasing key size was the most important change that would improve the keyboard</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 4.19 - Summary of support for heuristic MOT1 – enlarge the size of keyboards, physical buttons and target areas

Survey: Over half of respondents were dissatisfied with physical keyboards on their mobile phones and more than two thirds cited increasing key size as the most important change.

It was expected that the majority of older adults would not be satisfied with physical keyboards on their mobile phones. Surprisingly, 45.3% of respondents were satisfied with physical keyboards (Survey Q22).
Of the respondents who were not satisfied, 71.1% indicated that increasing key size was the most important change that would improve the keyboard (Survey Q23).

**Age Related Analysis:** It was expected that satisfaction with physical keyboards would decrease with age, but the difference between 50-59 year olds and 60-74 year olds was not statistically significant (Survey Q22, Fisher’s ($N=106$), $p=.697$). The difference preference for increased key size (Survey Q23, Fisher's ($N=45$), $p=1.000$) was also not statistically significant between 50-59 year olds and 60-74 year olds who were not satisfied with their physical keyboards.

**Discussion:** The results of interviews and survey support the recommendation that the size of keyboards, physical buttons and target areas should be enlarged to address age-related impairments in motor control, muscular coordination, strength and tactile sensitivity. An overwhelming number of interviewees were dissatisfied with physical keyboards and many of them suggested increasing key size as a way to improve them. These findings were further validated with a large portion of respondents unsatisfied with physical keyboards, two-thirds of whom suggested increasing key size. These findings could be validated by future studies to determine the preferred size of keys on physical and virtual keyboards for older adults.
5 Conclusions and Future Work

The research conducted in this study serves as a good start to validating the proposed smartphone evaluation heuristics. Noteworthy findings, suggested technique improvements and future work are described in the sections that follow.

5.1 Findings

Interviews and surveys yielded support for 8 of 9 heuristics evaluated in this study. The process of creating heuristics based on a review of age-related literature, and then finding support for them with older adults through the use of interviews and surveys proved to be effective. The methods used in this thesis were found to be effective in evaluating heuristics in a timely and cost-efficient way when compared to usability testing. The interview recruitment and facilitation proved to be a quick and inexpensive method for uncovering age-related issues in smartphones. Finding support for the heuristics with a larger group of older adults was well served by an online survey.

When examining the differences between groups of older adults (50-59 and 60+) the survey showed statistically significant results in questions related to phone configurations and usage patterns, but only in one question related to heuristics.

This finding may imply that there are few age-related differences between older adults over the age of 50 and that the proposed heuristics are equally beneficial for 50-59 year olds and 60+ year olds. It could also mean that our sample size was inadequate, or that changes are more prevalent either below or above these two age groups. For example, age-related deficiencies related to cell phone usage may manifest themselves prior to the age of 40 and by the age of 50 older adults learn how to accommodate for these changes.
5.2 Additional Findings

Although this thesis focused on finding support for the proposed heuristics, important factors related to cell phone design for older adults were uncovered. The findings were related to phone configurations, usage patterns and motivations for use.

Phone Configurations

The majority of interviewees (90.0%) and a considerable portion of respondents who owned phones with physical keyboards owned flip phones (42.9%). It was observed that a higher percentage of older respondents (53.1%) were flip phone owners than the younger respondents (32.3%). Since this difference was statistically significant according to Fisher’s exact test of independence (Fisher’s (N=126), \( p=0.020 \)), one can infer that older adults are more likely to own flip phones than younger adults. These findings should be considered in smartphone design, since flip phone usually contain less features than other form factors. Flip phones also serve as a physical switch for answering and ending calls, offer protection from dialling numbers accidentally and to protect the screen when not in use.

Another factor that should be considered in cell phone design for older adults is the fact that the majority of older interviewees (80.0%) used reading glasses when operating cell phones and more than half of the survey respondents (50.6%) put on or took off glasses to use their phones more comfortably. One interviewee indicated that they would have trouble seeing the screen and another that he tends to be inaccurate without glasses. These findings combined with the fact that the majority of interviewees and respondents described their cell phones as small and showed preference for increased screen size should be considered when designing cell phones for an older audience.

Usage Patterns

It was observed that a higher percentage of older adults owned their cell phones longer than 3 years (47.1%) than younger adults (32.9%). Since this difference was approaching significance according to Pearson’s Chi-Squared Test of Independence (Pearson’s Chi-Squared (N=170), \( p=0.121 \)), we can infer that
older adults are more likely to own cell phones longer than younger adults. Since older adults are less likely to replace their cell phones with new models regularly, products for this audience should be designed with durability and longevity in mind.

A considerable portion of interviewees used their cell phones 1-2 times a week (30%). It was also observed that a larger portion of older adults (42.3%) than younger adults (23.5%) use their cell phones less than an hour in a typical week. Since this difference was statistically significant, (Pearson’s Chi-Squared (N=170), \( p = .013 \)), we can infer that older adults are more likely than younger adults to use their cell phones infrequently on a weekly basis. The implication of this finding is that smartphones should be designed in a usable way that accommodates for frequent re-learning of common operations.

**Motivations for Use**

An overwhelming number of survey respondents (90.0%) reported emergency communications as an important motivation for cell phone usage. It was observed that a third of respondents indicated preference for easily accessible shortcuts to emergency contacts. Cell phone designers could address this finding by providing older adults with easy accessible emergency shortcuts and perhaps even enabling strangers who find a cell phone owner unconscious to get in touch with their close ones.

**5.3 Improving Methodology**

The techniques used to validate the proposed heuristics could be improved to yield more powerful results. A summary of suggested improvements follows.

**Survey Sample size and Age Groups**

The survey used in Phase 2 was designed to validate interview findings with a larger population of older adults. The survey question used 5 age groups (50-54, 55-59, 60-64, 65-69 and 70-74). Since there were only 4 respondents 75 or older, their responses were discarded, because there was not enough data to compare their results to younger age groups. A Chi-Squared test of independence was used to analyze
age-related differences based on the 5 group and significance was found in only a few questions. This is likely due to low number of responses for each group.

A second evaluation took all age groups (50-54, 55-59, 60-64, 65-69 and 70-74, 75+) and split them into two larger groups; less than 60 years old and greater than 60. Fisher’s exact test of independence was then used for questions falling within the 2x2 matrices and Pearson’s Chi Squared Test of Independence was used to analyze questions with matrices larger than 2x2 (Appendix E contains a list of all online survey questions along with the significance levels for the corresponding age-related analyses).

Out of 6 survey questions related to usage patterns, 3 age-related correlations were statistically significant and 2 approached significance. Out of 6 questions related to phone configurations, 1 age-related correlation was found to be statistically significant and 1 approached significance. Surprisingly, an age-related correlation that approached significance was found in only 1 out of 10 questions related to the proposed heuristics. Age-related correlation that approached significance was found in 1 question related to vision heuristics, but significance was not found between the answers of younger and older respondents related to auditory, memory or motor control heuristics. Lack of significance in age-related correlations could be tied to the age groups used in the study.

A survey that includes both younger (<50) and older adults (>75) may provide evidence of when the heuristics become most useful. Age-related differences between these two groups of adults could prove to be more pronounced and they could help demonstrate age-related differences between younger adults and older adults.

**Survey Question Structure**

The use of heavy handed filter questions in the survey contributed to a decreased sample size in a large number of questions related to heuristics. For example, in Survey Q15, respondents were asked about their satisfaction with the visibility of the screen on their cell phone. Only participants, who indicated
that they were very unsatisfied, unsatisfied, or neutral, were allowed to proceed to Survey Q16. In this question, participants were asked to rank suggestions that would improve the screen on their cell phone. The filter applied in Survey Q15 resulted in a small sample size in Survey Q16, which in turn contributed to the lack of significance between the results of younger and older adults. A larger portion of older participants was expected to be dissatisfied with visibility of cell phone screens. A larger number of respondents and less heavy handed filters would yield larger numbers and possible significance. For example, instead of asking participants about their satisfaction with visibility of screen (Survey Q15) before asking for suggestions on improvement, these questions could be asked independently. Similarly filters in Survey Q17 (operation satisfaction), Survey Q20 (challenges with hearing cell phone sounds), Survey Q22 (physical keyboard satisfaction) could have resulted in less statistically significant results.

5.4 Future work
The techniques used to show support for the proposed heuristics in this thesis included interviews and surveys. Different usability evaluation techniques should be used to show support for the remaining 10 untested evaluation heuristics. Future studies should reflect the unique challenges experienced by older adults in the mobile context of use. For example, the attention and memory heuristics could be evaluated in realistic settings with older adults performing tasks while walking down a busy street with the researcher observing their performance. In addition, ethnographic studies of older adults could prove useful in documenting issues for older adults and potentially show support for the proposed heuristics.

Applicability of Smartphone Evaluation Heuristics
Evaluation heuristics developed in this thesis might be applicable to a wider range of devices and users than originally anticipated. Additional work should be conducted to determine the applicability of our heuristics to mobile devices including tablets, laptops and portable electronics. Smartphone evaluation
heuristics for older adults could be beneficial to younger disabled users affected by issues not directly related to ageing. These could include persons younger than 50 with loss of vision, hearing, cognitive function and motor control. Further work should be conducted to determine the value of the age-related smartphone evaluation heuristics to people with disabilities, as well as able users in cognitively demanding contexts, such as when using a mobile device while performing other tasks.

**Support for Heuristics in Accessibility Literature**

Since the age-related smartphone evaluation heuristics developed in this thesis might be applicable to disabled users, future studies should focus on evaluating support for heuristics within the disabilities literature. A preliminary review of two web accessibility guidelines by Caldwell, Cooper, Reid & Vanderheiden (2008) and Theofanos & Redish (2003) suggests that our heuristics could be related (see Table 5.1 and Table 5.2 respectively).

<table>
<thead>
<tr>
<th>Guideline for Accessible and Usable Web Sites</th>
<th>Related Smartphone Evaluation Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideline 4. Make the site structure clear and obvious</td>
<td>MEM2 - Clearly present task status at all times</td>
</tr>
<tr>
<td>Guideline 7. Do not make up unusual names for products, services, or elements of a Web site</td>
<td>MEM3 - Leverage mental models familiar to older adults</td>
</tr>
<tr>
<td>Guideline 16. Make sure that the keywords are not in images</td>
<td>MEM4 - Use clear text instead of pictorial stimuli to relay information</td>
</tr>
</tbody>
</table>

*Table 5.1 - Support for smartphone evaluation heuristics for older adults in Guidelines for Accessible and Usable Web Sites (Theofanos & Redish, 2003)*
Table 5.2 - Support for smartphone evaluation heuristics for older adults in Web Content Accessibility Guidelines (WCAG) 2.0 (Caldwell et al., 2008)

<table>
<thead>
<tr>
<th>WCAG 2.0 Guideline</th>
<th>Related Smartphone Evaluation Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideline 1.1 Text Alternatives: Provide text alternatives for any non-text content so that it can be changed into other forms people need, such as large print, braille, speech, symbols or simpler language</td>
<td>VIS2 - Expand size of text and UI elements</td>
</tr>
<tr>
<td>Guideline 1.4 Distinguishable: Make it easier for users to see and hear content including separating foreground from background 1.4.1 Use of Color: Color is not used as the only visual means of conveying information, indicating an action, prompting a response, or distinguishing a visual element</td>
<td>VIS5 - Avoid the use of colour to relay information</td>
</tr>
<tr>
<td>1.4.3 Contrast (Minimum): The visual presentation of text and images of text has a contrast ratio of at least 4.5:1</td>
<td>VIS3 - Increase text and image contrast</td>
</tr>
<tr>
<td>1.4.8 Visual Presentation: 1. Foreground and background colors can be selected by the user</td>
<td>ATT2 - Minimize UI clutter and avoid extraneous details</td>
</tr>
<tr>
<td>2.2.1 Timing Adjustable: For each time limit that is set by the content, at least one of the following is true: Turn off: The user is allowed to turn off the time limit before encountering it</td>
<td>MOT2 - Avoid the use of interaction timeouts</td>
</tr>
<tr>
<td>Guideline 2.3 Seizures: Do not design content in a way that is known to cause seizures 2.3.1 Three Flashes or Below Threshold: Web pages do not contain anything that flashes more than three times in any one second period, or the flash is below the general flash and red flash thresholds</td>
<td>VIS6 - Avoid the use of animation and fast-moving objects</td>
</tr>
<tr>
<td>Guideline 2.4 Navigable: Provide ways to help users navigate, find content, and determine where they are 2.4.8 Location: Information about the user’s location within a set of Web pages is available</td>
<td>MEM3 - Leverage mental models familiar to older adults</td>
</tr>
</tbody>
</table>

Relationship between smartphone evaluation heuristics and web accessibility guidelines suggests that future work should be conducted to determine whether the heuristics developed in this thesis are of value to disabled users.

Support for Smartphone Evaluation Heuristics in Technology Guidelines

Support for heuristics developed in this thesis should be further evaluated in technology guidelines.

Preliminary research suggests that there is limited support for smartphone evaluation heuristics in in web design and usability guidelines, as well as usability heuristics and UI guidelines. Nielsen’s 10 Usability heuristics (Nielsen, 2005), Shneiderman’s 8 Golden Rules of Interface Design (Shneiderman &
Plaisant, 2009) and Research-Based Web Design & Usability Guidelines by (Leavitt & Shneiderman, 2006) were analyzed for factors related to aging. A summary of support for smartphone evaluation heuristics can be found in Table 5.3 - Table 5.5.

<table>
<thead>
<tr>
<th>Nielsen’s Usability Heuristic</th>
<th>Related Smartphone Evaluation Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility of system status</td>
<td>MEM2 - Clearly present task status at all times</td>
</tr>
<tr>
<td>Match between system and the real world</td>
<td>MEM3 - Leverage mental models familiar to older adults</td>
</tr>
<tr>
<td>Recognition rather than recall</td>
<td>MEM1 - Use single task interaction instead of multitasking whenever possible</td>
</tr>
</tbody>
</table>

Table 5.3 - Support for smartphone evaluation heuristics for older adults in Nielsen’s Usability Heuristics (Nielsen, 2005)

<table>
<thead>
<tr>
<th>Shneiderman’s Golden Rule of Interface Design</th>
<th>Related Smartphone Evaluation Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offer informative feedback</td>
<td>MEM2 - Clearly present task status at all times</td>
</tr>
<tr>
<td>Design dialog to yield closure</td>
<td>MEM3 - Leverage mental models familiar to older adults</td>
</tr>
<tr>
<td>Reduce short-term memory load</td>
<td>MEM1 - Use single task interaction instead of multitasking whenever possible</td>
</tr>
</tbody>
</table>

Table 5.4 - Support for smartphone evaluation heuristics for older adults in Shneiderman’s Golden Rules of Interface Design (Shneiderman & Plaisant, 2009)
Table 5.5 - Support for smartphone evaluation heuristics for older adults in Research-Based Web Design & Usability Guidelines (Leavitt & Shneiderman, 2006)

Based on the preliminary support for age-related smartphone evaluation heuristics in web design and usability guidelines, as well as usability heuristics and UI guidelines, further work to evaluate support in detail should be conducted.

Interdependencies between Heuristics
Future work should focus on determining interdependencies between the proposed heuristics. For example, heuristics "VIS4 - Allow users to fine-tune screen brightness and contrast" and "AUD2 - Allow users to fine-tune volume level of auditory cues" are both related to giving users more control. This suggests that both heuristics could be dependent. Future work should concentrate on determining relationships between heuristics and making them independent of each other.

Impact of Education and Technology Experience on Heuristics
O’Brien, Rogers and Fisk (2012) state that “prior knowledge in a target user population” must be understood by technology designers in order to encourage adoption and effective use of technology. Researchers found that knowledge users’ familiarity with similar technologies may be helpful in
designing products easy to use with a minimal amount of training and instruction (Blackler, Popovic, & Mahar, 2003; O’Brien et al., 2012; Polson & Lewis, 1990). The impact of a person’s education and experience with technology and specifically mobile devices on the proposed heuristics should be explored in future studies.

**Utility of Age-Related Smartphone Evaluation Heuristics for Target Audience**
The usefulness of heuristics to the target audience should be studied. To determine how valuable the proposed heuristics are to usability practitioners and cell phone designers, both groups should be asked to use them to evaluate the usability of existing products for older adults. These studies would help determine which heuristics are most feasible and which ones would prove hard to apply.

**Increasing Awareness of Age-Related Issues in Design**
Techniques of disseminating the heuristics should be used to create awareness of age-related issues in design amongst the target audience. They include publishing papers on the subject, maintaining a blog to evaluate current smartphone designs and facilitating smartphone design workshops.

This study resulted in a set of smartphone evaluation heuristics for older adults. Future work should focus on validating the proposed heuristics and increasing awareness of age-related issues amongst usability practitioners and designers.
6 References


Vanderheiden, G. C., & Vanderheiden, K. R. (1991). *Accessible design of consumer products: Guidelines for the design of consumer products to increase their accessibility to people with disabilities or who are aging*. Madison, WI, USA: Trace R & D Center.


Appendix A  Heuristic Support in Guidelines

Smartphone design guidelines were analyzed for age-related factors. Support for proposed smartphone evaluation heuristics was included at the end of each section corresponding to the related heuristic (2.4.1 – 2.4.9).

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Focus and Audience:</th>
<th>Referenced Age-Related Factors</th>
</tr>
</thead>
</table>
| uXd Style Guide (AT&T Mobility, 2008) | 6 universal design principles with examples of real-world scenarios and references to mobile devices that follow best practices. Intended audience includes mobile device manufacturers and UI designers. | • Vision  
• Memory                                          |
| iOS Human Interface Guidelines (Apple, 2012) | Human interface design principles to create usable UI’s and optimized user experiences for iPhone applications. Intended audience includes iPhone application developers. | • Attention  
• Memory  
• Motor control                                     |
• Memory  
• Motor control                                     |
| User Experience Design Guidelines for Windows Phone (Microsoft, 2012) | Mobile app design principles for the mobile context of use. Intended audience includes user interaction designers and mobile app developers. | • Vision  
• Attention  
• Memory  
• Motor control                                     |
Appendix B  Heuristics Not Evaluated

The methods used in this thesis did not allow for all of the proposed smartphone heuristics to be evaluated. Heuristics that will have to be tested using alternative methods as part of a follow-up study are listed below.

<table>
<thead>
<tr>
<th>Age-Related Factor</th>
<th>Heuristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>VIS5 - Avoid the use of colour to relay information</td>
</tr>
<tr>
<td></td>
<td>VIS6 - Avoid the use of animation and fast-moving objects</td>
</tr>
<tr>
<td>Attention</td>
<td>ATT1 - Minimize the need to actively monitor two or more tasks</td>
</tr>
<tr>
<td></td>
<td>ATT2 - Minimize UI clutter and avoid extraneous details</td>
</tr>
<tr>
<td></td>
<td>ATT3 - Disable inactive UI objects</td>
</tr>
<tr>
<td>Memory</td>
<td>MEM1 - Use single task interaction instead of multitasking whenever possible</td>
</tr>
<tr>
<td></td>
<td>MEM2 - Clearly present task status at all times</td>
</tr>
<tr>
<td>Motor control</td>
<td>MOT2 - Avoid the use of interaction timeouts</td>
</tr>
<tr>
<td></td>
<td>MOT3 - Allow user to adjust the position of limb before executing an action</td>
</tr>
<tr>
<td></td>
<td>MOT4 - Provide strong tactile and auditory feedback upon executing an operation</td>
</tr>
</tbody>
</table>
### Appendix C  User Interview Questions

#### Demographics

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. What is your age?</td>
<td>Establish demographic breakdown of participants</td>
</tr>
<tr>
<td></td>
<td>Ensure that only participants 50 years old or older are permitted to</td>
</tr>
<tr>
<td></td>
<td>complete the survey</td>
</tr>
<tr>
<td>Q2. What is your occupation?</td>
<td>Establish vocation of participants</td>
</tr>
</tbody>
</table>

#### Usage Patterns and Motivations

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
<th>Related Heuristic(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3. What kind of mobile phone do you currently own?</td>
<td>Determine the type and complexity of device used by participant</td>
<td>None</td>
</tr>
<tr>
<td>Q4. How frequently do you use your mobile phone?</td>
<td>Establish frequency of use</td>
<td>None</td>
</tr>
<tr>
<td>Q5. What do you use your mobile phone for?</td>
<td>Establish the motivation for mobile phone use by older adults</td>
<td>None</td>
</tr>
</tbody>
</table>
### Features

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
<th>Related Heuristic(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q6. What do you like best about your mobile phone?</td>
<td>Establish preferences and usage goals</td>
<td>Potentially any of the proposed heuristics</td>
</tr>
<tr>
<td>Q7. What do you dislike about your mobile phone?</td>
<td>Establish how mobile device design could be improved to better address the needs of older adults</td>
<td>Potentially any of the proposed heuristics</td>
</tr>
<tr>
<td>Q8. Describe the features that you frequently use.</td>
<td>Establish functional preferences for mobile phones</td>
<td>None</td>
</tr>
<tr>
<td>Q9. Are there features you don't use?</td>
<td>Establish functional preferences for mobile phones</td>
<td>None</td>
</tr>
<tr>
<td>Q10. What functions of your mobile phone do you find difficult to use?</td>
<td>Determine which functions could be redesigned to better suit the needs of older adults</td>
<td>None</td>
</tr>
<tr>
<td>Q11. How frequently do you send or receive text messages?</td>
<td>Establish frequency of use for more advanced features</td>
<td>None</td>
</tr>
<tr>
<td>Q12. Have you ever searched the web for information on your mobile phone?</td>
<td>Establish interest in mobile internet usage amongst older adults</td>
<td>None</td>
</tr>
<tr>
<td>Q13. Have you ever downloaded any ringtones, wallpapers or games on your mobile phone?</td>
<td>Establish whether older adults are interested in customizing their mobile phones</td>
<td>None</td>
</tr>
<tr>
<td>Q14. Are there any additional features that you would like your mobile phone to have in order for it to be better suited to your needs?</td>
<td>Establish whether there are features that older adults would like to have on their mobile phones</td>
<td>Potentially any of the proposed heuristics</td>
</tr>
<tr>
<td>Question</td>
<td>Goal</td>
<td>Related Heuristic(s)</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Q15. Do you find the menus in your mobile phone easy to navigate?</td>
<td>Establish whether older adults can navigate mobile phone menus with ease</td>
<td>None</td>
</tr>
<tr>
<td>Q16. How would you improve the menus in your mobile phone?</td>
<td>Determine how menus can be redesigned to make them easier to use for older adults.</td>
<td>MEM3 MEM4</td>
</tr>
<tr>
<td>Q17. Do you use shortcuts on your mobile phone?</td>
<td>Determine whether older adults use shortcuts</td>
<td>None</td>
</tr>
<tr>
<td>Q18. What functions would you like to have easily accessible shortcuts for?</td>
<td>Establish which mobile phone functions should be made easily accessible for older adults</td>
<td>None</td>
</tr>
<tr>
<td>Q19. Do you frequently use on-device help on your mobile phone?</td>
<td>Determine whether older adults search for help on device</td>
<td>None</td>
</tr>
<tr>
<td>Q20. Do you find it easy to find help related to a particular task that you're performing on your mobile phone?</td>
<td>Establish if users easily find on-device help aids</td>
<td>None</td>
</tr>
<tr>
<td>Q21. Do you feel that you understand what your mobile phone is doing at all times?</td>
<td>Establish if users are aware of what tasks their mobile phone is performing at all times</td>
<td>None</td>
</tr>
</tbody>
</table>
## Physical Design

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
<th>Related Heuristic(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q22. Describe the size and shape of your mobile phone.</td>
<td>Determine the physical features of mobile phones used by older adults</td>
<td>None</td>
</tr>
<tr>
<td>Q23. Do you find the keyboard on your mobile phone easy to use?</td>
<td>Determine whether older adults have trouble using the keyboard on their mobile phones</td>
<td>MOT1</td>
</tr>
<tr>
<td>Q24. How would you improve the keyboard on your mobile phone?</td>
<td>Establish how keyboard design could be improved to better suit the needs of older adults</td>
<td>MOT1</td>
</tr>
<tr>
<td>Q25. Have you ever used a mobile phone with a touch-screen interface?</td>
<td>Determine whether older adults are interested in devices with touch-screen UI's</td>
<td>None</td>
</tr>
<tr>
<td>Q26. If yes, then what were your impressions of a touch-screen interface?</td>
<td>Establish the positive and negative aspects of touch-screen UI’s for older adults</td>
<td>None</td>
</tr>
<tr>
<td>Q27. Do you use reading glasses when using your mobile phone?</td>
<td>Establish whether older adults wear glasses when operating mobile phones</td>
<td>None</td>
</tr>
<tr>
<td>Q28. Do you find the text size large enough to read comfortably on your mobile phone?</td>
<td>Establish whether text size on mobile phone screens is large enough for older adults</td>
<td>VIS2</td>
</tr>
<tr>
<td>Q29. Did you ever find it difficult to see the screen on your mobile phone in certain environments?</td>
<td>Establish whether older adults can easily see mobile phone displays in all lighting conditions</td>
<td>VIS3 VIS4</td>
</tr>
<tr>
<td>Q30. How would you improve the screen on your mobile device?</td>
<td>Determine how older adults would improve mobile phone displays</td>
<td>VIS1 VIS3 VIS4</td>
</tr>
<tr>
<td>Q31. Do you find the interface on your mobile phone easy to use?</td>
<td>Establish whether older adults can use mobile phone UI’s with ease</td>
<td>MEM4</td>
</tr>
<tr>
<td>Q32. How would you improve the interface on your mobile phone?</td>
<td>Determine if mobile phone UI’s can be improved to better suit the needs of older adults</td>
<td>VIS2 MEM4</td>
</tr>
<tr>
<td>Q33. Did you ever find it difficult to hear the sound on your mobile device?</td>
<td>Establish if there are situations in which older adults find it difficult to hear the sound on their mobile phones</td>
<td>AUD1 AUD2</td>
</tr>
<tr>
<td>Q34. How would you improve the sound on your mobile device?</td>
<td>Determine if sounds on mobile phones could be improved to better suit the needs of older adults</td>
<td>AUD1 AUD2</td>
</tr>
</tbody>
</table>
## Interactive Tasks

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q35. Can you show me an <em>easy</em> task that you have to perform on a regular basis?</td>
<td>Establish common tasks that are easy</td>
</tr>
<tr>
<td>Q36. Can you show me a <em>hard</em> task that you have to perform on a regular basis?</td>
<td>Establish common tasks that are hard</td>
</tr>
<tr>
<td>Q37. Can you show me an <em>easy</em> task that you don't have to do on a regular basis?</td>
<td>Establish discretionary tasks that are easy</td>
</tr>
<tr>
<td>Q38. Can you show me a <em>hard</em> task that you don't have to do on a regular basis?</td>
<td>Establish discretionary tasks that are hard</td>
</tr>
</tbody>
</table>
## Appendix D  Key Interview Findings and Related Survey Questions

<table>
<thead>
<tr>
<th>Interview Result</th>
<th>Related Survey Question(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.0% owned flip phones</td>
<td>Q6 - Is your cell phone a flip phone?</td>
</tr>
<tr>
<td></td>
<td>Q9 - Is your cell phone a regular cell phone or a smartphone?</td>
</tr>
<tr>
<td>30.0% use cell phone 1-2 times per week</td>
<td>Q11 - In a typical week, for approximately how long do you use your cell phone in total?</td>
</tr>
<tr>
<td>Frequently used features:</td>
<td>Q12 - Please indicate which of the following cell phone features listed you use:</td>
</tr>
<tr>
<td>- 40.0% address book</td>
<td>- Phone</td>
</tr>
<tr>
<td>- 30.0% texting</td>
<td>- Internet</td>
</tr>
<tr>
<td>- 30.0% call history</td>
<td>- Email</td>
</tr>
<tr>
<td>- 30.0% speed dial</td>
<td>- Games</td>
</tr>
<tr>
<td>90.0% use phone for emergency purposes</td>
<td>- Maps / GPS</td>
</tr>
<tr>
<td></td>
<td>- Calendar</td>
</tr>
<tr>
<td></td>
<td>- Address book</td>
</tr>
<tr>
<td></td>
<td>- Texting</td>
</tr>
<tr>
<td>80.0% wore glasses when using cell phone</td>
<td>Q14 - In order to use the phone comfortably, do you do any of the following:</td>
</tr>
<tr>
<td></td>
<td>- Put on or take off glasses</td>
</tr>
<tr>
<td>70.0% found it difficult to hear cell phone</td>
<td>Q14 - In order to use the phone comfortably, do you do any of the following:</td>
</tr>
<tr>
<td></td>
<td>- Increase volume</td>
</tr>
<tr>
<td>30.0% did not find text size large enough</td>
<td>Q14 - In order to use the phone comfortably, do you do any of the following:</td>
</tr>
<tr>
<td></td>
<td>- Increase text size</td>
</tr>
<tr>
<td>10.0% disliked cell phone screen brightness</td>
<td>Q14 - In order to use the phone comfortably, do you do any of the following:</td>
</tr>
<tr>
<td></td>
<td>- Increase screen brightness</td>
</tr>
<tr>
<td>70.0% found it hard to see screen 40.0% found it hard to see screen a sunny environment</td>
<td>Q15 - How satisfied are you with the visibility of the screen on your cell phone?</td>
</tr>
<tr>
<td>80.0% increase size</td>
<td>Q16 - Which of the following would improve the screen on your cell phone? Rank the suggestions below in order of need of improvement:</td>
</tr>
<tr>
<td>30.0% increase contrast</td>
<td>- Increase screen size</td>
</tr>
<tr>
<td>10.0% wanted solid background colours</td>
<td>- Increase contrast</td>
</tr>
</tbody>
</table>
| 10.0% wanted night time colour scheme | - Improve visibility in sunny conditions  
- Improve visibility in low light conditions  
- Improve the use of colour |
| 30.0% found it hard to navigate menus  
20.0% wanted simpler menus  
20.0% wanted alphabetical index of all features  
10.0% wanted increased text size beside icons  
10.0% wanted text descriptions beside icons  
10.0% wanted plain, high contrast backgrounds | Q17 - How satisfied are you with the operation of your cell phone?  
Q18 - Select any of the following that would improve the operation of your cell phone. Rank the suggestions below in order of greatest improvement:  
- Simplify the menus  
- Use less icons and more text  
- Use language that's easier to understand in menus  
- Increase size of text  
- Increase size of icons  
- Provide descriptive textual labels beside icons  
- Provide a list of frequently used features  
- Provide an alphabetical list of all features  
- Use solid background colours instead of wallpapers |
| 30.0% found it hard to figure out icons  
10.0% found it hard to understand what certain menu icons meant in the beginning  
10.0% wanted more recognizable icons | Q19 - How easy is it to understand the icons and buttons on your cell phone? |
| 70.0% found it hard to hear sounds  
30.0% wanted louder ringtones  
30.0% wanted more control over volume  
10.0% wanted higher pitched ringtones  
10.0% wanted lower pitch ringtones | Q20. Do you find it difficult to hear your cell phone sounds?  
Q21. Select any of the following that would make it easier to hear the sounds on your cell phone. Rank your choices in order of greatest improvement:  
- Make it easier to adjust the volume  
- Louder ringtones  
- Higher pitched ringtones  
- Lower pitched ringtones |
| 30.0% wanted QWERTY keyboard  
20.0% found keyboard too small  
20.0% wanted slide out keyboard  
10.0% wanted bumps on cell phone keyboard  
10.0% wanted touchscreen keyboard | Q22 - If your cell phone has a physical keyboard, how satisfied are you with it?  
Q23 - How would you improve your current cell phone keyboard? Rank your choices in order of greatest improvement:  
- Increase key size  
- Replace physical keyboard with touchscreen keyboard  
- Add bumps to keys, in order to make it easier to distinguish between them  
- Provide slide-out keyboard  
- Provide PC-style QWERTY keyboard |
| 10.0% found the manual hard to read and did not find on-device help useful | Q24 - How satisfied are you with the user manual?  
Q25 - How would you improve the user manual? Rank your choices in order of greatest improvement:  
- Larger print text size  
- Less jargon  
- Improve index and table of contents |
- Improve visuals and diagrams
- Provide a quick start guide

| 50.0% did not use Internet on cell phones | Q26 - Do you surf the Internet on your cell phone?  
Q27 - Why don't you surf the Internet on your cell phone?  
Rank your choices in order of importance:  
  - Viewing Internet pages on a cell phone difficult  
  - Don't use the Internet  
  - Don't have a data plan  
  - Find it too expensive  
  - Prefer to browse the Internet on a PC |
Appendix E  Online Survey Questions

Demographics

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
</tr>
</thead>
</table>
| Q1. What is your age? | Establish demographic breakdown of participants  
Ensure that only participants 50 years old or older are permitted to complete the survey |
| Q2. Do you have any of the following disabilities? | Ensure that only full capable participants as well as those with moderate loss of vision or hearing are permitted to complete the survey |
| Q3. Do you own a cell phone? | Ensure that participants are current cell phone owners |

Phone Configurations

Significance levels:

* - Approaching significance <.20  
** - Statistically significant < .05  
*** - Highly significant < 0.01

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q4. Does your cell phone have a physical keyboard?</td>
<td>Establish phone configurations</td>
<td>Fisher’s (N=170), p=.861</td>
</tr>
</tbody>
</table>
| Q5. Does your cell phone have a QWERTY keyboard? | Establish phone configurations | Fisher’s (N=126), p=0.151*  
Younger 51.6%, Older 37.5% |
| Q6. Is your cell phone a flip phone? | Establish phone configurations | Fisher’s (N=126), p=0.020**  
Younger 32.3%, Older 53.1% |
| Q7. Is your cell phone a slider phone? | Establish phone configurations | Fisher’s (N=126), p=.055*  
Younger 50.0%, Older 26.7% |
| Q8. Does your phone have a touchscreen? | Establish phone configurations | Fisher’s (N=72), p=.048**  
Younger 42.9%, Older 20.0% |
| Q9. Is your cell phone a regular cell phone or a smartphone? | Establish phone configurations | Fisher’s (N=170), p=.009***  
Smartphone "Yes": Younger 61.2%, Older 40.0% |
## Usage Patterns

<table>
<thead>
<tr>
<th>Question</th>
<th>Goal</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q10. How long have you owned your cell phone?</td>
<td>Establish ownership patterns</td>
<td>Pearson Chi-Squared ($N=170$), $p = .121^*$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Younger: Less than 1 year, 31.8%, 1 to less than 2 years, 18.8%, 2 to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>less than 3 years, 16.5%, 3 years or more, 32.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Older: Less than 1 year, 17.6%, 1 to less than 2 years, 16.5%, 2 to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>less than 3 years, 18.8%, 3 years or more, 47.1%</td>
</tr>
<tr>
<td>Q11. In a typical week, for approximately how long do you use your cell phone in total?</td>
<td>Establish usage patterns</td>
<td>Pearson Chi-Squared ($N=170$), $p = .013^{**}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Younger: Not at all, 1.2%, less than an hour, 23.5%, 1 to less than 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hours, 20.0%, 2 to less than 3 hours, 15.3%, 3 hours or more 40.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Older: Not at all, 3.5%, less than an hour, 44.7%, 1 to less than 2 hours,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.2%, 2 to less than 3 hours, 8.2%, 3 hours or more 22.4%</td>
</tr>
<tr>
<td>Q12. Please indicate which of the following cell phone features listed you use:</td>
<td>Establish whether participants use basic, or advanced features of their cell phones</td>
<td>N / A</td>
</tr>
<tr>
<td>- Phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Internet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Email</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Games</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Maps / GPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Calendar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Address book</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Texting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q13. How comfortable are you with using the features listed below?</td>
<td>Establish how comfortable participants are with using basic as well as advanced cell phone features</td>
<td>N / A</td>
</tr>
<tr>
<td>- Phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Internet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Email</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Games</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Maps / GPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Calendar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Address book</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Texting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q24. How satisfied are you with the user manual?</td>
<td>Establish how comfortable participants are with cell</td>
<td>N / A</td>
</tr>
<tr>
<td>Q25. How would you improve the user manual? Rank your choices in order of greatest improvement:</td>
<td>Establish how older adults would like to improve cell phone user manuals</td>
<td>N / A</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>- Larger print text size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Less jargon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Improve index and table of contents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Improve visuals and diagrams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Provide a quick start guide</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Q26. Do you surf the Internet on your cell phone? | Establish whether older adults surf the Internet on their cell phones | N / A |

<table>
<thead>
<tr>
<th>Q27. Why don't you surf the Internet on your cell phone? Rank your choices in order of importance:</th>
<th>Establish the reasons why older adults don’t surf the Internet on their cell phones</th>
<th>N / A</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Viewing Internet pages on a cell phone difficult</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Don't use the Internet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Don't have a data plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Find it too expensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Prefer to browse the Internet on a PC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Heuristic Validation

<table>
<thead>
<tr>
<th>Question</th>
<th>Related Heuristic(s)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q14. In order to use the phone comfortably, do you do any of the following:</td>
<td>VIS2, VIS3, VIS4, AUD2</td>
<td>Put on or take off glasses: Fisher’s (N=170), p=.645&lt;br&gt; Increase text size: Fisher’s (N=170), p=.508&lt;br&gt; Increase screen brightness: Fisher’s (N=170), p=1.000&lt;br&gt; Increase volume: Fisher’s (N=170), p=.523</td>
</tr>
<tr>
<td>- Put on or take off glasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increase volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increase text size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increase screen brightness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q15. How satisfied are you with the visibility of the screen on your cell phone?</td>
<td>VIS1, VIS3, VIS4</td>
<td>Fisher’s (N=170), p=.835</td>
</tr>
<tr>
<td>Q16. Which of the following would improve the screen on your cell phone?</td>
<td>VIS1, VIS3, VIS4</td>
<td>Increase screen size: Fisher’s (N=45), p=.556&lt;br&gt; Increase contrast: Fisher’s (N=40), p=1.000&lt;br&gt; Improve visibility in sunny conditions: Fisher’s (N=45), p=.120*&lt;br&gt; Improve visibility in sunny conditions &quot;Most important&quot;: Younger 52.2%, Older 77.3%&lt;br&gt; Improve visibility in low light conditions: Fisher’s (N=42), p=.354</td>
</tr>
<tr>
<td>- Increase screen size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increase contrast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Improve visibility in sunny conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Improve visibility in low light conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Improve the use of colour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q17. How satisfied are you with the operation of your cell phone?</td>
<td>VIS2, MEM3, MEM4</td>
<td>Fisher’s (N=170), p=.716</td>
</tr>
<tr>
<td>Q18. Select any of the following that would improve the operation of your cell phone. Rank the suggestions below in order of greatest improvement:</td>
<td>VIS2, MEM3, MEM4</td>
<td>Simplify the menus Fisher’s (N=36), p=1.000&lt;br&gt; Less icons more text: Fisher’s (N=32), p=1.000&lt;br&gt; Use language that’s easier to understand in menus: Fisher’s (N=32), p=1.000&lt;br&gt; Increase size of text: Fisher’s (N=36), p=1.000&lt;br&gt; Increase size of icons: Fisher’s (N=34), p=.681&lt;br&gt; Provide descriptive textual labels beside icons: Fisher’s (N=34), p=1.000&lt;br&gt; Provide a list of frequently used features: Fisher’s (N=32), p=1.000&lt;br&gt; Provide an alphabetical list of features: Fisher’s (N=32), p=1.000&lt;br&gt; Provide solid background colours instead of wallpapers</td>
</tr>
<tr>
<td>- Simplify the menus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Use less icons and more text</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Use language that’s easier to understand in menus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increase size of text</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increase size of icons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Provide descriptive textual labels beside icons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Provide a list of frequently used features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Provide an alphabetical list of all features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Use solid background colours instead of wallpapers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Variable</td>
<td>Test Statistic</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>Q19. How easy is it to understand the icons and buttons on your cell phone?</td>
<td>VIS2</td>
<td>Fisher's (N=32), p=1.000</td>
</tr>
<tr>
<td>Q20. Do you find it difficult to hear your cell phone sounds?</td>
<td>AUD1</td>
<td>Fisher's (N=170), p=.431</td>
</tr>
<tr>
<td>Q21. Select any of the following that would make it easier to hear the sounds on your cell phone. Rank your choices in order of greatest improvement:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Make it easier to adjust the volume</td>
<td>AUD1</td>
<td>Make it easier to adjust the volume: Fisher's (N=38), p=.741</td>
</tr>
<tr>
<td>- Louder ringtones</td>
<td>AUD2</td>
<td>Make it easier to adjust the volume: Fisher's (N=38), p=.741</td>
</tr>
<tr>
<td>- Higher pitched ringtones</td>
<td></td>
<td>Make it easier to adjust the volume: Fisher's (N=38), p=.741</td>
</tr>
<tr>
<td>- Lower pitched ringtones</td>
<td></td>
<td>Make it easier to adjust the volume: Fisher's (N=38), p=.741</td>
</tr>
<tr>
<td>Q22. If your cell phone has a physical keyboard, how satisfied are you with it?</td>
<td>MOT1</td>
<td>Fisher's (N=106), p=.697</td>
</tr>
<tr>
<td>Q23. How would you improve your current cell phone keyboard? Rank your choices in order of greatest improvement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Increase key size</td>
<td>MOT1</td>
<td>Increase key size: Fisher's (N=45), p=1.000</td>
</tr>
<tr>
<td>- Replace physical keyboard with touchscreen keyboard</td>
<td></td>
<td>Replace physical keyboard with touchscreen keyboard: Fisher's (N=39), p=.731</td>
</tr>
<tr>
<td>- Add bumps to keys, in order to make it easier to distinguish between them</td>
<td></td>
<td>Provide slide-out keyboard: Fisher's (N=36), p=.481</td>
</tr>
<tr>
<td>- Provide slide-out keyboard</td>
<td></td>
<td>Provide PC-style QWERTY keyboard: Fisher's (N=38), p=1.000</td>
</tr>
<tr>
<td>- Provide PC-style QWERTY keyboard</td>
<td></td>
<td>Provide PC-style QWERTY keyboard: Fisher's (N=38), p=1.000</td>
</tr>
</tbody>
</table>
Appendix F  Sample Calculation - Fisher's Exact Test of Independence

Survey Q4. Does your cell phone have a physical keyboard?

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Yes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 to 59</td>
<td>23</td>
<td>62</td>
<td>85</td>
</tr>
<tr>
<td>60 to 74</td>
<td>21</td>
<td>64</td>
<td>85</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>126</td>
<td>170</td>
</tr>
</tbody>
</table>

Fisher's Exact Test of Independence:

\[ p = \frac{(a+b)! (c+d)! (a+c)! (b+d)!}{a! b! c! d! N!} \]

SPSS Output:

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
<th>Exact Sig. (2-sided)</th>
<th>Exact Sig. (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>.123</td>
<td>1</td>
<td>.726</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuity Correction</td>
<td>.031</td>
<td>1</td>
<td>.861</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>.123</td>
<td>1</td>
<td>.726</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisher's Exact Test</td>
<td></td>
<td></td>
<td></td>
<td>.861</td>
<td>.431</td>
</tr>
<tr>
<td>Linear-by-Linear</td>
<td>.122</td>
<td>1</td>
<td>.727</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Association</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 22.00.
Note b. Computed only for a 2x2 table
Appendix G  Sample Calculation - Pearson’s Chi-Square Test of Independence

Interview Q. 11 - In a typical week, for approximately how long do you use your cell phone in total?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Less than an hour</th>
<th>1 to less than 2 hours</th>
<th>2 to less than 3 hours</th>
<th>3 hours or more</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 to 59</td>
<td>1</td>
<td>20</td>
<td>17</td>
<td>13</td>
<td>34</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>29</td>
<td>17.5</td>
<td>10</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td>60 to 74</td>
<td>3</td>
<td>38</td>
<td>18</td>
<td>7</td>
<td>19</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>29</td>
<td>17.5</td>
<td>10</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>58</td>
<td>35</td>
<td>20</td>
<td>53</td>
<td>170</td>
</tr>
</tbody>
</table>

**Expected counts:**

Expected count in cell (1,1) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((4 \times 85)/170 = 2\)

Expected count in cell (2,1) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((58 \times 85)/170 = 29\)

Expected count in cell (3,1) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((35 \times 85)/170 = 17.5\)

Expected count in cell (4,1) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((20 \times 85)/170 = 10\)

Expected count in cell (5,1) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((53 \times 85)/170 = 26.5\)

Expected count in cell (1,2) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((4 \times 85)/170 = 2\)

Expected count in cell (2,2) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((58 \times 85)/170 = 29\)

Expected count in cell (3,2) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((35 \times 85)/170 = 17.5\)

Expected count in cell (4,2) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((20 \times 85)/170 = 10\)

Expected count in cell (5,2) = \((\text{RowTotal} \times \text{ColTotal})/\text{GridTotal}\) = \((53 \times 85)/170 = 26.5\)
Pearson’s Chi-Squared Test:

\[ \chi^2 = \sum \frac{(O-E)^2}{E} \]

\[ \chi^2 = \frac{(1-2)^2}{2} + \frac{(20-29)^2}{29} + \frac{(17-17.5)^2}{17.5} + \frac{(13-10)^2}{10} + \frac{(34-26.5)^2}{26.5} + \frac{(3-2)^2}{2} + \frac{(38-29)^2}{29} + \frac{(18-17.5)^2}{17.5} + \frac{(7-10)^2}{10} + \frac{(19-26.5)^2}{26.5} \]

\[ \chi^2 = 0.5 + 2.7931 + 0.0143 + 0.9 + 2.1226 + 0.5 + 2.7931 + 0.0143 + 0.9 + 2.1226 \]

\[ \chi^2 = 12.66 \]

**SPSS Output:**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>12.660</td>
<td>4</td>
<td>.013</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>12.886</td>
<td>4</td>
<td>.012</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>11.741</td>
<td>1</td>
<td>.001</td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>170</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 2 cells (20.0%) have expected count less than 5. The minimum expected count is 2.00.