Touchscreen Accuracy and Usability for Older Adults: A Comparison of Target Selection Methods

By

Gwendolyn Witecki

A Thesis
presented to
The University of Guelph

In partial fulfillment of requirements
for the degree of
Master of Science
in
Computer Science

Guelph, Ontario, Canada
© Gwendolyn Witecki, September, 2017
ABSTRACT

**Touchscreen Accuracy and Usability for Older Adults**

Gwendolyn Witecki
University of Guelph

Advisor: Dr. Blair Nonnecke

Canada, along with the rest of the world, is experiencing a steep growth in their oldest demographics who, due to the effects of aging, require support as they adopt or continue to use smartphones in their advancing years. Target selection is a common task that is difficult for older adults to perform. An alternative selection method that is more accurate and usable would support existing smartphone users suffering age-related decline as well as encourage smartphone adoption by non-users who are 60 and over. Previous research suggests that lift selection will improve accuracy of target selection and be more usable than the method used currently, touch selection.

This thesis investigated whether lift selection was more accurate and usable than touch selection for both older (60+) and younger (18-29) adults. Predictive relationships for accuracy and usability were also examined. Participants completed a target selection task on a smartphone using both lift and touch selection on targets of small (5 x 7 mm), average (10 x 13 mm) and large (15 x 20 mm) sizes before completing a survey of usability perceptions and self-reported smartphone habits.

Results showed that touch selection was significantly more accurate than lift selection for both older and younger adults. Further analysis showed that regular smartphone usage was a weak, but significant positive predictor of touch selection accuracy and that age was a moderate, but significant negative predictor of touch selection accuracy. Some older adults showed improved accuracy during lift selection trials, and older adults were more likely to experience an accuracy improvement during lift selection compared to younger adults. Touch selection was rated significantly easier to use, more satisfying and more learnable by both older and younger adults. Smartphone owners were more likely to rate lift selection as less usable than non-smartphone owners, and there was no difference in usability ratings between touch and lift selection among non-smartphone owners.
Acknowledgements

I would first like to thank my advisor, Dr. Blair Nonnecke, of the School of Computer Science at the University of Guelph. Dr. Nonnecke was always available when I ran into a difficult spot, and was always patient with me regardless of the challenges I faced. Dr. Nonnecke always encouraged my own exploration of the field of usability, while also guiding me towards the most fruitful avenues of research and steering my work in a positive direction. He was always available to read, listen or look at my work, regardless of how many times he had already done so, and his insight and experience were both critical to my success.

I would also like to thank Dr. Judi McCuaig, of the School of Computer Science at the University of Guelph. Dr. McCuaig was always open to giving me advice and her wisdom and willingness to share her own experiences helped me on a number of occasions to improve both myself and my work. Additionally, as the secondary reader of my thesis, I am very grateful for the time and thought she put into the revision of this work. Her comments and feedback were invaluable and incredibly appreciated.

Finally, I would like to express my most profound gratitude to my family, and in particular my husband, Christopher Witecki, for providing me with unflinching support and unending encouragement. Chris’s constant understanding, care and encouragement throughout the many years it has taken me to research and write this thesis is immeasurably appreciated. None of my academic accomplishments would have been possible without my family, and I would have never completed this thesis without the love and support of my wonderful husband.

Thank-you.
Table of Contents

Acknowledgements ........................................................................................................................ iii

List of Tables ....................................................................................................................................... ix

List of Figures .......................................................................................................................................... x

Chapter 1 Introduction ........................................................................................................................... 1

1.1 Research Problem ..................................................................................................................... 6

1.2 Document Summary .................................................................................................................. 7

Chapter 2 Smartphone Use by Older Adults ..................................................................................... 9

2.1 Defining Older Adults and Smartphones ................................................................................... 9

2.1.1 Older Adults ......................................................................................................................... 9

2.1.2 Age-Related Decline ........................................................................................................... 12

2.1.3 Smartphones ...................................................................................................................... 15

2.2 Understanding Smartphone Use by Older Adults .................................................................... 16

2.2.1 Smartphone Use by Older Adults ..................................................................................... 17

2.2.2 Smartphone Ownership Among Older Adults ..................................................................... 24

2.2.3 Adoption Challenges .......................................................................................................... 25

2.2.4 Influencing Adoption ........................................................................................................... 27

Chapter 3 Improving Smartphone Usability for Older Adults .......................................................... 29

3.1 Target Selection ........................................................................................................................... 29

3.2 Target Selection Methods ......................................................................................................... 31
3.2.1 Touch Selection ........................................................................................................... 32
3.2.2 Lift Selection ................................................................................................................ 36
3.2.3 Contact Selection ......................................................................................................... 41
3.3 Improving the Usability of Target Selection ................................................................. 43

Chapter 4 Methodology ........................................................................................................ 47
4.1 Participants ....................................................................................................................... 47
4.1.1 Age ............................................................................................................................... 48
4.1.2 Smartphone Usage ..................................................................................................... 49
4.1.3 Smartphone Ownership ............................................................................................ 49
4.1.4 Handedness ................................................................................................................ 50
4.2 Materials .......................................................................................................................... 54
4.2.1 Introduction and Instruction Aids ............................................................................... 54
4.2.2 Smartphone ................................................................................................................ 56
4.2.3 Experimental Interface ............................................................................................... 56
4.2.4 Usability Survey .......................................................................................................... 58
4.3 Design ............................................................................................................................... 59
4.3.1 Experimental Design Beta Testing ............................................................................. 59
4.3.2 Experimental Groups .................................................................................................. 59
4.4 Measures .......................................................................................................................... 60
4.4.1 Interface ...................................................................................................................... 60

v
4.4.2 Usability Survey........................................................................................................... 61

4.5 Conditions ........................................................................................................................... 62

4.5.1 Selection Method ......................................................................................................... 63

4.5.2 Target Size ................................................................................................................... 64

Chapter 5 Results ......................................................................................................................... 65

5.1 RQ1: Does lift selection improve selection accuracy for older adults? ......................... 66

5.1.1 Demographic Comparison of Accuracy....................................................................... 66

5.1.2 Accuracy of Younger Adults ....................................................................................... 68

5.1.3 Accuracy of Older Adults ........................................................................................... 70

5.2 RQ2: Are age, regular smartphone use, smartphone ownership or digit(s) used predictors of selection accuracy? ........................................................................................................... 71

5.2.1 Touch Accuracy Factors .............................................................................................. 72

5.2.2 Lift Accuracy Factors .................................................................................................. 76

5.3 RQ3: Which selection method is perceived as more usable? ........................................ 77

5.3.1 Usability Ratings Comparison ..................................................................................... 78

5.3.2 Usability Ratings by Younger Adults .......................................................................... 79

5.3.3 Usability Ratings by Older Adults ............................................................................... 81

5.4 RQ4: Is selection speed related to the usability ratings of either selection method? ........ 82

5.4.1 Selection Speed by Demographic and Selection Method ............................................ 82

5.4.2 Touch Selection ......................................................................................................... 83
Touch Instructions .............................................................................................................. 116
Drag/Lift Instructions ........................................................................................................... 116
Appendix F Post-Experimental Survey .............................................................................. 117
Appendix G Experimental Procedure Beta Test Results ...................................................... 118
Older Adults ....................................................................................................................... 118
Younger Adults ................................................................................................................ 119
Appendix H Summary of Experimental Procedure ............................................................ 121
Introduction ....................................................................................................................... 121
Selection Method Demonstration ....................................................................................... 122
Target Selection .................................................................................................................. 122
Self-Report Usability Survey ............................................................................................. 124
List of Tables

Table 2-1 Summary of relevant definitions of older adult ............................................................ 10
Table 3-1 Summary of target selection studies ............................................................................. 32
Table 3-2 Summary of research questions .................................................................................... 46
Table 4-1 Self-reported smartphone experience by demographic ................................................ 49
Table 4-2 Self-reported smartphone ownership by demographic ................................................ 50
Table 4-3 Observed supporting hand strategies by demographic .................................................. 51
Table 4-4 Observed selecting hand strategies by demographic ..................................................... 52
Table 4-5 Breakdown of selecting hand and digit combinations by demographic ....................... 52
Table 4-6 Summary of supporting and selecting hand combinations .......................................... 54
Table 4-7 Summary of supporting and selecting hand sameness by demographic ................. 54
Table 4-8 Selection methods and target sizes ............................................................................. 57
Table 4-9 Smartphone usage options from usability survey ....................................................... 62
Table 4-10 Summary of conditions ............................................................................................. 63
Table 5-1 Usability perceptions of touch selection by demographic ............................................ 79
Table 5-2 Usability perceptions of lift selection by demographic ............................................... 79
Table 5-3 Usability perceptions of younger adults towards touch and lift selection .................... 81
Table 5-4 Usability perceptions of older adults towards touch and lift selection ...................... 82
Table A-1 Beta testing results for older tester by screen ............................................................ 119
Table A-2 Beta testing results for younger tester by screen ....................................................... 120
Table A-3 Target selection trial steps ......................................................................................... 123
List of Figures

Figure 4-1 Selecting hand and digit combinations ................................................................. 53
Figure 4-2 Round screen flow diagram .................................................................................... 57
Figure 4-3 Target size UI conditions ....................................................................................... 64
Figure 5-1 Accuracy of touch and lift selection by demographic ............................................. 67
Figure 5-2 Percentage of participants who improved with lift selection in each demographic... 67
Figure 5-3 Accuracy of younger adults by target size and selection method .......................... 69
Figure 5-4 Accuracy of older adults by target size and selection method ............................... 70
Figure 5-5 Touch accuracy by self-reported smartphone usage .............................................. 73
Figure 5-6 Touch accuracy by age after 55 ............................................................................ 74
Figure 5-7 Accuracy of touch selection by age and self-reported routine smartphone use ....... 75
Figure 5-8 Usability ratings of touch and lift selection by demographic ................................. 78
Figure 5-9 Usability ratings of younger adults by selection method ....................................... 80
Figure 5-10 Usability ratings of older adults by selection method ......................................... 81
Figure 5-11 Selection speed by demographic and selection method ....................................... 83
Figure 5-12 Usability ratings of touch and lift selection by smartphone ownership ............... 86
Figure 5-13 Usability factor ratings of touch and lift selection by smartphone ownership ....... 86
Chapter 1 Introduction

Canada’s oldest demographic continues to grow, keeping pace with the rest of the world’s greying population (He, Goodkind, & Kowal, 2016). We now live in a time where seniors outnumber children in Canada (Statistics Canada, 2017). Life expectancy continues to increase, allowing older adults to live longer, healthier lives, with Statistics Canada estimating that 90% of adults in the Country will live to be 65 years old. Moreover, adults over the age of 65 saw the largest demographic share growth (20% increase) in this past census since conception of the census after confederation.

With an increasingly older population, helping individuals maintain their independence longer into life has become even more important. Smartphones stand to be an important contributor in maintaining late-life independence. Smartphones are an extension of the mobile phone, telephones that connect wirelessly to cellular networks from almost anywhere. Smartphones, with the power of a portable computer, offer programs and services to older adults that can support their health and independent aging. Nutrition, exercise and medication reminders, for example, can improve healthy living choices (Steinert, Haesner, Tetley, & Steinhagen-Thiessen, 2016). Smartphones have also been used to increase the independence of older adults prone to falling (Bert, Giacometti, Gualano, & Siliquini, 2013). Moreover, applications like HealtheBrain have shown promise bringing in-patient cognitive treatments to older adults in their homes, enabling more individuals to participate in programs that have been demonstrated to improve cognitive function in adults 60 and over with mild cognitive impairment and self-reported symptoms of cognitive decline (Shellington, Felfeli, Shigematsu, Gill, & Petrella, 2017). Additionally, smartphones are being more and more integrated into society. In New York, a
state-wide smartphone service has already been designed to allow older New Yorkers with smartphones to connect to services and information relevant to them (State of New York, 2017). The project is attempting to engage older adults in the communities they live in, and support independent access to relevant services through smartphone use.

Furthermore, smartphones combine the benefits of a mobile phone (Martínez-Pecino & Lera, 2012; Renaud & van Biljon, 2010; Sabin, 1993; A. Smith, 2011) with the benefits of the Internet while being easy to use (Billip, 2001; Ordonez, Yassuda, & Cachioni, 2011). Touchscreen interaction has also been reported as a preferred method of interaction compared to a physical keyboard by adults 60 and over for numerical entry tasks (Chung, Kim, Na, & Lee, 2009). Moreover, since mobile phones support their need for autonomy, mobile phones are associated with increased feelings of independence among adults over the age of 50 (Martínez-Pecino & Lera, 2012; Renaud & van Biljon, 2010), as well as improved feelings of competence due to their increased ability to access services and perform tasks independently (Martínez-Pecino & Lera, 2012; Renaud & van Biljon, 2010; A. Smith, 2011). In addition, regular social phone contact was found to be negatively correlated with mortality in adults over the age of 60 (Sabin, 1993) and Internet use among the same demographic has been associated with positive increases in affect (Billip, 2001) and cognitive functioning (Ordonez et al., 2011). These benefits likely generalize to smartphones, and smartphones are preferable to mobile phones and personal computers because a touchscreen is easier to learn (Caprani, O’Connor, & Gurrin, 2012; Chung et al., 2009), requires less physical strength to operate (Caprani et al., 2012; Haigh, 1993) and does not split the user’s attention between the screen and keypad or keyboard and mouse during a task (Caprani et al., 2012; Pattison & Stedmon, 2006).
A national survey of American adults found that smartphone adoption among adults 65 years and older has been increasing for several years and recently almost half (42%) owned a smartphone, a 24% increase over the last three years (Anderson & Perrin, 2017). In general, smartphone ownership findings were skewed towards younger, older adults with adults aged 50 to 64 having the highest proportion of ownership. Of those who did not report owning a smartphone, 65% reported owning a mobile phone that was not a smartphone (Anderson & Perrin, 2017). This is consistent with previous findings that adults 60 and older are reluctant to upgrade to a smartphone if they already own a mobile phone that is not a smartphone (A. Smith, 2012). The perception that smartphones are too complicated and hard to use (Anderson & Perrin, 2017; A. Smith, 2012), hard to learn (Anderson & Perrin, 2017; Renaud & van Biljon, 2010), or too frustrating to learn (Hernandez-Encuentra, Pousada, & Gomez-Zuniga, 2009) is common among adults 65 and older and also among those between the ages of 50 and 64 (Anderson & Perrin, 2017; A. Smith, 2012). Improving the usability of smartphones to address the challenges faced by an aging population will likely result in increased adoption of smartphones among that demographic (Davis, Bagozzi, & Warshaw, 1989; T. Smith, 2008).

Evidence supports the potential for smartphones to increase independence later in life through improvement of healthy living (Shellington et al., 2017; Steinert et al., 2016; Winter et al., 2012), adherence to medical advice (Steinert et al., 2016), and access to care (Bert et al., 2013). In addition, smartphones have been shown to be prevalent among those on the cusp of joining the older demographic, with 88% of adults aged 30-49 reporting owning smartphones and 74% of adults aged 50-65 reporting the same (A. Smith, 2017). Older adults who become smartphone users and younger smartphone users who grow older both need support to maintain their independence as they age.
While usable smartphones for adults 60 and over is important, this group does not want user interfaces designed specifically for older adults (Keates, Trewin, & Paradise, 2005). Rather, they prefer that interfaces accommodate all users and not target older adults. This sentiment will likely be even stronger among the next generation of older adults since they will already have smartphone experience.

Target selection is one of the most common and critical interactions on a smartphone as both navigating and inputting information require the ability to select targets accurately, e.g. traversing a menu system or dialling a phone number. Currently, the most common solution for target selection is touch selection, which requires the user to accurately touch the screen at the location of the desired target (Harada, Sato, Takagi, & Asakawa, 2013; Kobayashi et al., 2011). Touch selection is strongly impacted by age-related decline that can affect adults 60 and over in their ability to perform touch selection accurately and is influenced by the gradual deterioration of:

- **vision** (Haigh, 1993; Pattison & Stedmon, 2006; Scialfa & Cline, 2007)
- **fine motor control** (Caprani et al., 2012; Haigh, 1993; Perret & Regli, 1974; Pratt, Chasteen, & Abrams, 1994; Ruff & Parker, 1993)
- **memory** (Haigh, 1993; Kandel, Schwartz, & Jessell, 2000; Pattison & Stedmon, 2006)
- **attention** (Haigh, 1993; Kramer & Kray, 2006; Renaud & van Biljon, 2010)

Touch selection research has found that adults aged 60 and over have difficulty performing touch selection accurately (Kobayashi et al., 2011; Wacharamanotham et al., 2011), and older adults anecdotaly report having difficulty with touch interactions (Winter et al., 2012). Recognizing that the current implementation of touch selection presents challenges for older users, several
researchers recommend ways for improving touch selection accuracy or usability for older adults (Calak & Nonnecke, 2013; Caprani et al., 2012; Hwangbo, Yoon, Suk Jin, Suk Han, & Gu Ji, 2013). Many methods for improving touch accuracy are largely impractical in the context of smartphones, however, due to the size limitations of the screen needing to fit in one’s hand.

Alternative selection methods have been studied and can be grouped into three categories: (1) **touch selection** is defined as any selection method where the target selected is determined by the initial point of contact between the finger and the screen, (2) **lift selection** is defined as any selection method where the target to be selected is either determined or confirmed by the location of the finger when it is removed from the screen, and (3) **contact selection** is defined as any selection method where the target selected is determined by a collision between the finger and a selectable target while the finger remains in contact with the screen, and confirmed without removing the finger from the screen.

There was no evidence to support that contact selection is more accurate or more usable than touch selection (Guerreiro, Nicolau, Jorge, & Goncalves, 2010; Mertens, Jochems, Schlick, Dünnebacke, & Dornberg, 2010; Potter, Weldom, & Shneiderman, 1988), and is therefore not a suitable candidate as a method for improving target selection for older adults. Implementations of lift selection, however, were found to be more accurate and usable compared to touch selection (Kobayashi et al., 2011; Potter et al., 1988; Wacharamanotham et al., 2011) and contact selection (Potter et al., 1988). Moreover, lift selection may be preferred to touch selection among adults aged 60 and over (Kobayashi et al., 2011).

While previous results are promising, further research is still needed. For example, current research has yet to directly compare touch and lift selection for older adults on a smartphone.
Previous research into lift selection includes results from mounted touchscreens (Potter et al., 1988; Wacharamanotham et al., 2011), participants without previous experience with smartphones (Hwangbo et al., 2013), research without a touch selection comparison group (Wacharamanotham et al., 2011) or an age group for adults 60 and over (Potter et al., 1988). Some research, while studying adults 60 and over, focus only on specific subgroups, e.g. seniors with tremor (Wacharamanotham et al., 2011). More research is needed to determine whether lift selection is a suitable alternative to touch selection for older adults.

### 1.1 Research Problem

There is a growing need to support adults over the age of 60 as they either adopt or continue to use smartphones in their old age. Furthermore, smartphone use among this demographic should be encouraged, as it has been associated with positive outcomes and either increasing or retaining independence later in life. Target selection remains a difficult and common task for older adults to perform on a smartphone, and an alternative selection method that allows adults 60 years or older to interact more accurately with any app installed on the phone would both support existing smartphone users suffering from symptoms of age-related decline and encourage adoption among adults 60 or older who do not currently own smartphones.

Previous research suggests that lift selection will improve accuracy of target selection and be more usable compared to touch selection. Evidence to support this notion includes studies using mounted touchscreens, missing participants with previous smartphone experience, focusing on subgroups of adults 60 and over, or using an implementation of lift requiring a touch-based component to initiate.
The purpose of this research is to compare touch and lift selection in terms of accuracy and usability to determine its benefits as a smartphone target selection method, particularly for older adults. This goal can be divided into three components:

1) For adults 60 and over, determine whether lift selection improves target selection accuracy and usability as compared to touch selection,

2) Determine what factors influence accuracy and usability of touch and lift selection, and

3) Determine whether lift selection is an acceptable target selection solution for both younger and older users, i.e., determine whether lift selection is a universal solution for increasing accuracy and usability.

1.2 Document Summary

The remainder of this thesis is divided into six chapters:

Chapter 2 discusses literature pertaining to older adults and age-related decline as well as the advantages of smartphone adoption in the demographic. Additionally, this chapter will cover how usability is likely to lead to increased adoption. Definitions used in this thesis are developed in Chapter 2.

Chapter 3 identifies target selection as a critical area in which usability can be improved for older adults. Afterwards, literature pertaining to target selection on touch screens is reviewed and the three selection methods identified in the Introduction are compared. The research questions of the thesis are developed at the end of this chapter, in Section 3.3.
Chapter 4 provides an overview of the participants involved and the methodology used in the experiment to answer the research questions outlined in the conclusion of Chapter 3. Materials, measures and conditions are all covered in this chapter.

Chapter 5 contains a summary of the quantitative analyses of the experimental results used to answer the research questions.

Chapter 6 discusses each of the research questions and analyses the results of the experiment within the context of previous literature.

Chapter 7 presents limitations of this thesis and suggestions for future research. The chapter finishes by discussing the conclusions of the thesis.
Chapter 2 Smartphone Use by Older Adults

The chapter begins by presenting the definitions and key terms used in this thesis. In Section 2.2 the reasons for encouraging smartphone adoption among older adults is discussed followed by the current state of adoption among the demographic. The last topic presented is a model which predicts that increasing usability of smartphones will result in increased adoption rates among older adults.

2.1 Defining Older Adults and Smartphones

Two terms are used throughout this thesis, older adult and smartphone. This section discusses both and defines each as used in this thesis.

2.1.1 Older Adults

Defining what it means to be an older adult generally revolves around selecting an age cut-off after which an individual can be considered “old”. While a few papers define an older adult as an adult 50 years and over, many papers that have studied older adults and mobile phones define an older adult as an adult 60 years and over and some even define an older adult as an adult 65 and over (See Table 2-1).
<table>
<thead>
<tr>
<th>Papers Examining Older Adults</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record shares of Americans now own smartphones, have home broadband (A. Smith, 2017)</td>
<td>50+</td>
</tr>
<tr>
<td>Smartphone heuristics for older adults (Calak &amp; Nonnecke, 2013)</td>
<td>50+</td>
</tr>
<tr>
<td>Active seniors and mobile phone interaction (Martinez-Pecino &amp; Lera, 2012)</td>
<td>50+</td>
</tr>
<tr>
<td>The best and worst of mobile connectivity (A. Smith, 2012)</td>
<td>50+</td>
</tr>
<tr>
<td>Americans and their cell phones (A. Smith, 2011)</td>
<td>50+</td>
</tr>
<tr>
<td>Older adults and social media (Madden, 2010)</td>
<td>50+</td>
</tr>
<tr>
<td>The ageing process: a challenge for design (Haigh, 1993)</td>
<td>50+</td>
</tr>
<tr>
<td>HealtheBrain: An innovative smartphone application to improve cognitive function in older adults (Shellington et al., 2017)</td>
<td>55+</td>
</tr>
<tr>
<td>Self-monitoring of health-related goals in older adults with use of a smartphone application (Steinet et al., 2016)</td>
<td>60+</td>
</tr>
<tr>
<td>Characteristics of elderly user behaviour on mobile multi-touch devices (Harada et al., 2013)</td>
<td>60+</td>
</tr>
<tr>
<td>Elderly Online (Ordonez et al., 2011)</td>
<td>60+</td>
</tr>
<tr>
<td>Elderly user evaluation of mobile touchscreen interactions (Kobayashi et al., 2011)</td>
<td>60+</td>
</tr>
<tr>
<td>Evaluating swabbing: A touchscreen input method for elderly users with tremor (Wacharamanotham et al., 2011)</td>
<td>60+</td>
</tr>
<tr>
<td>Worth-centered mobile phone design for older users (Renaud &amp; van Biljon, 2010)</td>
<td>60+</td>
</tr>
<tr>
<td>Usability evaluation of numeric entry tasks on keypad type and age (Chung et al., 2009)</td>
<td>60+</td>
</tr>
<tr>
<td>Rapid aimed limb movements: Age differences and practice effects in component submovements (Pratt et al., 1994)</td>
<td>60+</td>
</tr>
<tr>
<td>Effects of aging and task difficulty on divided attention performance (McDowd &amp; Craik, 1988)</td>
<td>60+</td>
</tr>
<tr>
<td>Tech adoption climbs among older adults (Anderson &amp; Perrin, 2017)</td>
<td>65+</td>
</tr>
<tr>
<td>Older adults and technology use (A. Smith, 2014)</td>
<td>65+</td>
</tr>
<tr>
<td>A study of pointing performance of elderly users on smartphones (Hwangbo et al., 2013)</td>
<td>65+</td>
</tr>
<tr>
<td>ICT and older people (Hernandez-Encuentra et al., 2009)</td>
<td>65+</td>
</tr>
<tr>
<td>iFall: An Android application for fall monitoring and response (Sposaro &amp; Tyson, 2009)</td>
<td>65+</td>
</tr>
<tr>
<td>Senior citizens and e-commerce websites: The role of perceived usefulness, perceived ease of use, and website usability (T. Smith, 2008)</td>
<td>65+</td>
</tr>
<tr>
<td>Psychosocial impact of interactive computer use within a vulnerable elderly population (Billip, 2001)</td>
<td>65+</td>
</tr>
<tr>
<td>Using pointing devices: Quantifying differences across user groups (Keates et al., 2005)</td>
<td>70+</td>
</tr>
<tr>
<td>Social relationships and mortality among the elderly (Sabin, 1993)</td>
<td>70+</td>
</tr>
</tbody>
</table>
In a review of literature related to age-related decline, Calak & Nonnecke (2013) observe that despite gerontologists’ general definition of older adults as adults aged 60 or older, several authors have found results indicating that the age-related decline of many faculties including contrast sensitivity, ability to focus on objects close by, and auditory sensitivity can begin as early as 50 before worsening progressively with age. In a discussion of age-related decline by Caprani et. al. (2012), vision changes are noted to begin as early as 40 for many individuals. In this thesis, an older adult is defined as an adult aged 60 years or older.

Newell (2008), discusses age not as a state of being over or under a certain threshold of years but rather aging as a range of experiences and changes that naturally occur over the lifespan. Consequently, someone younger than 60 may experience symptoms of age-related decline while someone else may experience very few well after the age of 60. Pattinson and Stedmon (2006) note that even though studies have found guidelines related to the average progression of decline, older adults as a group are highly heterogeneous and anecdotally, many people experience a peak at 20 years of age with no decline until after their 70’s. Newell (2008) makes a distinction between three groups of older adults that categorize individuals based on their experiences and perceptions rather than their chronological age:

(1) Older adults who are fit may not appear to be or consider themselves as “old”. These individuals would not be considered disabled, but their needs and concerns are different from when they were younger.

(2) Older adults who are frail would be considered disabled, and experience a general reduction in function due to aging.
(3) Disabled individuals who have aged were always considered disabled, but may experience a worsening of symptoms due to aging. Additionally, these individuals may be critically reliant on other faculties to function which are also declining with age.

2.1.2 Age-Related Decline

Symptoms of age-related decline can be broadly categorized into four groups: visual impairment, fine motor impairment, cognitive impairment and auditory impairment. Each of these impairments can begin at varying times in a person’s life and can impact smartphone use in different ways. Several authors observe that after the age of 50, people experience aging at distinctly different rates (Caprani et al., 2012; Haigh, 1993; Newell, 2008; Pattison & Stedmon, 2006).

**Visual Impairment:** Older adults experience declines in visual function and can have difficulty performing common visual tasks, particularly under difficult conditions such as low lighting (Scialfa & Cline, 2007). Difficulty focusing on nearby objects can become noticeable as early as 40 or 50 with an average decline in focus ability of 50-55% by 50 years old from 8 years old as well as a reduction in how quickly focus can be changed from one object to another (Haigh, 1993; Pattison & Stedmon, 2006). Furthermore, older adults have more difficulty seeing details and shapes. The eyes of a 60 year old require an estimated three times as much light as those of a 20 year old in order to perceive the same level of detail (Haigh, 1993; Pattison & Stedmon, 2006). Haigh (1993) also describes a slowing of the process by which the eyes adapt to changing conditions of darkness and light, making it more difficult for an older adult to see when lighting conditions are changed. Moreover, colour contrast sensitivity can begin to show noticeable decline as early as 30 or 40 years of age, with blue-green colour distinctions beginning to
diminish early on and red-green deterioration showing onset later between the ages of 55 and 60 (Haigh, 1993). It has been theorized that the reason for colour sensitivity loss is a gradual yellowing of the eye lens which filters out progressively more blue and violet hues. Additionally, adults over the age of 50 gradually have more and more difficulty perceiving the outlines of objects (Scialfa & Cline, 2007). Pattison and Stedmon (2006) note that even though age-related visual impairment can range in severity up to partial or even complete blindness, the majority of individuals will instead suffer gradual and consistent decline of their existing visual abilities with age (Pattison & Stedmon, 2006).

Fine Motor Impairment: Several facets of motor control and physical motor function are affected by advancing age. For example, older adults experience a reduction in tensile grip strength as well as grip endurance measured in terms of time a grip can be sustained. By the age of 65, most individuals will have lost 75% of the tensile grip strength present during their peak years (Haigh, 1993). Furthermore, decreases in finger and thumb strength can cause difficulty pressing buttons, particularly when the button is on an object being held in the same hand (e.g. on a television remote) since in this case both tensile grip and thumb strength are required to complete the action (Caprani et al., 2012; Haigh, 1993). Moreover, the reductions in bulk muscular strength that commonly occur after the age of 60 often cause a decrease in movement accuracy (Haigh, 1993). Reduction in the time it takes for sensory feedback regarding the limb’s position relative to a target can also cause jerky or uneven movements, even when performing a motion that is well-practised (Pratt et al., 1994). Older males have been observed to have poorer hand-eye coordination than older females, however older females have been observed to have slower motor speed overall compared to older males (Ruff & Parker, 1993). Other effects of aging on the motor system are a loss in torsional strength of the wrist, making twisting
movements such as that required to open a jar more difficult (Haigh, 1993). Lastly, older adults lose sensory feeling as they age as well, with research reporting adults aged 60 and older needing between two and ten times the strength of haptic feedback to feel its effects as compared to younger adults (Perret & Regli, 1974).

**Cognitive Impairment:** Based on cross-sectional research, cognitive abilities of working memory have been said to peak in one’s late 30’s or late 40’s, then begin to decline gradually in one’s 50’s and 60’s before marked decline begins to set in past the age of 70 for most individuals (Haigh, 1993). The capacity of an individual’s working memory does not appear to decline over time, rather the efficiency with which the same capacity can be used is what declines with age (Pattison & Stedmon, 2006). Furthermore, long term episodic memory generally shows impairment with age, but declarative memory impairment is comparatively rare. Procedural memory can be difficult to measure since it appears stable when the task being used to measure it is well-learned, however procedural memory, for new tasks in particular, suffers more as the task increases in complexity (Kandel et al., 2000).

Older adults maintain neuroplasticity and the ability to learn new information, skills, procedures and tasks, but the process is more difficult for them and takes longer (Kandel et al., 2000). Pattison and Stedmon (2006) also note that learning new information takes more time for older adults, especially when the material being learned is more complex. Additionally, adults show increasing problem solving abilities up until the age of 40 or 50 before a gradual decline begins thereafter with its speed depending on the experiences of the individual during their younger years (Haigh, 1993; Pattison & Stedmon, 2006). Adults over 50 also show increased difficulty in performing two tasks simultaneously, particularly when tasks are complex (Haigh, 1993;
McDowd & Craik, 1988), and older adults are less capable than younger adults at voluntarily switching attention from one task to another (Kramer & Kray, 2006). Similarly, older adults have a harder time filtering out irrelevant stimuli and diverting attention away from distractions during search tasks (Kramer & Kray, 2006).

**Auditory Impairment:** While the exact timeline of auditory decline can be difficult to discern because of the number of factors that influence hearing loss, there has generally been sufficient loss for many individuals to begin noticing impairment during difficult hearing conditions (i.e. high frequency sounds, ambient noise, quiet sounds, sounds from multiple sources) by the age of 50 (Haigh, 1993; Pattison & Stedmon, 2006). Gradual but not complete loss of auditory function is the most common progression of hearing loss (Pattison & Stedmon, 2006). The ability to discriminate between frequencies gradually declines in a linear fashion between the ages of 25 and 55 before more severe decline is observed (Pattison & Stedmon, 2006). Moreover, tinnitus, an uncomfortable and persistent ringing in the ears, is commonly present in older adults (Ahmad & Seidman, 2004). Lastly, older adults show more difficulty interpreting and responding to complex auditory cues (Haigh, 1993; Pattison & Stedmon, 2006). Amplifying sound can sometimes help individuals with auditory impairment, but as the auditory system continues to decline amplification makes less and less of a difference (Haigh, 1993).

2.1.3 Smartphones

Calak & Nonnecke (2013) define a *smartphone* as a mobile device that combines the functionality commonly found in mobile phones with that of a personal computer. Since the primary purpose of this research is to address accuracy and usability concerns of touchscreens, in the current study the term smartphone will primarily be used to refer to mobile devices that
combine the features of a mobile phone and personal computer, and use a touch screen as its primary method of interaction. Phones such as Blackberries, which combine the features of a mobile phone and personal computer but do not use a touchscreen as its primary method of interaction, are also considered smartphones; however, since the topic of this thesis is touchscreen interaction, mobile devices of this variety are not included when the term smartphone is used in this thesis.

In this thesis, the term *feature phone* will be defined as a mobile phone that does not include features of a personal computer and does not have a touchscreen. Feature phones generally include features such as a contact book, instant messaging, call logs, or simple games, but their primary feature is the telephone.

*A mobile phone* is any mobile device that connects to a cellular radio system, allowing for the use of telephone services without a physical connection to a telephone network. Both smartphones and feature phones are considered mobile phones.

### 2.2 Understanding Smartphone Use by Older Adults

This section will discuss the primary motivation for improving smartphone usability in general for older adults. The advantages of smartphone use among older adults is first discussed to establish the importance of the topic, followed by a presentation of the current state of smartphone adoption amongst the demographic. A summary of reported adoption challenges among the demographic is given next and the section will conclude by offering a model that predicts smartphone adoption among older adults will improve if usability concerns for the demographic are addressed.
2.2.1 Smartphone Use by Older Adults

Older adults report feeling that mobile phones are useful (e.g. Martinez-Pecino & Lera, 2012), and authors agree that smartphones have the potential to improve quality of life (e.g. Steinert et al., 2016), but research into the advantages of smartphone use have not yielded conclusive evidence of a causal relationship between smartphone use and general improvement in quality of life. Furthermore, since smartphones are comparatively new, much of the research that has been done has focussed on feature phones or the Internet. Smartphones extend the functionality of a feature phone to include the capabilities of a personal computer as well as the Internet, and would therefore provide the same benefits as feature phones and the Internet, but with the additional benefit of being easier to use (Caprani et al., 2012; Chung et al., 2009). Therefore, research into the benefits of feature phones and the Internet have been included as relevant in addition to research specifically studying smartphones. While there is clearly a need for more research into the effects of integrating smartphones into the lives of older adults, the current body of literature allows some insight into the potential benefits smartphones could present to an aging population. This research is summarized below, divided by the technology being examined.

**Smartphone Research:** Literature relating to how smartphones present benefits to older adults can generally be divided along two lines of thinking. The first body of literature takes advantage of novel functionality found in smartphones to improve quality of life for older adults (e.g. Steinert et al., 2016) and the second explores how smartphones can provide the same benefits offered by either feature phones or personal computers, but in a way that is more usable to older adults (e.g. Chung et al., 2009).
Several studies have explored the potential of smartphones to encourage older adults to adopt healthier lifestyles and extend their independence (e.g. Bert et al., 2013; Winter et al., 2012). For example, in an intervention study of 30 adults aged 60 or older, participants were asked to set personal lifestyle goals and were provided with a smartphone with a downloaded app that would give them reminders and track their progress towards the goal (Steinert et al., 2016). Participants who set nutritional goals, such as consuming more fruit or drinking more water, achieved significant gains towards these goals after a week of using a smartphone to track their nutrition and receive nutritional reminders. The same study found that using the smartphone app to remind patients to take medication significantly improved medication adherence scores. Similarly, in a study of middle and older aged adults (average age 58), participants who tested an activity monitoring app reported that using a smartphone to track their sedentary and physical activity was effective at making them aware of their behaviour patterns and at motivating them to exercise more (Winter et al., 2012). Furthermore, smartphones have allowed older adults to easily access healthcare and leverage social supports (e.g. Sposaro & Tyson, 2009). For example, a review of literature related to fall detection and prevention found that there were promising results for detecting falls when they happen and alerting the appropriate social supports (Bert et al., 2013). Apps like iPrevention use smartphone sensors to detect abnormalities in walking gait and alert the individual as they are walking that they are at risk of falling (Majumder, Rahman, Zerin, Ebel, & Ahamed, 2013). Moreover, apps like HealtheBrain are allowing older adults to access programs that were previously accessible only in hospital or clinical settings in both rural and in-home care settings (Shellington et al., 2017). HealtheBrain has been used to increase the breadth of availability for cognitive programs already demonstrated to be effective in increasing cognitive abilities in older adults experiencing symptoms of cognitive decline.
The studies discussed all share a similar feature of taking advantage of recent technological advancements that access the power and functionality of a computer in a portable context. The majority of these studies focus on a specific app or technology (Majumder et al., 2013; Shellington et al., 2017; Sposaro & Tyson, 2009; Steinert et al., 2016; Winter et al., 2012). The other perspective explored in the literature is accessing the benefits of feature phones and the Internet more easily, primarily through use of a touchscreen to facilitate interactions.

In a review of design principles applicable to adults aged 60 and older as well as those suffering from age-related physiological or cognitive decline, several advantages of using smartphones instead of feature phones or personal computers are identified (Caprani et al., 2012). For example, smartphones eliminate the need to shift or split attention between the screen and a mouse or keypad located elsewhere since all the interactions take place directly on the screen. Older adults often have reduced ability to split their attention between multiple sources, so maintaining focus on only the screen is beneficial. Moreover, directly interacting with the screen is easier to understand and requires less time and effort to learn. This advantage is particularly important in the context of making the leap from feature phones to smartphones, since use of the number pad or ambiguously labelled specialized keys for navigation and selection is common among feature phone designs. Furthermore, a study of comparing the accuracy and perceptions of physical buttons to touch screen buttons found that adults 60 and over reported significantly higher preference for the touchscreen keypad for numeric entry tasks (Chung et al., 2009).

Caprani et al. (2012) point out that virtual buttons force the user to rely on visual feedback and not tactile feedback which could be problematic for adults with declining vision. Findings from Chung et al.’s (2009) numeric entry experiment showed that adults 60 and over made more
errors when using a touch keypad compared to a physical one, but inputted numbers significantly
took this disadvantage by saying that designers can
also customize button sizes, including buttons that are as large or larger than a finger in order to
make targets easier both to see and select, or use different types of feedback, such as auditory or
haptic feedback, to help the user know when they are selecting a target.

Smartphones have been shown to be uniquely capable of helping older adults increase their
quality of life and extend their independence by improving lifestyle (Steinert et al., 2016; Winter
et al., 2012), reducing fall risk (Majumder et al., 2013; Sposaro & Tyson, 2009) and increasing
access to healthcare and social supports (Bert et al., 2013; Shellington et al., 2017). Moreover,
older adults have reported preferring touchscreen keys to physical keys in numeric entry tasks
similar to dialling a phone (Chung et al., 2009) and several advantages of touch interfaces over
screen and keypad or screen and keyboard interfaces have been proposed (Caprani et al., 2012).

**Feature Phone Research:** Previous research has indicated that feature phone ownership and use
supports older adults’ motivational needs of autonomy, relatedness and competence, contributing
to the preservation of independence later into life (e.g. Martinez-Pecino & Lera, 2012; Renaud &
van Biljon, 2010). Renaud and van Biljon (2010) explored this relationship in two experiments
by associating features and applications accessible on a variety of mobile phones with
motivational needs. In one experiment, participants were asked to perform a sorting task in
which they selected the functions that they would use or want to use the most and arranged them
on a mock home screen. Selections chosen consistently corresponded to autonomy, relatedness
and competence, and the authors concluded that use of a feature phone supported these needs.
Autonomy, defined as the ability to direct or control one’s life, was associated with applications that informed decision-making (i.e. maps) and accessed necessary or desired services (i.e. accessing emergency services) (Renaud & van Biljon, 2010). A. Smith (2011) found that that 34% of adults 65 or older reported using their phone in an emergency situation, and 37% of adults aged 50-64 also reported the same thing. These values were not significantly different from adults aged 30-49, of whom 41% also reported using their phone in an emergency, indicating that older adults are able to take equal advantage of a feature phone’s ability to improve autonomy compared to those who are as young as 30. This finding is supported by evidence from an interview of 34 adults aged 60 to 92, in which 62% of participants reported that a feature phone would be useful in an emergency and 79% agreed that feature phones had the potential to improve safety while travelling (Renaud & van Biljon, 2010). Moreover, a survey of feature phone use in Spain found that older adults who owned feature phones reported feeling more secure in case of an emergency after purchasing a feature phone compared to before when they did not own a mobile phone at all (Martinez-Pecino & Lera, 2012).

Relatedness, defined as the need to form meaningful social relationships, was associated with applications used to communicate with others (i.e. phone or text messaging) and manage social networks (i.e. Facebook) (Renaud & van Biljon, 2010). Relatedness has been shown to be supported primarily through the use of voice calling (e.g. Martinez-Pecino & Lera, 2012; Sabin, 1993), though some evidence also points to older adults becoming more comfortable filling this need with text messaging (Renaud & van Biljon, 2010) and social networking (Anderson & Perrin, 2017) as well. For example, a feature phone ownership and usage survey of 165 adults 50 and older in attendance at the Seville University for Seniors found that participants reported using their feature phones to call relatives significantly more than any other activity (Martinez-
Pecino & Lera, 2012). Furthermore, a study exploring the connection between social relationships and mortality among older adults 70 and older, used a national sample of survey respondents from the 1984 National Health Survey and found that there was a significant negative correlation between social contact and mortality (Sabin, 1993). Specifically, increased sociability was associated with reduced mortality and talking on the phone was negatively correlated with mortality even when other factors were controlled for. These findings are further supported by the finding that the two most commonly used features on a feature phone were features motivated by relatedness: the phone and text messaging (Renaud & van Biljon, 2010).

Lastly, competence, defined as the ability to effectively navigate and interact with the environment, was associated with applications that supported routine tasks (i.e. alarm clock) or aided memory of important information (i.e. reminders) (Renaud & van Biljon, 2010). Competence presents a unique challenge, since older adults feel uniquely incompetent about technology compared to other age groups (Anderson & Perrin, 2017). In the interview component of their study, Renaud and van Biljon (2010) found that 82% of participants felt that setting reminders on their phone could help reduce memory difficulties, but that “many did not know how to do this” and almost a fifth (18%) of them were unsure that either themselves or others of their age group would have the capability to set reminders on a feature phone at all.

Feature phone use and ownership has been shown in previous research to offer benefits to older adults in the form of supporting their motivational needs of autonomy and relatedness (Martinez-Pecino & Lera, 2012; Renaud & van Biljon, 2010; Sabin, 1993; A. Smith, 2011). Competence has shown the potential to be supported by feature phones as well (Renaud & van Biljon, 2010), however technology anxiety and uncertainty about learning to use technology may influence how
this benefit is experienced (Renaud & van Biljon, 2010; A. Smith, 2017). Smartphones are an easier mobile phone alternative that would allow older adults to experience the benefits of feature phones while minimizing usability problems and anxiety.

**Internet Research:** Two studies were examined that focused on older adults using the Internet because the focus of the research was using the Internet as a communication and information gathering tool. The first study compared a control group to an Internet-training group that received 15 lessons and found that after training, the group that learned to use the Internet performed significantly better on a standardized battery of cognitive tests compared to the control group (Ordonez et al., 2011). The results of the experiment showed that the group that received the Internet training achieved significant gains in memory, language and visual-spatial skills. The authors caution that these gains may be associated with learning a new skill, and not the Internet specifically, but also note that evidence from previous research supports the idea that use of the Internet is associated with improved cognitive performance among adults 60 and over. The second study examined in-house older adults aged 65 and older who received Internet access coupled with training from a family member, Internet access coupled with training from a nurse and access to the Internet without any training (Billip, 2001). Weekly computer training by a family member coupled with regular access to a computer with Internet access was correlated with improved self esteem scores, and when weekly training was given by a nurse, regular access was correlated with both improved self esteem and reduced depression. This study is of particular importance because the finding that regular training coupled with access and not just access alone was associated with improvement highlighted both the difficulty that older adults 65 and over face when they are unsure about how to use or interact with technology and the potential benefits of using it.
While the Internet can be intimidating or challenging to use without guidance for adults 65 and over (Billip, 2001), there is evidence that Internet use can increase cognitive function (Ordonez et al., 2011) and measures of affect (Billip, 2001). Smartphones are an easy alternative to access the Internet and experience these benefits.

2.2.2 Smartphone Ownership Among Older Adults

A phone survey of 3015 American adults by Pew Research Center included 740 participants aged 65 or older and found that while smartphone adoption continues to increase, a large portion of older adults still own traditional feature phones and adoption for this demographic still lags behind other demographics (Anderson & Perrin, 2017). The survey found that 42% of American adults aged 65 and older report owning a smartphone, which represents a 24% increase in the three years since their previous survey as reported by A. Smith (2014). Anderson and Perrin’s (2017) report showed a slight increase in mobile phone ownership overall as well, with 80% reporting owning a mobile phone compared with 77% reporting owning one in A. Smith’s (2014) earlier survey. Furthermore, the proportion of smartphone to feature phone was reversed in the Anderson & Perrin (2017) survey compared to three years previous (A. Smith, 2014). A. Smith (2014) found that 18% of American adults over the age of 65 reported owning a smartphone and 59% reported owning a traditional feature phone. In the Anderson & Perrin (2017) report, this trend is flipped, with 42% reporting smartphone ownership and 38% reporting traditional feature phone ownership. Adoption was heavily skewed towards adults in the 65 to 75-year old age range, with only 31% of adults over the age of 75 owning a smartphone and 17% of adults over 80 reporting ownership (Anderson & Perrin, 2017).
Moreover, Anderson & Perrin (2017) found that among Internet users in the age bracket of 65 and over, those who used a smartphone as well were more likely to use the Internet everyday. 67% of Americans 65 or older reported using the Internet, and many of those reported using social media (34% of Americans 65 or older, and 66% of Internet users of this demographic). Of Internet users aged 65 or older, 76% reported using the Internet at least once everyday, and of Internet users 65 and over who were also smartphone owners, that figure jumped to 91% reporting using the Internet at least once everyday and 77% reporting use several times a day.

2.2.3 Adoption Challenges

Older adults present a number of adoption challenges unique to their age bracket, and face unique difficulties when interacting with technology due to age-related declines in physical, perceptual, and cognitive abilities which may further discourage adoption of smartphones (Anderson & Perrin, 2017; A. Smith, 2014). Moreover, psychological factors such as technology anxiety have been proposed to be related to adoption rates as well (Hernandez-Encuentra et al., 2009).

Despite recent increases in ownership, Anderson & Perrin (2017) found that most American adults over the age of 65 do not feel confident using their devices. Only 26% of Internet users 65 years or older reported “feel[ing] very confident when using computers, smartphones or other electronic devices to do the things they need to do online.” Furthermore, 34% reported feeling little to no confidence in using electronic devices like smartphones and computers to accomplish tasks online. Similarly, the survey asked respondents to rate how well they related to the phrase “When I get a new electronic device I usually need someone else to set it up or show me how to use it.” Older adults aged 65 and older disproportionately rated themselves higher, with 73%
saying it describes them very well or somewhat well. Notably, 62% of adults between the ages of 50 and 64 also stated that this describes them very well or somewhat well. This finding is supported by the finding that having regular support is one of the most important predictive factors of whether or not older adults will effectively integrate new technologies into their lives (Hernandez-Encuentra, Pousada, & Gomez-Zuniga, 2013). Moreover, Kelley & Charness (1995) also found that older adults tended to require more support and time to learn new software.

Perhaps it is not surprising then, that of those 65 and over who did not report owning smartphones, 65% reported owning feature phones (Anderson & Perrin, 2017). Another Pew Research survey of 2254 American adults, including 290 adults between the ages of 50 and 64 and 212 adults over the age of 65, found that adults 50 and over report feeling uniquely strongly about not needing or desiring to upgrade to a smartphone (A. Smith, 2012). This study reported that the top three reasons adults 50 and over with feature phones do not upgrade to smartphones are that: (1) an upgrade to a smartphone does not present sufficient benefits over a feature phone, (2) smartphones are too expensive and (3) smartphones are too complex or too difficult to use. Additionally, adults 50 and over were reported to be twice as likely as adults under the age of 50 to report that smartphones are too complex or difficult to use. These findings are consistent with the finding that the two most predictive variables of smartphone adoption among adults who suffer from age-related decline are perceived usefulness and ease of use (Renaud & van Biljon, 2010).

Furthermore, the Anderson & Perrin (2017) report found that 28% of adults 65 and over reported having “health problems, disabilities or handicaps that keep them from participating fully in work, school, housework or other activities”. This finding was similar to A. Smith’s (2014)
finding that 29% of adults 65 years and older reported a “disability, handicap or chronic disease that prevents them from fully participating in many common daily activities”. The same survey also found that 23% of older adults 65 and over reported a “physical or health condition that makes reading difficult or challenging,” a significant factor in using a smartphone. Moreover, Anderson & Perrin (2017) found that older adults with any form of disability were less likely to own a mobile phone as well as significantly less likely to use the Internet. Smartphone interfaces should be designed with these considerations in mind, so their impact on interaction can be mitigated.

2.2.4 Influencing Adoption

Since older adults are prone to experiencing difficulties with smartphone interfaces in predictable ways, it is important to understand how improving the usability of smartphones can result in increased adoption rates and subsequent benefits. Some researchers have expressed subjective opinions based on their own research (Hernandez-Encuentra et al., 2009), and it is logical that improving the usability of smartphones would be beneficial to users. In addition, an empirically supported model has been presented predicting that improving the usability of a technical system will increase its use among older adults (T. Smith, 2008). The “technology acceptance model” predicts that a user’s usage of a system such as a computer or mobile phone is mediated by the user’s intent to use it and that intent is mediated by two factors: (1) the perceived usefulness of the device, and (2) the perceived ease of use of the device (Davis et al., 1989). Several authors have demonstrated empirical support of this model (e.g. Joo & Sang, 2013; Klopping & McKinney, 2004; Lederer, Maupin, Sena, & Youlong, 2000) however T. Smith’s (2008) study demonstrated that the technology acceptance model is applicable to older adults. Since the model is applicable both to older adults and to smartphones, it stands to reason that usability
improvements made to smartphones to correct difficulties experienced by older adults are likely to result in increased smartphone usage among the target demographic.
Chapter 3 Improving Smartphone Usability for Older Adults

Davis et. al (1989) and T. Smith (2008) demonstrated that older adults are more likely to adopt and use technologies that are more usable, however there are numerous ways in which smartphone usability could potentially be improved. This chapter introduces the challenges older adults are prone to experience related to target selection on smartphones, and identifies target selection as a key area of smartphone interaction that requires usability improvement. The current state of target selection is presented as well as a summary of alternative selection methods that have been examined in previous literature. A review of these methods is made and the most likely candidate to improve accuracy and usability among older adults is selected for further research. The last section of the chapter concludes with a summary of the research questions to be pursued in this thesis.

3.1 Target Selection

Selecting a target is one of the most common actions on a touch-based user interface such as that of a smartphone. The majority of common tasks require target selection to input information or direct task flow. For example, dialing a phone number requires target selection to input digits; opening a message requires selection of the message; and using any app requires target selection to even open it. Very few tasks can be accomplished on a smartphone without accurate target selection.

The current market solution for target selection is touch selection, defined as selection of the target at the point where contact is initially made with the screen (Potter et al., 1988). If no selectable item is located directly beneath the point of contact, then no selection is made. This selection method requires the user to accurately touch the target on the first attempt, and does not
allow for error correction once initial selection has been made. More recently the definition has included rapid contact and removal, eliminating long press from being considered a tap. For the purposes of this thesis, *touch selection* will be defined as any selection method where selection is based on the initial point of contact with the touchscreen with all other touch input ignored.

Age-related decline presents challenges when using touch selection (e.g. Harada et al., 2013) and older adults have noted that interacting with the touchscreen is difficult when using smartphone apps (e.g. Winter et al., 2012). Calak & Nonnecke (2013) provide a review and recommendation of smartphone heuristics, and several of their software recommendations for improving the usability of smartphones for adults aged 50 and older are relevant to target selection. These recommendations highlight difficulties adults 50 and over experience selecting targets due to symptoms such as reduction in contrast sensitivity, slowing of sensory feedback regarding proximity of the hand to a target, and reduced attention capacity. Visual decline, for example, can make identifying the required target more difficult due to loss of contrast sensitivity, colour sensitivity and the ability to detect object outlines (Caprani et al., 2012; Scialfa & Cline, 2007). Furthermore, tremors or jagged movement as well as decreases in hand-eye coordination can seriously reduce accuracy during touch selection (Wacharamanotham et al., 2011). One study notes that for individuals with severe tremor, interfaces requiring touch interaction can be very frustrating or even impossible to use successfully (Mertens et al., 2010). Moreover, sex differences may also play a role in how older adults experience smartphones as they age since men and women suffer from fine motor deterioration in predictably different ways (Ruff & Parker, 1993). Additionally, touch selection requires the user to simultaneously filter out undesired targets cognitively and move the finger to the desired target on screen. Older adults have difficulty suppressing unnecessary information during search tasks, making it difficult for
them to find the target, particularly as the number of differing targets increases (Pattison & Stedmon, 2006). While the reason for this difficulty is unclear, authors speculate that older adults may evaluate each target individually rather than searching for patterns and disregarding targets that do not fit with the desired pattern (Kausler, 1991).

Finding the desired target is challenging due to difficulty suppressing information and visual deterioration. Touching a target accurately is challenging due to sensory slowdown and uneven movement. Therefore, to perform a touch selection act, older adults must perform two challenging tasks simultaneously: find the target and touch the target. Unfortunately, the ability to perform two tasks simultaneously also deteriorates in older adults, especially in situations where both tasks are demanding (Haigh, 1993; Pattison & Stedmon, 2006) and even when different modalities are employed (e.g. reading and typing a letter, controlling a car and observing surroundings) (Kausler, 1991). Age-related decline poses serious challenges to touch selection, particularly as symptoms of deterioration advance in mid and later stages.

3.2 Target Selection Methods

A summary of target selection research using touch screens to date, ordered by recency, is given in Table 3-1. In most papers, the terminology in the original paper differed from terminology used in this thesis, so the original term is used in the column on the left, and the selection method it is most similar to for the purposes of this thesis is provided in the column adjacent on the right. Each selection method is described in further detail in the sections following Table 3-1.
Table 3-1 Summary of target selection studies

<table>
<thead>
<tr>
<th>Study Author(s), Year and Title</th>
<th>Selection Method Name</th>
<th>Selection Method Category</th>
<th>Participants</th>
<th>N</th>
<th>Touch Device</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>A study of pointing performance of elderly users of smartphones (Hwangbo et al., 2013)</td>
<td>Touch</td>
<td>Touch</td>
<td>Older adults, aged 65-79</td>
<td>22</td>
<td>Smartphone</td>
<td>Error Count Selection speed Usability Survey</td>
</tr>
<tr>
<td>Characteristics of elderly user behaviour on mobile multi-touch devices (Harada, Sato, Takagi, &amp; Asakawa, 2013)</td>
<td>Touch</td>
<td>Touch</td>
<td>Older adults, aged 63-79</td>
<td>21</td>
<td>Smartphone Tablet</td>
<td>Audio recording of interviews Video recording of tasks performed Contact positions</td>
</tr>
<tr>
<td>Elderly user evaluation of mobile touchscreen interactions (Kobayashi et al., 2011)</td>
<td>Tap</td>
<td>Touch</td>
<td>Older adults, aged 60-79</td>
<td>20</td>
<td>Smartphone Tablet</td>
<td>Error rate Selection speed Contact position</td>
</tr>
<tr>
<td>Evaluating swabbing: A touchscreen input method for elderly users with tremor (Wacharamannotham et al., 2011)</td>
<td>Crossing</td>
<td>Contact(^1)</td>
<td>Older adults with tremor (slight to severe), aged 58-87</td>
<td>10</td>
<td>Mounted touch tablet</td>
<td>Finger oscillation Error rate User satisfaction</td>
</tr>
<tr>
<td>Design pattern TRABING: Touchscreen based input for people affected by intention tremor (Mertens et al., 2010)</td>
<td>Trabing</td>
<td>Contact</td>
<td>Patients with intention tremor, aged 56-91</td>
<td>15</td>
<td>Mounted touch tablet</td>
<td>Total task completion time</td>
</tr>
<tr>
<td>Towards accessible touch interfaces (Guerreiro et al., 2010)</td>
<td>Tapping</td>
<td>Touch</td>
<td>Tetraplegic patients aged 28-64</td>
<td>15(^2)</td>
<td>Touch-screen PDA</td>
<td>Video recordings Task error Precision Movement error Movement time</td>
</tr>
<tr>
<td>Improving the accuracy of touch screens: An environmental evaluation of three strategies (Potter et al., 1988)</td>
<td>Land-on</td>
<td>Touch</td>
<td>Adults (Age unspecified)</td>
<td>24</td>
<td>Mounted touch tablet</td>
<td>Speed Accuracy User satisfaction</td>
</tr>
</tbody>
</table>

3.2.1 Touch Selection

Touch selection was previously defined as selection based on the initial point of contact with the touchscreen, with subsequent touch information ignored. Six of the seven studies identified

---

\(^1\) Discussion, not experimental results
examined touch selection, and in some studies, touch selection was the only selection method examined. More recent research using smartphones as the touch device focused primarily on touch selection, likely because it is the predominant selection method used in the market currently.

Four of the studies examined touch selection on a smartphone, and each of them reported touch selection difficulty by older adults in the form of high error rates, difficulty accomplishing tasks or frustration. For example, a study of 21 older adults between the ages of 63 and 79 examined their ability to perform common smartphone tasks under naturalized conditions (Harada et al., 2013). In this study, participants were given a sandbox smartphone which recorded their activity and were asked to complete tasks that smartphones are commonly used for such as finding a contact from a list or dialling a phone number. Many errors were observed during touch interactions and both touches that were seen by the researchers but not registered by the software and touches that were unintentionally registered by the software occurred during the experiment. Similarly, another study of 20 older adults in their 60’s and 70’s that observed how older adults use touchscreens under normal task conditions found that touch error rates were unacceptably high (above 4%) for all sizes of target presented in touch selection trials (Kobayashi et al., 2011). Guerriero et al. (2010) found error rates to be even higher, with some participants missing more than one out of every five targets. Furthermore, Kobayashi et al. (2011) also observed participants frequently experiencing problems while selecting targets such as striking the wrong key on a soft keyboard or being unable to position the cursor in a textbox during practical

---

2 5 older than 55
components of the experiment. Moreover, both mistaken touches and unresponsive touches were observed to be a source of frustration (Harada et al., 2013).

In addition, in a study of 10 older adults suffering from tremor, finger oscillation was measured as the finger approached the screen to perform touch selection and again when the finger was pressed against the surface of the screen and performing a dragging motion (Wacharamanotham et al., 2011). The study found that oscillation was less when the finger was pressed against the screen as compared to when the screen was tapped in the same pattern, leading the authors to conclude that for individuals suffering from age-related fine motor decline, touch selection is less accurate than a selection method that allows the user to drag their finger along the surface of the screen. The same paper included a second experiment that showed touch selection was significantly less accurate than an implementation of lift selection (see Section 3.2.2) that predicted the target the user was moving towards and then confirmed by lifting the finger from the screen.

Three studies discussed findings related to the usability of touch selection. In Kobayashi et al.’s (2011) study, participants reported preferring a gesture that allowed them to drag their finger across the screen instead of touching. The authors speculated that this was due to lower error rates when performing a drag-type gesture as compared to touching a target. Moreover, participants in Wacharamanotham et al.’s (2011) study also found that participants rated lift selection higher than touch selection on usability factors of satisfaction and system use. In contrast, a study comparing the use of two selection methods on a PDA touchscreen by 15 tetraplegics, a third of whom were over the age of 55, found that participants preferred touch selection to an implementation of contact selection (see Section 3.2.3) requiring the participant to
drag their finger through the target (Guerreiro et al., 2010). These studies provide contrasting evidence regarding the opinions that older adults are likely to have regarding the adoption of a selection method other than touch selection. Guerreiro et al.’s (2010) study included adults under the age of 55, however, and did not report on the group under and over 55 years of age separately. It is possible that the older group rated the usability of the selection methods differently than those who were younger. More research is needed to determine whether or not older adults would consistently rate touch selection lower in usability than lift or contact selection, however most of the evidence points to older adults rating implementations of lift selection as more usable and satisfying than touch selection (Kobayashi et al., 2011; Wacharamanotham et al., 2011).

Evidence supports that touch selection is error-prone (Guerreiro et al., 2010; Harada et al., 2013; Kobayashi et al., 2011) and frustrating (Harada et al., 2013) for older adults. Two studies presented research aimed at improving touch selection by reducing error rates among older adults. For example, a study of 22 older adults 65 years and over compared touch selection performance in terms of speed and accuracy in varying conditions of size, spacing and feedback (Hwangbo et al., 2013). Participants in the study performed significantly worse with smaller targets and with less spacing. Performance when selecting large targets, however, was not affected by the spacing between targets. Additionally, participants performed significantly better with auditory and combination auditory and haptic feedback compared to haptic feedback alone. These findings are supported by Kobayashi et al.’s (2011) finding that with visual feedback only, smaller targets of 30 x 30 pixels (approximately 4.6mm x 4.6mm on the smartphone, and 11.5mm x 11.5mm on the tablet) presented a uniquely difficult challenge, and measured the average error rate at 39%. The authors observed improvement in accuracy when the targets were
larger as well as when the screen was larger. Furthermore, in a comparison of size and selection accuracy, Wacharamanotham et al. (2011) found that touch selection was not an accurate selection method for targets smaller than 54mm. Previous work indicates that touch accuracy can be improved by increasing the size of the targets, increasing the space between the targets or increasing the screen size. Furthermore, feedback such as auditory or combination auditory and haptic feedback has also been demonstrated to improve touch selection accuracy. Limitations of a smartphone make strategies other than feedback difficult to implement on a large scale. Increasing the size and spacing between targets would necessarily change the layout of existing interfaces and the device itself is required to be small enough to fit in an average person’s hand. Therefore strategies that rely on increasing the size of targets or the screen or creating additional space between targets are not optimal solutions for improving selection accuracy on a smartphone.

Touch selection is common, but older adults have been observed to make many errors (Guerreiro et al., 2010; Harada et al., 2013; Kobayashi et al., 2011) and are prone to get frustrated as a result (Harada et al., 2013). Solutions have been identified that can improve touch selection accuracy (Hwangbo et al., 2013; Kobayashi et al., 2011), but most of them are not ideal in the context of smartphones. Moreover, touch selection has been rated as less satisfying and usable compared to lift selection by older adults (Kobayashi et al., 2011; Wacharamanotham et al., 2011).

3.2.2 Lift Selection

*Lift selection* is defined in this thesis as any selection method where the location of selection is either determined or confirmed by the location of the finger at the time it is removed from the screen. Three of the seven studies identified examined a selection method that fit this definition
Every study that presented a selection method matching this definition did so using a unique implementation of the idea.

Two studies implemented lift selection as a selection strategy deliberately (Potter et al., 1988; Wacharamanotham et al., 2011), while a third study recognized dragging could be applied as a selection technique after the experiment was complete (Kobayashi et al., 2011).

Wacharamanotham et al. (2011) implemented lift selection by calculating a predicted target based on the trajectory of movement after a minimum travelled distance, which could be confirmed by the user by lifting the finger off the screen at the position of the target, or cancelled by moving the finger off the target while remaining in contact with the screen. It was proposed that the target should be highlighted when the finger collides with it, though in the experiment visual feedback was omitted. In this model, only the predicted target can be selected or cancelled, and to select a new target the finger must be removed from the screen in a neutral location before a new trajectory can be established by placing the finger back on the screen.

Wacharamanotham et al. (2011) developed the technique based on their experiments reducing finger oscillation and called it “swabbing.” A more flexible lift selection implementation is presented in Potter et al.’s (1988) comparison of three selection methods which included a technique the authors described as a “finger mouse.” In this implementation, when the finger contacted the screen, a cursor was displayed approximately half an inch above the finger which could be moved by dragging the finger along the screen. When the cursor was positioned over a selectable target, visual confirmation was provided by inverting the colours of the target and target background. Selection was determined by the position of the cursor when contact with the screen was ended. In their paper, the technique was called “take-off.” Lastly, Kobayashi et al.’s (2011) study of older adults in their 60’s and 70’s included a gesture called “drag” which
required participants to touch an image and drag it into a target zone. The action was not directly used as a selection method in the experiment, but the authors note in their discussion of the results that using a gesture similar to dragging the finger along the screen as a selection method would likely be received positively by older adults.

Both implementations of lift selection that were intentionally used as selection methods were found to be very accurate selection methods in each of their respective studies. For example, “swabbing” was found to be significantly more accurate compared to touch selection (Wacharamanotham et al., 2011). Similarly, Potter et al.’s (1988) “take-off” technique produced significantly fewer errors during interaction as compared to touch selection. Lastly, the experiment “swabbing” was based on provides further evidence that an implementation of lift selection would likely be more accurate than touch selection since for older adults with tremor finger oscillation was found to be significantly less when participants dragged their finger across the screen as compared to tapping in the same pattern (Wacharamanotham et al., 2011).

Similarly, all three studies that discussed lift selection consistently found that it was rated higher on measures of usability compared to touch selection (Kobayashi et al., 2011; Potter et al., 1988; Wacharamanotham et al., 2011). In Kobayashi et al.’s (2011) study, participants reported that they preferred interactions done with the drag gesture as opposed to the tapping gesture (touch selection), and most participants stated that dragging was the easiest gesture to perform of the gestures tested during the experiment (which also included pinching and pinching with pan) (Kobayashi et al., 2011). Moreover, lift selection was determined to be more learnable than touch selection since practising for a week was shown to significantly improve drag speed and performance for older adults on both tablets and smartphones, while touch selection showed no
such improvement. Wacharamanotham et al. (2011) found participants also rated lift selection significantly higher in measures of satisfaction and system use on the PSSUQ compared to touch selection. Lastly, in Potter et al.’s (1988) study, participants rated lift selection significantly higher than touch selection. The authors theorized that the increased usability ratings were due to the flexibility offered by the selection method. They also noted, however, that some participants “took great exception” to the cursor not being directly beneath the finger, and having to adapt to a cursor position above the finger.

Another consistent finding regarding lift selection was that it was significantly slower. Both Potter et al. (1988) and Wacharamanotham (2011) found that touch selection was significantly faster to perform compared to lift selection. Since both studies also found that lift selection was rated significantly higher on measures of usability it was theorized that speed was considered a worthwhile trade-off for improved accuracy. This theory is consistent with earlier findings presenting evidence that older adults prefer to take more time when using technology (Keates et al., 2005). Evidence supports that older adults prefer a slower, but more accurate selection method such as lift selection over a faster, but more error-prone selection method such as touch selection.

Findings related to lift selection are promising. Lift selection has been shown in multiple studies to be more accurate and rated as more usable and learnable by older adults compared to touch selection (Kobayashi et al., 2011; Potter et al., 1988; Wacharamanotham et al., 2011). Furthermore, there is evidence that the main drawback of lift selection, its slowness, is an acceptable trade-off for its improved accuracy to older adults (Keates et al., 2005; Potter et al., 1988; Wacharamanotham et al., 2011). The limitations of the research done, however,
necessitate further study to determine if these results will generalize well to any adult 60 years or older using a smartphone. For example, Kobayashi et al.’s (2011) study did not identify lift selection as a selection method initially. Furthermore, Wacharamanotham et al.’s (2011) sample size was small, and the implementation of lift selection was very strictly defined. The inability to change targets without cancelling out the predicted target may also make the implementation less desirable as compared to an implementation where the target is flexible. In comparison, selection flexibility was discussed as a potential usability feature of lift selection by Potter et al. (1988), however both studies found similar usability ratings when comparing their implementations to touch selection. In addition, two of the studies used mounted touch screens as the research apparatus instead of smartphones (Potter et al., 1988; Wacharamanotham et al., 2011). Further research is needed to determine if results from smartphones would be the same, though initial findings have been positive (Kobayashi et al., 2011). Lastly, one study focused on a specific subset of older adults (Wacharamanotham et al., 2011) and another used primarily younger adults rather than older adults in their comparison (Potter et al., 1988). Moreover, any findings that have been established may be generational, as they do not include older adults with experience from their younger years using smartphones or touchscreens.

Due to the increase in accuracy (Potter et al., 1988; Wacharamanotham et al., 2011), satisfaction (Wacharamanotham et al., 2011), learnability (Kobayashi et al., 2011) and ease of use (Kobayashi et al., 2011; Potter et al., 1988) of lift selection compared to touch selection, the authors of the papers concluded that lift selection was an appropriate alternative to touch selection. For example, Kobayashi et al. (2011) recommend that dragging should be incorporated as a selection method in place of touch whenever possible in order to improve the usability experience for older adults. Similarly, Wacharamanotham et al. (2011) concluded that lift
selection was particularly beneficial as an alternative selection method when the targets are smaller in size than 41 mm. Despite these promising results, further research is needed to establish trends considering the limitations of previous studies.

3.2.3 Contact Selection

Contact selection was defined as any selection whose location was determined by a collision between the finger and a selectable target while the finger remains in contact with the screen and whose confirmation was done without removing the finger from screen. Four of the seven studies identified examined a selection method that fit this definition (see Table 3-1).

Contact selection was often implemented very similarly to a method used on desktop computers called “crossing”, where selection is made by creating a line through the target with the mouse cursor (Wobbrock & Gajos, 2008). “Crossing” was advanced as an alternative selection method for individuals with motor impairments. As an implementation for smartphones, Guerreiro et al. (2010) use the same term, “crossing”, as well as a similar approach where the finger is required to cross through the target to select it. The same authors proposed a variant on “crossing”, called “exiting”, which required the finger to pass through the target and beyond the border of the screen in a single motion. A similar method was developed by Wacharamanotham et al. (2011) in which the target was selected by determining the target the finger collided with in the center of its trajectory across the screen. Lastly, “trabing” was described as a wiping gesture which extends beyond the dimensions of the screen and determines which target the finger collided with using a corrected trajectory calculated using a balancing curve (Mertens et al., 2010). “Trabing” was similar to “exiting”, except that the path of the finger was used to calculate a corrected curve to determine the target selected. In contrast, Potter et al. (1988) were the only
authors who included a contact selection method which was not similar to the idea of “crossing” used on the desktop. In this method, selection was determined by the first target the finger collided with after making contact with the screen. The authors commented that if the user contacts a selectable target before the desired target, the undesired target will be selected instead.

One study explored the idea of contact selection by timing participants with intention tremor as they completed a numerical entry task using contact selection (Mertens et al., 2010). Improvements were observed with practice, and the authors concluded that contact selection had potential for further research. Unfortunately, error rates were not measured. Speed was considered reflective of errors since participants were given infinite tries to complete the task and time was measured from start to finish of the task, not start to finish of each individual selection. Additionally, no measures of usability were gathered. Furthermore, in other studies when contact selection was empirically compared to touch selection in terms of accuracy, contact selection was found to be equally or less accurate (Guerreiro et al., 2010; Potter et al., 1988). Contact selection was also found to be less accurate than lift selection in the only study that compared the two methods (Potter et al., 1988).

In terms of usability, only a single study measured usability of contact selection in any form. Potter et al. (1988) found that contact selection was rated as more usable than touch selection, but that there was no difference between ratings of lift and contact selection. Since there is no evidence that contact selection would provide an accuracy benefit compared to touch selection, this single usability finding is insufficient to recommend contact selection as an adequate alternative. Furthermore, these usability findings are from a study that did not target older adults specifically.
3.3 Improving the Usability of Target Selection

Evidence supports that touch selection, the standard implementation of target selection currently available for smartphones on the market, is challenging for older adults suffering from age-related decline to execute accurately and reliably (Harada et al., 2013; Kobayashi et al., 2011; Wacharamanotham et al., 2011). The accuracy of touch selection can be improved for older adults by increasing the amount of space between targets, the size of individual targets or the size of the screen (Kobayashi et al., 2011; Wacharamanotham et al., 2011). Not all tasks can easily be modified, however, to have fewer targets or more space between targets, particularly within the context of smartphones where the screen needs to be small enough to be portable. Additionally, other authors have noted that older adults prefer not to have software or hardware designed exclusively for them, but rather would prefer to have current software and hardware be adaptable to their changing needs as they age (Renaud & van Biljon, 2010). For these reasons, a selection method that is accurate with any size of target and target spacing would be preferable.

There was no evidence to support that contact selection would be an improvement in either accuracy or usability for older adults (Mertens et al., 2010; Potter et al., 1988). Additionally, when contact selection is implemented with the target selected being the first target the finger collides with while in contact with the screen, there is a further disadvantage of being impractical in the case of individuals with the most severe tremor. Severe tremor can affect lateral oscillation of the finger, even when it is pressed downwards against the screen (Wacharamanotham et al., 2011), and therefore make sufferers more likely to experience mistakenly selected targets while using this method of target selection. Moreover, implementations that rely on trajectory calculations rely on having large amounts of space between targets (Wacharamanotham et al., 2011), which has already been established as undesirable in the context of smartphones.
Lift selection had several variations, however the evidence supports that this selection method is likely to be a more accurate selection method for older adults using a smartphone (Kobayashi et al., 2011; Wacharamanotham et al., 2011). Lift selection has shown the potential to be an appropriate substitution for touch selection due to significantly improved accuracy scores and usability ratings as compared to touch selection. However, each of the studies examined was missing a critical element needed to generalize the research further. One study did not use the dragging gesture as a selection method, another targeted older adults with tremor specifically, and the last study did not target older adults, and may not have included them at all. More research is needed to verify that lift selection is more accurate than touch selection for older adults using smartphones.

**RQ1: Does lift selection improve selection accuracy for older adults?**

In addition, evidence showed that participants were able to improve accuracy of lift selection over a period of one week of practice, while no such improvement was observed with touch selection (Kobayashi et al., 2011). With more of the population aging, it is likely that more and more older adults will enter into their advancing years with previous experience with smartphones and increasing computer literacy skills. Previous literature describing improvements in selection accuracy may not be observing all the same factors as will inevitably be at play as the current generation of adults using smartphones ages into older adults who still use smartphones. More research is necessary to identify the factors that can influence selection accuracy for both the current market solution, and any proposed alternative.

**RQ2: Are age, regular smartphone use, smartphone ownership or digit(s) used predictors of selection accuracy?**
As was previously mentioned, studies reported increased usability ratings for lift selection as compared to touch selection among older adults (Kobayashi et al., 2011; Wacharamanotham et al., 2011). These also need repetition to validate the results in the context of smartphones and a more current generation of older adults for the same reasons as discussed above. Based on research regarding age-related decline, and the previous discussion related to the challenges touch selection presents to older adults, an improved selection method would reduce working memory load by being easier to execute, reduce the time needed to learn it by being easier to learn, and reduce technology anxiety by increasing satisfaction and reducing frustration. Further research is needed to identify whether these usability factors are addressed by lift selection.

**RQ3: Which selection method is perceived as more usable?**

Lastly, two of the studies that examined a lift selection method found that touch selection was significantly faster than lift selection (Potter et al., 1988; Wacharamanotham et al., 2011). These studies concluded that accuracy was preferred over speed (Potter et al., 1988), particularly for older adults (Wacharamanotham et al., 2011). Furthermore, other studies exploring older adults’ attitudes towards technology have found that older users prefer to take longer and take more pauses while making selections and interacting with technology (Keates et al., 2005). More research would be beneficial to determine whether speed influences the usability ratings of touch and lift selection.

**RQ4: Is selection speed related to the usability ratings of either selection method?**

A summary of the research questions to be examined in this thesis is presented in Table 2-3.
<table>
<thead>
<tr>
<th>RQ1</th>
<th>Does lift selection improve selection accuracy for older adults?</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ2</td>
<td>Are age, regular smartphone use, smartphone ownership or digit(s) used predictors of selection accuracy?</td>
</tr>
<tr>
<td>RQ3</td>
<td>Which selection method is perceived as more usable?</td>
</tr>
<tr>
<td>RQ4</td>
<td>Is selection speed related to the usability ratings of either selection method?</td>
</tr>
</tbody>
</table>
Chapter 4 Methodology

This chapter describes the methodology used to answer the research questions developed in Chapter 3. The chapter begins with a discussion of the participants in the study. Afterwards, the materials used in the experiment are presented followed by a description of the design and groups. The measures are presented afterwards grouped according to the source of the measurement. Interface measures, gathered from the experimental smartphone, are discussed first and then self-report measures, gathered from the usability survey, are discussed second. The conditions completed by the participants are described last.

4.1 Participants

Participants were collected from two age demographics: a younger demographic of individuals aged 18 to 29, inclusive, and an older demographic of individuals 60 and over. One participant from the younger demographic, and one from the older confirmed their demographic, but declined to provide a numerical age. Participants from the younger demographic were mostly students at the University of Guelph during the winter semester of 2016, from no particular department, degree program or course. Younger adults were approached and asked to volunteer by the researcher in the University Center and performed the experiment immediately using a provided smartphone. See Appendix A for the script used to approach younger adults and invite them to participate in the research.

Participants from the older demographic were professors, retired professors or employees of the University of Guelph, as well as some friends and family of other participants. An initial participant list of older adults was created by reviewing online profiles of professors at the University of Guelph. The list included professors who met at least one of the following three
criteria: (1) held emeritus status, (2) were retired with an active office or phone extension, or (3) completed one or more degrees before the year 1985. These professors were invited by email to participate in the experiment. See Appendix B for the email sent to professors to invite them to participate. Since it was more convenient to sample younger adults in person, but older adults over email, a number of contextual differences were introduced in the environment each group completed the experiment. A detailed discussion of these differences is provided in Chapter 7, Section 7.1: Study Limitations.

172 potential older adults were contacted, and 19 agreed to participate. Of those that initially agreed to participate, 17 completed the experiment. The response rate was 9.8%. After completing initial interviews, some participants offered to ask friends or family of the same age demographic whether they would be willing to participate. 8 participants were solicited in this way. Older adults who agreed to participate in the study were visited by the researcher in their office or another location on campus and performed the experiment on a provided smartphone.

25 participants from each of the two age groups completed the usability study. Demographic information was obtained through a post-experimental survey. 58% of participants were male (N=29) and 42% were female (N=21).

4.1.1 Age

23 participants 60 or older and two participants over the age of 55 were interviewed. The average age of all participants over 55 years of age was 65.5 years. The oldest participant in the study was 86 and the youngest participant in the demographic was 56. The second participant who was
younger than 60 was aged 59. 68% of older participants were male (N=17) and 32% were female (N=8).

25 participants in the age group of 18 to 29, inclusive, were interviewed. The average age of participants in this age category was 20.4 years old. The youngest participant was 18 and the oldest participant in the demographic was 27. 48% of participants were male (N=12) and 52% of participants were female (N=13).

4.1.2 Smartphone Usage

Self-reported smartphone usage is broken down in Table 4-1 by experience and age demographic. Older adults were observed to report less frequent smartphone use, however over half (56%) still reported using a smartphone every day and almost a third (28%) reported using a smartphone, but less frequently than every day. Younger adults were almost unanimous in reporting daily smartphone use.

Table 4-1 Self-reported smartphone experience by demographic

<table>
<thead>
<tr>
<th>Smartphone Use Category</th>
<th>Younger Adults (N=25)</th>
<th>Older Adults (N=25)</th>
<th>All (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>0 0%</td>
<td>4 16%</td>
<td>4 8%</td>
</tr>
<tr>
<td>Once or Twice</td>
<td>0 0%</td>
<td>0 0%</td>
<td>0 0%</td>
</tr>
<tr>
<td>Occasionally</td>
<td>0 0%</td>
<td>5 20%</td>
<td>5 10%</td>
</tr>
<tr>
<td>Semi-Regularly</td>
<td>1 4%</td>
<td>2 8%</td>
<td>3 6%</td>
</tr>
<tr>
<td>Every Day</td>
<td>24 96%</td>
<td>14 56%</td>
<td>38 76%</td>
</tr>
</tbody>
</table>

4.1.3 Smartphone Ownership

The percentage of participants who reported owning each type of mobile phone is listed in Table 4-2. Since so few participants reported either owning a feature phone or not owning a phone, the
feature phone and no phone groups were collapsed into a single no smartphone group for the purposes of analysis, also shown in Table 4-2.

Older adults were more likely to report owning a feature phone or not owning a mobile phone compared to younger adults, with all younger adults reporting owning a smartphone. Only older adults fell into the category of “no smartphone” described above.

Table 4-2 Self-reported smartphone ownership by demographic

<table>
<thead>
<tr>
<th>Type of Mobile</th>
<th>Younger Adults (N=25)</th>
<th>Older Adults (N=25)</th>
<th>All (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smartphone</td>
<td>25 100%</td>
<td>19 76%</td>
<td>44 88%</td>
</tr>
<tr>
<td>Feature Phone</td>
<td>0 0%</td>
<td>3 12%</td>
<td>3 6%</td>
</tr>
<tr>
<td>No Phone</td>
<td>0 0%</td>
<td>3 12%</td>
<td>3 6%</td>
</tr>
<tr>
<td>No Smartphone</td>
<td>0 0%</td>
<td>6 24%</td>
<td>6 12%</td>
</tr>
</tbody>
</table>

4.1.4 Handedness

During the experiment, participants were asked to make selections of variously sized targets using either touch or lift selection methods on a smartphone (see Section 4.5.1 for definitions of touch and lift, and Appendix H for a summary of the experimental protocol). Participants were given the freedom of holding the smartphone however was comfortable (see Table 4-3). Handedness was recorded by the researcher. Participants were not asked to report on their own handedness because they were given the freedom to use whichever hand they were most comfortable with to make selections and the hand used was recorded for later analysis.

To confirm that handedness (left, right) was not a consequential factor in the analysis of selection accuracy of either demographic (younger, older) or selection method (touch, lift), a split plot ANOVA was performed. There was no main effect of handedness on accuracy, $F(2, 45) = 1.031$, ns (not significant), no significant interaction between handedness and demographic, $F(1, 45) =$
.737, ns, no significant interaction between handedness and selection method, F(2, 45) = .294, ns, and no significant interaction between handedness, selection method and demographic, F(1, 45) = .707, ns. Therefore, there was no effect of handedness in the analysis of the research questions.

Older adults were more likely to elect to hold the phone in one hand or the other, leaving the opposite hand free to perform selection. In contrast, younger adults were more likely to use both hands to hold the phone, and use one hand both to support the phone’s weight and to perform selection.

Table 4-3 Observed supporting hand strategies by demographic

<table>
<thead>
<tr>
<th>Supporting Hand Strategy</th>
<th>Younger Adults (N=25)</th>
<th>Older Adults (N=25)</th>
<th>All (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left hand only</td>
<td>7 28%</td>
<td>12 48%</td>
<td>19 38%</td>
</tr>
<tr>
<td>Both hands</td>
<td><strong>12 48%</strong></td>
<td>3 12%</td>
<td>15 30%</td>
</tr>
<tr>
<td>Right hand only</td>
<td>4 16%</td>
<td>5 20%</td>
<td>9 18%</td>
</tr>
<tr>
<td>Used surface</td>
<td>1 4%</td>
<td>2 8%</td>
<td>3 6%</td>
</tr>
<tr>
<td>Left hand with right bracing</td>
<td>0 0%</td>
<td>3 12%</td>
<td>3 6%</td>
</tr>
<tr>
<td>Right hand with left bracing</td>
<td>1 4%</td>
<td>0 0%</td>
<td>1 2%</td>
</tr>
</tbody>
</table>

A variety of strategies were observed in terms of how selection was performed when no direction was given beyond the touch requirements needed to complete selection. A complete list of strategies observed is given in Table 4-4, and these strategies are broken down according to hand and digit in Table 4-5. Overall, the three most common strategies used were selecting with the right index finger only (46%, N=23), selecting with the right thumb only (26%, N=13) and selecting using a mix of the two (8%, N=4).
Table 4-4 Observed selecting hand strategies by demographic

<table>
<thead>
<tr>
<th>Selecting Hand Strategy</th>
<th>Younger Adults (N=25)</th>
<th>Older Adults (N=25)</th>
<th>All (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right index only</td>
<td>9 36%</td>
<td>14 56%</td>
<td>23 46%</td>
</tr>
<tr>
<td>Right thumb only</td>
<td>10 40%</td>
<td>3 12%</td>
<td>13 26%</td>
</tr>
<tr>
<td>Right hand mixed thumb and index</td>
<td>3 12%</td>
<td>1 4%</td>
<td>4 8%</td>
</tr>
<tr>
<td>Right and left thumb</td>
<td>2 8%</td>
<td>- 0%</td>
<td>2 4%</td>
</tr>
<tr>
<td>Left index only</td>
<td>- 0%</td>
<td>2 8%</td>
<td>2 4%</td>
</tr>
<tr>
<td>Left middle only</td>
<td>- 0%</td>
<td>2 8%</td>
<td>2 4%</td>
</tr>
<tr>
<td>Right thumb and left index</td>
<td>1 4%</td>
<td>- 0%</td>
<td>1 2%</td>
</tr>
<tr>
<td>Right hand mixed index and little</td>
<td>- 0%</td>
<td>1 4%</td>
<td>1 2%</td>
</tr>
<tr>
<td>Right middle only</td>
<td>- 0%</td>
<td>1 4%</td>
<td>1 2%</td>
</tr>
<tr>
<td>Right hand mixed thumb, middle and little</td>
<td>- 0%</td>
<td>1 4%</td>
<td>1 2%</td>
</tr>
</tbody>
</table>

Table 4-5 Breakdown of selecting hand and digit combinations by demographic

<table>
<thead>
<tr>
<th>Selecting Hand</th>
<th>Selecting Digit</th>
<th>Younger Adults (N=25)</th>
<th>Older Adults (N=25)</th>
<th>All (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Hand</td>
<td>Thumb</td>
<td>16 64%</td>
<td>4 16%</td>
<td>20 40%</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>12 48%</td>
<td>16 64%</td>
<td>28 56%</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>- 0%</td>
<td>2 8%</td>
<td>2 4%</td>
</tr>
<tr>
<td></td>
<td>Pinky</td>
<td>- 0%</td>
<td>2 8%</td>
<td>2 4%</td>
</tr>
<tr>
<td>Left Hand</td>
<td>Thumb</td>
<td>2 8%</td>
<td>- 0%</td>
<td>2 4%</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>1 4%</td>
<td>2 8%</td>
<td>3 6%</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>- 0%</td>
<td>2 8%</td>
<td>2 4%</td>
</tr>
<tr>
<td></td>
<td>Pinky</td>
<td>- 0%</td>
<td>- 0%</td>
<td>- 0%</td>
</tr>
</tbody>
</table>

The hand and finger used to select varied widely among older participants, while being quite consistent among younger participants. Additionally, younger adults seemed more comfortable using their thumbs to perform target selection tasks compared to older adults who seemed to avoid using the thumb as a selection digit. In contrast, both older and younger adults seemed comfortable performing target selection with their index fingers. Figure 4-1 illustrates the differences in variation of selecting hands and digits between younger and older adults.
Table 4-6 lists the combination of smartphone supporting and selecting hand(s). Based on this table, the proportion of hand sameness, defined as using the same supporting hand as the selecting hand\(^3\), for each demographic can be determined. Hand sameness is summarized in Table 4-7. Younger and older adults showed distinctly different holding patterns in terms of hand sameness. Younger adults were more likely to hold the phone in the same hand as the hand they used to select targets and older adults were more likely to use opposite hands.

\(^3\) If both hands were used equally as the supporting hand, then any selecting hand was considered as “the same hand”
### Table 4-6 Summary of supporting and selecting hand combinations

<table>
<thead>
<tr>
<th>Supporting</th>
<th>Selecting</th>
<th>Younger Adults (N=24)</th>
<th>Older Adults (N=23)</th>
<th>All (N=47)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both Hands</td>
<td>Right Hand</td>
<td>10 42%</td>
<td>4 17%</td>
<td>14 30%</td>
</tr>
<tr>
<td></td>
<td>Left Hand</td>
<td>0 0%</td>
<td>0 0%</td>
<td>0 0%</td>
</tr>
<tr>
<td></td>
<td>Both Hands</td>
<td>2 8%</td>
<td>0 0%</td>
<td>2 4%</td>
</tr>
<tr>
<td>Right Hand</td>
<td>Right Hand</td>
<td>4 17%</td>
<td>0 0%</td>
<td>4 9%</td>
</tr>
<tr>
<td></td>
<td>Left Hand</td>
<td>0 0%</td>
<td>4 17%</td>
<td>4 9%</td>
</tr>
<tr>
<td></td>
<td>Both Hands</td>
<td>1 4%</td>
<td>0 0%</td>
<td>1 2%</td>
</tr>
<tr>
<td>Left Hand</td>
<td>Right Hand</td>
<td>7 29%</td>
<td>15 65%</td>
<td>22 47%</td>
</tr>
<tr>
<td></td>
<td>Left Hand</td>
<td>0 0%</td>
<td>0 0%</td>
<td>0 0%</td>
</tr>
<tr>
<td></td>
<td>Both Hands</td>
<td>0 0%</td>
<td>0 0%</td>
<td>0 0%</td>
</tr>
</tbody>
</table>

### Table 4-7 Summary of supporting and selecting hand sameness by demographic

<table>
<thead>
<tr>
<th>Supporting/Selecting Sameness</th>
<th>Younger Adults (N=24)</th>
<th>Older Adults (N=23)</th>
<th>All (N=47)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same hand</td>
<td>16</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Different hand</td>
<td>8</td>
<td>19</td>
<td>27</td>
</tr>
</tbody>
</table>

### 4.2 Materials

Materials used in the experiment included four components. The introduction and instructional aids were used to familiarize participants with the experiment they were going to perform. The smartphone device was used to run the experimental interface software, which together gathered the accuracy and speed measures used in the analysis (see Section 4.4.1 for a discussion of interface measures). Lastly, the usability survey, filled out on paper, was used to collect usability and demographic measures (see Section 4.4.2 for a discussion of usability survey measures).

#### 4.2.1 Introduction and Instruction Aids

The introduction to the experiment consisted of a different script for each group as older adults had already received an introductory email and younger adults were approached in person

---

4 Individuals who independently sought out a surface to place the phone on were not included in this analysis
5 Individuals who independently sought out a surface to place the phone on were not included in this analysis
without having previously interacted with the researcher (see Appendices A and B for each version of the script).

**Introduction Script:** Both scripts briefly described the purpose and steps of the study, and each participant was asked to confirm their age demographic and sign an informed consent document before continuing. See Appendix C for the informed consent document. Every participant was given a verbal overview of the informed consent document and then time to read and sign it as well as ask any questions. See Appendix D for the consent form overview script.

**Experiment Instructions:** The participant was given the smartphone and instructed to hold it in the portrait position however was comfortable to them. A brief tutorial of each selection method, including a demonstration using a printed image of the target selection screen, was given. The researcher demonstrated touch selection first, and lift selection second. Participants were shown how lift selection could be used like touch selection or like a dragging motion, starting off the target and ending on the target. Participants were also shown how lift selection could be used to correct selection if the wrong target was selected initially, either by moving to a different target or by moving the finger off of the target to neutral space. Older participants were given a copy of the instructions printed on paper for their reference in case they were unsure and wanted to re-read any part during the experiment. Younger participants read the instructions on the smartphone only and were not provided with a paper copy of the instructions. The instructions provided on the smartphone were identical to the instructions provided on the paper copy. The paper copy of the instructions was printed in large, bold font to ease reading for older participants. Instructions were provided on paper for older adults after beta experimentation led to the conclusion that older adults may be less comfortable with on screen instructions compared
to younger adults or may need to re-read them to understand the experiment with equal clarity to younger adults. Moreover, the older participant in the beta study had a clear preference for the paper instructions. Since the paper instructions were not different, were presented in the same order and presented at the same time as the on-screen instructions, it was decided that the addition of paper instructions would ease the experience for some older participants without having a significant confounding effect on the overall results of the study. See Appendix E for the instructions given to the participants.

4.2.2 Smartphone

The experimental interface was run on a smartphone purchased for the project. Every participant used the same smartphone to complete the experiment. The smartphone used was the BLU Life One M 4GB running Android 4.2 Jelly Bean.

4.2.3 Experimental Interface

**Design:** The experimental interface consisted of two target selection tasks, each using a different selection method (touch/lift). For each selection method, the task set consisted of 3 rounds of 12 selections (see Table 4-8). Each round presented different sized targets (see Figure 4-2 showing the screen flow for each round). The pace was controlled by the participant, with each trial only beginning once he/she signalled readiness by touching the “continue” button. The measurements captured by the experimental interface were accuracy and speed. These measures are discussed further in Section 4.4.
Table 4-8 Selection methods and target sizes

<table>
<thead>
<tr>
<th>Selection Method</th>
<th>Target Size Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touch</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>Lift</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td>Large</td>
</tr>
</tbody>
</table>

Development: The experimental interface was written in Java using the Android Studio IDE (Integrated Development Environment). The primary software architecture pattern used was MVC (Model-View-Controller), however the factory pattern was also employed to automate the instantiation of intents used to load each activity view. The controller directed the flow between the interface views and the data models of the interfaces (each size and selection method
combination was considered a single interface object in the application), trials and participants.

In total, there were eleven activity view classes:

1. App Home Screen – for entering participant ID to begin the experiment and test interfaces
2. Introduction and Instructions Screen – for displaying experiment instructions
3. Selection Method Instructions Screen – for displaying selection method instructions
4. Practice Screen – for testing participants’ understanding of each selection method
5. Target Screen – for displaying progress and the next target to be selected
6. Small Lift Selection Screen – for selecting small targets with lift selection
7. Average Lift Selection Screen – for selecting average targets with lift selection
8. Large Lift Selection Screen – for selecting large targets with lift selection
9. Small Touch Selection Screen – for selecting small targets with touch selection
10. Average Touch Selection Screen – for selecting average targets with touch selection
11. Large Touch Selection Screen – for selecting large targets with touch selection

Once results were gathered, the Apache POI library was used to write the participant’s data to a few different Excel spreadsheets. The data was exported to a master spreadsheet, a backup master spreadsheet, an individual spreadsheet for that participant only and a backup of the individual spreadsheet.

4.2.4 Usability Survey

On completion of the tasks, participants completed a usability survey rating the ease, learnability and satisfaction for each selection method. Additionally, the survey collected demographic
information such as type of phone owned, and frequency of use. See Appendix F for the post-experimental survey.

4.3 Design

4.3.1 Experimental Design Beta Testing

To ensure that data collection went smoothly, a beta test was conducted with a participant from each age demographic. The beta test ran through the entire experiment, including the memorization of scripts, signing of the informed consent document, completing the usability interface tasks and filling out the survey. Beta testing led to the modification of the experiment protocol to include paper instructions and a selection method demonstration before the participant was given the smartphone. Additionally, the electronic survey was dropped in favour of a paper survey. The beta tests also helped refine the language used in the instructions and improve the interface to better test the effectiveness of the selection method without interference from other issues such as remembering the current target or being confused about what to do during the study. One of the most important findings of the beta tests was that instructions were unclear for participants, and particularly ineffective at describing the selection method that the study was designed to test. A summary of the results from the beta testing can be found in Appendix G.

4.3.2 Experimental Groups

A convenience sampling method was used to acquire participants. Participants were selected based on demographic cluster. The two demographics of interest were older adults, adults 60 and over, and younger adults, adults between the ages of 18 and 29 inclusive.
4.4 Measures

The following were collected:

1. accuracy and speed of target selection
2. target size and selection method
3. usability ratings
4. demographic information – discussed in Section 4.1
5. handedness and selecting digit(s) – discussed in Section 4.1.4

4.4.1 Interface

The experimental interface captured the accuracy and speed of each trial and recorded its associated target ID, target size, and selection method.

Accuracy: Each selection’s accuracy was recorded as either 1 (i.e. the target was selected successfully) or 0 (i.e. the target was not selected successfully). For each participant, accuracy was compiled for each target size and selection method.

Speed: Speed was defined as the time between the participant’s indication of readiness and the completion of the selection task. The participant indicated readiness to begin another task by touching a large button labelled “continue” and timing began as soon as the next screen was loaded. For touch selection, timing stopped when the participant’s finger or thumb made contact with the screen and for lift selection, timing stopped when the participant’s finger or thumb was removed from the screen.
4.4.2 Usability Survey

The usability survey consisted of three questions for each selection method as well as demographic questions. Questions were answered on a five-point Likert scale. The usability survey appears in Appendix F.

**Ease:** Ease was defined as how easy the participant felt it was to complete the task using each selection method. The question on the survey used to collect a measure of ease was “on a scale from 1 to 5, rate how easily you were able to select a shape by [touching/dragging and lifting]” with 1 being “very difficult” and 5 being “very easy.” Participants rated both touch and lift selection separately for ease.

**Satisfaction:** Satisfaction was defined as how emotionally gratifying the selection method was. In practice, this measure seemed to be perceived as a rating of how “not frustrating” the selection method was to perform. The question on the survey used to collect a measure of satisfaction was “on a scale from 1 to 5, rate how satisfied you were with selecting a shape by [touching/dragging and lifting]” with 1 being “really not satisfied” and 5 being “really satisfied.” Participants rated both touch and lift selection separately for satisfaction.

**Learnability:** Learnability was defined as how easily the selection method was to learn to use initially, regardless of how easy it was to use once learned. This measure received negative feedback from some participants who were uncomfortable reporting on the ease with which they initially learned to perform touch selection. A few participants reported having used touch selection for so long that they could not remember a time when they had to learn it. The question on the survey used to collect a measure of learnability was “on a scale of 1 to 5, how easy was it
to learn selection by [touching/dragging and lifting]” with 1 being “very difficult” and 5 being “very easy.” Participants rated both touch and lift selection separately for learnability.

**Smartphone Ownership:** Smartphone ownership was measured in terms of type of phone owned (No phone, feature phone, or smartphone), the number of years each type of phone was owned was not requested in the survey.

**Smartphone Usage:** How frequently individuals used smartphones on a routine basis was collected by asking participants to select which of five experience categories best represented them. The options for smartphone usage are summarized below:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I’ve never used a smartphone</td>
</tr>
<tr>
<td>2</td>
<td>I’ve used a smartphone once or twice</td>
</tr>
<tr>
<td>3</td>
<td>I’ve used a smartphone occasionally</td>
</tr>
<tr>
<td>4</td>
<td>I use a smartphone semi-regularly</td>
</tr>
<tr>
<td>5</td>
<td>I use a smartphone every day</td>
</tr>
</tbody>
</table>

Participants were not asked for how many years they had had smartphone experience or for any other measures of previous smartphone experience.

**4.5 Conditions**

As previously discussed, every participant completed every condition. Selection method was divided into two conditions: touch selection and lift selection. Target size was divided into three conditions: small targets of 5 by 7 mm, average targets of 10 by 13 mm, and large targets of 15 by 20 mm. A summary of groups and conditions is given in Table 4-10 with groups shown in bold and conditions shown in regular text.
4.5.1 Selection Method

Two selection methods were compared in the current study: touch selection and lift selection. All size conditions were completed with both selection methods.

**Touch Selection:** For the purposes of the literature review, touch selection was defined as any selection method where the target selected is determined based on the initial point of contact with the touchscreen with all other touch input ignored. This definition, however, can be implemented in several different ways, as discussed in the previous chapter. For the experimental portion of the thesis, touch selection was implemented by taking the first point of contact with the screen and selecting the target at that point if a selectable target was located there. No visual, auditory or haptic feedback was provided for touch selection. Any movement from the finger after initial contact was ignored and cancelling touch selections was prohibited.

**Lift Selection:** In the previous chapter, lift selection was defined as any selection method where the location of selection is either determined or confirmed by the location of the finger at the time it is removed from the screen. Due to the nature of this selection method, lift selection has an even broader variety of implementations. In the experimental portion of this thesis, lift...
selection was implemented by taking the final point of contact with the screen and selecting the target at that point if a selectable target was located there. Visual feedback was provided to the participant in the form of greying the background of the target when the finger came into contact with it, and remained greyed unless the finger was moved off the target while still in contact with the screen. No auditory or haptic feedback was used.

4.5.2 Target Size

Three target size conditions were completed using every selection method. To keep the spacing proportional and the spatial relationships between the targets similar between conditions, the targets were placed in relation to the center of the screen. All three target sizes are shown in Figure 4-3.
Chapter 5 Results

This chapter presents the findings from the study relevant to each of the research questions established in Chapter 3. Each research question will provide its own introduction with a breakdown of the flow for that question’s findings and rationale for doing so before presenting relevant results.

Summary of Findings: Accuracy was significantly, but marginally, higher for younger adults when using touch selection, but there was no difference in accuracy between younger and older adults when using lift selection. More older adults experienced a benefit from using lift selection than younger adults. Touch selection was significantly more accurate than lift selection for younger adults across all size conditions, but only more accurate for older adults when selecting small targets. For average and large-sized targets, there was no difference in accuracy between touch and lift selection for older adults. Accuracy of touch selection was predicted by self-reported routine smartphone use, as well as age for older adults, while accuracy of lift selection was not predicted by any of the examined factors for either younger or older adults.

There was no difference in ratings of ease, satisfaction or learnability between younger and older adults for either selection method. Usability ratings of ease, satisfaction and learnability were higher for touch selection as compared to lift selection among both younger and older adults. Participants who owned smartphones felt that lift selection was less usable than participants who did not own smartphones, but felt no differently about touch selection. Participants who did not own smartphones (mean age of 63.6) found no difference in usability between touch selection and lift selection.
Touch selection was faster than lift selection, however older adults did not perform either touch or lift selection significantly slower than younger adults. Individuals who rated touch selection as easier to perform, also performed touch selection faster. There was no relationship between touch selection speed and usability of touch selection overall or between touch selection speed and other touch selection usability factors. Lift selection speed was not related to usability ratings of lift selection overall, or any of its factors of ease, satisfaction and learnability.

5.1 RQ1: Does lift selection improve selection accuracy for older adults?

This section begins by presenting the accuracy performance of younger and older adults. Each demographic is then examined in more detail regarding the effects of selection method and target size on accuracy for each age group.

5.1.1 Demographic Comparison of Accuracy

**Finding:** As shown in Figure 5-1, accuracy was significantly, but marginally, higher for younger adults when using touch selection, but there was no difference in accuracy between younger and older adults when using lift selection. As seen if Figure 5-2, more older adults (24%, N=6) experienced some benefit from lift selection than younger adults (4%, N=1).
Figure 5-1 Accuracy of touch and lift selection by demographic

Figure 5-2 Percentage of participants who improved with lift selection in each demographic
**Analysis:** An independent groups t-test showed that when performing touch selection, younger adults (M=99.44, SD=1.61) performed significantly more accurately, t(48) = -2.368, p = .011, than older adults (M=96.98, SD=4.94). When performing lift selection, however, no significant difference was found, t(44.588) = -.463, ns, between younger adults (M=88.11, SD=7.15) and older adults (M=87.28, SD=5.38).

Despite no significant difference in performance overall, some participants did show improvement in accuracy when using lift selection as compared to touch selection. Observed accuracy improvement was defined as having scored higher in accuracy using lift selection compared to touch selection in at least one size condition. A chi squared test was used to examine the independence between demographic and observed accuracy improvement. The analysis was significant, χ²=4.153, p=.042, indicating a poor independent fit between demographic and observed accuracy improvement. Looking at Figure 4-2, older adults (24%, N=6) were more likely to experience some accuracy benefit when using lift selection as compared to younger adults (6%, N=1). The average age of the older group who experienced some accuracy benefit when using lift selection was 68.6 years old.

5.1.2 Accuracy of Younger Adults

**Finding:** As shown in Figure 5-3, touch selection was significantly more accurate than lift selection for younger adults. Additionally, the lowest accuracy occurred when selecting small targets using lift selection.
Figure 5-3 Accuracy of younger adults by target size and selection method

**Analysis:** To examine the effect of selection method (touch, lift) and target size (small, average, large) on selection accuracy, a two-way repeated measures ANOVA was performed. The interaction between selection method and target size was significant, $F(2, 48) = 60.170$, $p < .001$ and the interaction was explored with simple main effects post hoc. The effect of selection method was significant with touch selection accuracy scores being significantly higher than lift selection accuracy scores at the small, $F(1, 24) = 159.41$, $p < .001$, and large, $F(1, 24) = 9.33$, $p = .005$, sizes and approaching significance at the average size, $F(1, 24) = 3.47$, $p = .075$. The effect of target size was significant for lift selection, $F(2, 48) = 62.525$, $p < .001$. Specifically, when using lift selection, accuracy was significantly lower for small targets as compared to average sized targets, $p < .001$, and large targets, $p < .001$, but there was no significant difference between average sized and large targets. There was no significant effect of target size for touch selection, $F(1.448, 34.764) = .658$, ns.
The main effect of selection method was significant for the demographic, $F(1, 24) = 66.749$, $p < .001$, as was the main effect of target size, $F(2, 48) = 60.289$, $p < .001$. These significant main effects should be interpreted, however, within the context of the significant interaction.

5.1.3 Accuracy of Older Adults

**Finding:** As shown in Figure 5-4, when compared to lift selection, older adults were more accurate using touch selection to select small targets; however, for average and large-sized targets, there was no difference in accuracy between touch and lift selection.

![Figure 5-4 Accuracy of older adults by target size and selection method](image)

**Analysis:** To examine the effect of selection method (touch, lift) and target size (small, average, large) on selection accuracy, a two-way repeated measures ANOVA was performed, with corrections for violations in sphericity corrected using the Greenhouse-Geisser correction. A significant interaction was found between selection method and size, $F(1.649, 39.567) = 39.334,$
p < .001, which was explored with simple main effects post hoc. The effect of selection method was only significant at the small target size, F(1, 24) = 74.397, p < .001, with touch selection accuracy being higher than lift selection accuracy. The effect of selection method was not significant at the average target size, F(1, 24) = 1.105, ns, and approached significance at the large target size, F(1, 24) = 3.799, p = .063. The effect of size was significant for lift selection, F(1.579, 37.885) = 73.429, p < .001. Specifically, when using lift selection, accuracy was significantly lower when selecting smaller target sizes as compared to average target sizes, p < .001, and large target size, p < .001, but there was no significant difference in accuracy between average and large targets. The effect of size approached significance for touch selection, F(1, 24) = 3.799, p = .063, and no significant differences were found between small and average, small and large or average and large sizes.

The main effect of selection method was significant, F(1, 24) = 80.062, p < .001, as was the main effect of size, F(1.453, 34.881) = 63.119, p < .001, however these main effects should be interpreted within the context of the significant interaction described above.

5.2 RQ2: Are age, regular smartphone use, smartphone ownership or digit(s) used predictors of selection accuracy?

This section discusses touch selection trials first, then lift selection. Results are discussed for the entire sample (N=50), and when relevant, age-related distinctions are made.
5.2.1 Touch Accuracy Factors

Summary of Findings: Accuracy of touch selection was predicted by self-reported routine smartphone use, as well as age, though age was only predictive in older adults. Accuracy of touch selection was not predicted by any other factor.

Digit Finding: Accuracy of touch selection was not predicted by selection digit.

Digit Analysis: To determine whether the digit used to perform the selection (thumb, index, middle) had an effect on accuracy during touch trials, a one-way analysis of variance was performed. Levene’s test was insignificant, Levene’s F(2, 47) = 1.570, ns, indicating that the homogeneity of variance assumption was fulfilled. There was no significant effect found of digit used on accuracy during touch trials, F(2, 47) = 2.574, ns.

Ownership Finding: Accuracy of touch selection was not predicted by smartphone ownership.

Ownership Analysis: To explore the effect of owning a smartphone on accuracy during touch trials, an independent groups t-test was performed. There was no significant difference, t(5.470) = -.854, ns, between smartphone owners (M=98.47, SD=3.48) and non-smartphone owners (M=96.33, SD=5.99) with regards to accuracy during touch trials.

Usage Finding: As shown in Figure 5-5, self-reported smartphone use was weakly and positively predictive of touch selection accuracy. Specifically, as self-reported smartphone use increased, touch selection accuracy also increased.
Usage Analysis: To analyze whether the level of routine smartphone usage was predictive of accuracy during touch trials, a linear regression analysis was performed. A scatterplot showing accuracy during touch trials plotted against self reported smartphone usage is shown in Figure 5-5. A significant, but weak, correlation was found between self-reported smartphone experience and touch accuracy, $r^2(48) = .171$, $p = .003$. The correlation was positive, such that as routine smartphone usage increased, accuracy during touch trials also increased.

Age Finding: As shown in Figure 5-6, age was moderately and negatively predictive of touch selection accuracy among older adults. Specifically, a gradual decline in average accuracy during touch selection tasks was observed in older adults.
Age Analysis: To examine the relationship between accuracy during touch trials and participant age, a linear regression analysis was performed. A scatterplot showing accuracy during touch trials plotted against age for older adults only is shown below. Looking exclusively at participants in the older demographic, age was found to be a moderate predictor of variability in touch accuracy, $r^2(23) = .359$, $p = .002$. The correlation was negative, such that as age increased, accuracy during touch trials decreased. The scatterplot for touch accuracy and age for older adults visually indicates that a curve might fit more appropriately than a line. A curve analysis was performed, and it was found that a quadratic curve fits this range of data significantly and slightly more strongly than a straight line, $r^2(23) = .377$, $p = .007$. Looking across all ages, there was no significant correlation between age and touch accuracy, $r^2(48) = .016$, $p = .386$.

Combined Factor Finding: As shown in Figure 5-7, for older adults, the combination of age (moderate and negative) and experience (weak and positive) was a significant predictor of touch
accuracy. The graph shows age along the horizontal axis and self-reported routine smartphone use in a range of colours, with cooler colours (i.e. green and blue) indicating more routine smartphone use and warmer colours (i.e. red, orange and yellow) indicating less routine smartphone use. Accuracy scores that are higher tended to be towards the left of the graph (i.e. younger), cooler in colour (i.e. more routine smartphone use), or both and accuracy scores that are lower tended to be towards the right on the graph (i.e. older), warmer in colour (i.e. less routine smartphone use), or both.

**Combined Factor Analysis:** Since two factors were found to correlate with accuracy during touch trials, a multiple regression analysis was performed to see how much of the variance in the
touch accuracy trials could be explained by significant predictors. The factors included in the analysis were age and self-reported smartphone usage. Factors that were discarded for the multiple regression analysis were ownership and selection digit. Since age was only found to be a significant predictor for older adults, they were the only participants included in the analysis. For older adults, the combination of age and experience was a significant predictor of touch accuracy and accounted for 46% of its variation, \( r^2(23) = .461, p = .002 \). It is worth noting that despite both being used as predictive weights, the factors in the analysis have opposing predictive influence (i.e. age is negatively correlated while smartphone usage is positively correlated).

5.2.2 Lift Accuracy Factors

**Summary of Findings:** None of the suggested factors predicted variance in accuracy scores during lift selection trials. Accuracy during lift selection tasks was not correlated or significantly related to self-reported routine smartphone use, smartphone ownership, age or the digit used for gesturing.

**Digit Finding:** Accuracy of lift selection was not predicted by the selecting digit.

**Digit Analysis:** To determine whether the digit used to perform the selection (thumb, index, middle) had an effect on accuracy during lift trials, a one-way analysis of variance was performed. Levene’s test was insignificant, Levene’s \( F(2, 47) = 1.31, \) ns, indicating that the homogeneity of variance assumption was fulfilled. There was no significant effect found of digit used on accuracy during lift trials, \( F(2, 47) = .092, \) ns.

**Ownership Finding:** Accuracy of lift selection was not predicted by smartphone ownership.
Ownership Analysis: To explore whether smartphone ownership influenced the accuracy with which lift selection was used to select targets, an independent measures t-test was used. There was no significant difference in accuracy during lift selection trials, t(48) = -1.005, ns, between smartphone owners (M=88.02, SD=6.35) and non smartphone owners (M=85.23, SD=5.64).

Usage Finding: Accuracy of lift selection was not predicted by self-reported routine smartphone usage.

Usage Analysis: To examine the relationship between routine smartphone usage and lift selection accuracy, a linear regression analysis was performed. No significant correlation was found between self-reported smartphone usage and lift selection accuracy, r²(48) = .022, p = .303.

Age Finding: Accuracy of lift selection was not predicted by age.

Age Analysis: The relationship between age and accuracy during lift trials was explored using a linear regression analysis. Among older adults, no correlation could be identified between accuracy when using lift selection and age, r²(23) = .149, ns. Looking across both demographics, no significant correlation could be identified between accuracy when using lift selection and age, r²(48) = .016, ns.

5.3 RQ3: Which selection method is perceived as more usable?

This section first presents a summary of the reported usability measures for both older and younger adults and the two demographics are compared. Afterwards, a discussion is presented of differences in usability ratings between selection methods for both younger and older adults.
5.3.1 Usability Ratings Comparison

**Finding:** As shown in Figure 5-8, there was no difference in ratings of ease, satisfaction or learnability between younger and older adults for either selection method.

![Usability ratings of touch and lift selection by demographic](image)

**Figure 5-8 Usability ratings of touch and lift selection by demographic**

**Analysis:** The differences in views regarding touch selection between younger and older adults are summarized in Table 5-1. A Mann-Whitney U test was used to analyse survey responses between age groups. There was no significant difference between reported ease of use ($Z = -.403$, $p = .687$), satisfaction ($Z = -.218$, $p = .828$) or learnability ($Z = -.183$, $p = .855$).
Table 5-1 Usability perceptions of touch selection by demographic

<table>
<thead>
<tr>
<th></th>
<th>Younger Adults (N=25)</th>
<th>Older Adults (N=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ease</strong></td>
<td>4.84</td>
<td>4.88</td>
</tr>
<tr>
<td><strong>Satisfaction</strong></td>
<td>4.76</td>
<td>4.80</td>
</tr>
<tr>
<td><strong>Learnability</strong></td>
<td>4.72</td>
<td>4.84</td>
</tr>
</tbody>
</table>

The differences in views regarding lift selection between younger and older adults are summarized in Table 5-2. A Mann Whitney U test was used to analyse survey responses between age groups. There was no significant difference between reported ease of use (Z=-.230, p=.687), satisfaction (Z=-1.277, p=.201) or learnability (Z=-.523, p=.601).

Table 5-2 Usability perceptions of lift selection by demographic

<table>
<thead>
<tr>
<th></th>
<th>Younger Adults (N=25)</th>
<th>Older Adults (N=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ease</strong></td>
<td>4.44</td>
<td>4.44</td>
</tr>
<tr>
<td><strong>Satisfaction</strong></td>
<td>3.88</td>
<td>4.20</td>
</tr>
<tr>
<td><strong>Learnability</strong></td>
<td>4.32</td>
<td>4.32</td>
</tr>
</tbody>
</table>

5.3.2 Usability Ratings by Younger Adults

**Finding:** As shown in Figure 5-9, usability ratings of ease, satisfaction and learnability were higher for touch selection as compared to lift selection among younger adults.
Analysis: The results from the usability survey for younger adults are given in Table 5-3. A Wilcoxon signed rank test was used to analyse the results of the survey. Participants rated lift selection significantly lower than touch selection for ease of use. The average difference between touch and lift ratings of ease of use was 0.4 points in favour of touch selection ($Z=-2.496$, $p=.013$). Participants rated lift selection significantly lower than touch selection for satisfaction. The average difference between touch and lift ratings of satisfaction was 0.88 points in favour of touch selection ($Z=-3.156$, $p=.002$). Participants rated lift selection significantly lower than touch selection for learnability. The average difference between touch and lift ratings of learnability was 0.4 points in favour of touch selection ($Z=-2.124$, $p=.034$).
### Table 5-3 Usability perceptions of younger adults towards touch and lift selection

<table>
<thead>
<tr>
<th></th>
<th>Touch</th>
<th>Lift</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>N</em>=25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ease</strong></td>
<td>4.84</td>
<td>4.44</td>
<td>+0.40</td>
</tr>
<tr>
<td><strong>Satisfaction</strong></td>
<td>4.76</td>
<td>3.88</td>
<td>+0.88</td>
</tr>
<tr>
<td><strong>Learnability</strong></td>
<td>4.72</td>
<td>4.32</td>
<td>+0.40</td>
</tr>
</tbody>
</table>

#### 5.3.3 Usability Ratings by Older Adults

**Finding:** As shown in Figure 5-10, usability ratings of ease, satisfaction and learnability were higher for touch selection than lift selection for older adults.

#### Analysis:

The results from the usability survey for older adults are given in Table 5-4. A Wilcoxon signed rank test was used to analyse the results of the survey. Participants rated lift selection significantly lower than touch selection for ease of use. The average difference between touch and lift ratings of ease of use was 0.44 points in favour of touch selection ($Z=-2.840$, $p < 0.005$).
p=.005). Participants rated lift selection significantly lower than touch selection for satisfaction. The average difference between touch and lift ratings of satisfaction was 0.60 points in favour of touch selection (Z=−2.950, p=.003). Participants rated lift selection significantly lower than touch selection for ease of learning. The average difference between touch and lift ratings of learnability was 0.52 points in favour of touch selection (Z=−3.357, p=.001).

<table>
<thead>
<tr>
<th>N=13</th>
<th>Touch</th>
<th>Lift</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease</td>
<td>4.88</td>
<td>4.44</td>
<td>+0.44</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>4.80</td>
<td>4.20</td>
<td>+0.60</td>
</tr>
<tr>
<td>Learnability</td>
<td>4.84</td>
<td>4.32</td>
<td>+0.52</td>
</tr>
</tbody>
</table>

5.4 RQ4: Is selection speed related to the usability ratings of either selection method?

This section analyses the relationship between usability and selection speed for both touch and lift. An introduction is given to selection speed before each selection method is discussed separately.

5.4.1 Selection Speed by Demographic and Selection Method

Finding: As shown in Figure 5-11, touch selection was faster than lift selection, and older adults did not perform touch or lift selection slower than younger adults.
Analysis: To examine any overall differences in the time taken to complete trials for each selection method (touch, lift) and for each demographic (younger adult, older adult), a one-way mixed ANOVA was performed. There was no significant interaction found between age and selection method, $F(1, 48) = 3.001$, ns, and the effect of demographic was also not significant, $F(1, 48) = 2.804$, ns. The effect of selection method was significant, $F(1, 48) = 98.571$, $p < .001$. Specifically, touch selection was performed significantly faster than lift selection.

5.4.2 Touch Selection

Since there was no significant difference in ratings of ease, satisfaction or learnability between younger and older adults, and no significant difference in selection speed was found between younger and older adults for either touch or lift selection, the data were all pooled together for the analysis and no exploration of separate relationships for the age groups was done.
Furthermore, to create an overall measure of how individuals rated the usability of each selection method, an overall usability score was calculated based on the mean of the collected usability measures of ease, satisfaction and learnability.

**Finding:** Individuals who rated touch selection as easier to perform, also performed touch selection faster. There was no relationship between touch selection speed and usability of touch selection overall or between touch selection speed and other touch selection usability factors.

**Analysis:** Examining the relationship between touch selection speed and usability perceptions of touch selection was done using a linear regression analysis. The relationship between touch selection speed and usability score for touch selection was not significant $r^2(48) = .022$, ns. The relationships between selection speed and ratings of ease, satisfaction and learnability of touch selection were each analyzed using linear regression. There was a weak but significant and negative correlation between ratings of ease and selection speed, $r^2(48) = .080$, $p = .046$, such that as ratings of ease increased, selection speed decreased. There was no significant relationship between satisfaction and selection speed, $r^2(48) = .023$, ns, or between learnability and selection speed, $r^2(48) = .000$, ns.

5.4.3 Lift Selection

As with touch selection, the data were all pooled together for the analysis, and an overall usability score was calculated and analysed alongside individual usability factors.

**Finding:** Usability ratings of lift selection were not related to selection speed. Selection speed of lift selection was also not related to ratings of ease, satisfaction or learnability.
**Analysis:** Exploring the relationship between the average time taken to complete a lift trial and usability perception of lift selection was done using a linear regression analysis. The relationship between selection speed and usability ratings for lift selection was not significant, $r^2(48) = .016$, ns. The relationships between selection speed and ease, satisfaction and learnability of lift selection were analysed using linear regression. There was no significant correlation found between ease and selection speed, $r^2(48) = .018$, ns, satisfaction and selection speed, $r^2(48) = .006$, ns, or learnability and selection speed, $r^2(48) = .011$, ns.

5.4.4 Additional Usability Findings

**Smartphone Ownership Finding:** As seen if Figure 5-12, participants who owned smartphones felt that lift selection was less usable than participants who did not own smartphones, despite feeling no differently about touch selection. Figure 5-13 shows that participants who did not own smartphones (mean age of 63.6) found no difference in usability between touch selection and lift selection. Participants who did own a smartphone showed a similar pattern to the pattern discussed in Section 5.3 (compare Figure 5-13 to Figure 5-9 and Figure 5-10).
Figure 5-12 Usability ratings of touch and lift selection by smartphone ownership

Figure 5-13 Usability factor ratings of touch and lift selection by smartphone ownership
**Smartphone Ownership Analysis:** To compare usability scores between smartphone owners and non-smartphone owners, an independent measures t-test was performed for both touch and lift selection. Smartphone owners (M=4.20, SD=.68) rated lift selection significantly lower, t(48) = 1.816, p = .038, than participants who did not own a smartphone (M=4.72, SD=.39). In contrast, no significant difference in touch selection usability scores was found, t(48) = -.231, ns, between smartphone owners (M=4.81, SD=.38) and participants who did not own a smartphone (M=4.76, SD=.27). Since these groups differed in perceptions of lift selection, participants who did not own a smartphone were analysed for differences in usability ratings between touch and lift selection using paired samples t-tests. There was no significant difference in overall usability score found, t(5) = .244, ns, between touch selection (M=4.78, SD=.27) and lift selection (M=4.72, SD=.39) among participants who did not own smartphones. Similarly, there was no significant difference in ratings of ease, t(5) = .00, ns, satisfaction, t(5) = .00, ns, or learnability, t(5) = 1.00, ns. The average age of this subgroup was 63.6 years old.
Chapter 6 Discussion of Research Questions

This chapter will answer each of the research questions based on findings from the current study in the context of previous work.

6.1 RQ1: Does lift selection improve selection accuracy for older adults?

A quarter of the participants in the study from the older demographic showed some form of improvement in accuracy when using lift selection as compared to the same selection task using touch selection. The average age of these participants was 68.6 years old and they tended to be among the oldest participants in the current study (e.g. The participant who showed the most improvement was also the second oldest participant in the study). Most of the participants who experienced an accuracy benefit used lift selection like a “corrective touch” where the participant would attempt to touch the screen as close to the target as possible and then drag over to the target only in the case that the target was missed initially. This strategy seemed successful for average and large sized targets where accuracy could be confirmed with visual feedback, however, it was not similarly successful in the smaller size condition where the finger occluded any visual feedback. Two of the participants who experienced an increase in accuracy used lift selection by touching the screen immediately upon the trial’s start and then dragged over to the target each time. Generally, these two began each trial by touching the screen in a similar location as opposed to touching the screen close to the target to be selected. One participant who used this strategy remarked that this strategy allowed them to “conserve time away from the screen” and described feeling like there was less to think about during the act of selection because of being able to have the finger on the screen while making a selection, suggesting that this behaviour is a result of an attempt to reduce cognitive load during target selection. The idea
that older adults are placed under cognitive stress during touch selection is supported further by the observation that several older adults seemed to prepare for a touch selection by hovering the finger or thumb close to the screen for a moment before touching the screen, in contrast to younger adults who moved to the target and touched the target in the same movement. These observations and comments suggest that, at least for some individuals, lift selection would be beneficial for reducing cognitive load during selection tasks.

Additionally, several older participants commented favourably about other facets of lift selection. Several participants commented on the ability to change input once contact had already been made, for example, “Now that I think about it – I can correct” and “Ah, to prevent mistakes.” One participant said they liked the ability to cancel a selection that had been made mistakenly, and another replied that they liked the idea when told that lift selection could be used to correct a mistaken selection. One participant commented on the advantages lift selection stood to offer participants with motor difficulties, but also commented on how they themselves did not fit into such a category and would not experience any such benefits. Lastly there were a few comments related to general satisfaction with the feeling of lift selection made during trials. Overall, a number of participants either measurably experienced or subjectively experienced benefits.

The benefits experienced seemed to increase with age as touch accuracy became poorer and poorer, but statistically, there was no difference in accuracy performance for older adults between touch and lift selection. Among small targets, touch selection even outperformed lift selection for older adults. This effect was likely observed due to the fact that the small targets were small enough to be completely obfuscated by a finger or thumb during selection. Several
participants commented on the difficulty they experienced during small lift trials due to target occlusion. One participant stated that the “size of finger made lift more problematic because you couldn’t see the shape” and another said that their “finger really occlude[d] feedback.” A third participant said that without any way to see the target’s visual feedback during the small-sized trial, making selections accurately was difficult and two participants commented on wanting more feedback or correction after small target lift selection trials. These comments support that smaller targets were harder to select accurately because of target occlusion, and that the inability to see the target under the finger is the most likely explanation for why accuracy of lift selection was significantly lower for small target sizes. This explanation also suggests that a variation on lift selection, for example selection with a magnifying window to show what is beneath the finger contacting the screen, or that provides auditory and/or haptic feedback when contact with a target is established could improve on the usability of lift selection.

It is worth noting that despite there being no significant difference in performance between lift and touch selection when the target was not occluded, touch selection is a well-practised gesture that was significantly predicted by smartphone usage. The relationship between practice and accuracy makes it difficult to assess the benefits of lift selection since participants have been exposed to touch selection through use of smartphone devices available on the market but have not had equivalent exposure to or opportunity to practise with lift selection. For this reason, it is theorized that no difference in accuracy was observed because the majority of participants in the study were well-practised with touch selection but had only the brief time during the demo and trials to practise lift selection. With regular use or practice of lift selection it is very possible that older adults would experience an improvement in selection accuracy. This assertion is supported by the finding that lift selection accuracy was improved after only a week of practice, but that
touch selection did not improve after such a small practice window (Kobayashi et al., 2011). That being said, the results of the current study suggest that an individual is more likely to experience benefits from using lift selection the older he or she is and, assumedly therefor, the more symptoms of age-related decline he or she suffers from. Lift selection was not found to present any significant benefits to older adults who are younger (and assumedly not suffering as severely from symptoms of age-related decline), particularly among those who are already experienced with smartphone use and well-acquainted with the current predominant target selection method.

6.2 RQ2: Are age, regular smartphone use, smartphone ownership or digit(s) used predictors of selection accuracy?

Accuracy during touch selection tasks was correlated with two factors: age and routine smartphone use. There was no difference in accuracy between those who used their thumb, index or middle finger as their primary finger, nor any difference between those who owned a smartphone and those who did not. Regular smartphone use was weakly and positively correlated with accuracy on touch selection tasks, with accuracy increasing as routine smartphone use increased. The correlation found was weak, but the question used to measure smartphone use did not measure several key aspects of routine use. For example, the survey did not ask participants to report the number of years they had used their smartphone, how frequently they use it during the day, or how long they use their smartphone for when they use it. Non self-report measures such as the amount of time the screen has spent activated, the number of apps accessed in the past week or other such measures would likely yield an even stronger correlation, since this relationship essentially operationalizes the relationship between practice and performance. Touch
selection is the market standard for target selection on smartphones so it makes sense that more frequent use of smartphones is correlated with increased accuracy during touch selection tasks. In contrast, age was moderately correlated with accuracy during touch selection trials, but was negatively correlated. The curve of best fit was a downwards curve with a gradual decline in accuracy beginning to show approximately after the age of 60. This relationship is also to be expected based on the age-related symptoms previously discussed in Chapter 2 that make selecting a target accurately on the first attempt difficult. As these age-related symptoms progress, accuracy at touch selection tasks declines, and while this rate occurs differently for different individuals, the trend is to gradually decline in accuracy during touch selection tasks with age. Together, age and experience accounted for almost half (46%) of the variation observed in touch selection accuracy among older adults.

In comparison, lift selection accuracy was not found to correlate with any of the proposed factors. Whether the participant used the thumb, index or middle finger primarily to complete the trial had no influence on lift selection accuracy and neither did smartphone ownership or smartphone usage. The lack of correlation between smartphone usage and accuracy during lift trials could have been observed because there are not as many gestures used in the market that are similar to lift selection, so more experience using smartphones would not necessarily imply more experience using lift selection. Most importantly, there was no correlation found between accuracy during lift selection trials and age. Despite the trend for accuracy during touch trials to drop off with age, there was no such trend among older adults for accuracy during lift trials. This finding is very important, since it suggests that the older a person is, the more likely they are to benefit from lift selection, since lift selection was found to be age-independent and touch selection was not. The lift selection paradigm stands to support the demographic that needs the
most support to adopt smartphones, older adults over the age of 75. This group has even recently remained a holdout for adopting smartphone technology (Anderson & Perrin, 2017) and reports the most difficulty using smartphones and learning new technology (A. Smith, 2014).

6.3 RQ3: Which selection method is perceived as more usable?

Regarding usability findings, there was no significant difference between how younger and older participants rated either selection method for ease, satisfaction or learnability. Both groups rated touch selection more usable than lift, but there was also an effect of smartphone ownership with smartphone owners being more likely than non-smartphone owners to rate lift selection poorly. This could suggest that individuals who are accustomed to performing target selection on their smartphone one way are more likely to be resistant to a change in target selection method. For example, one of the participants from the younger demographic said when first trying out lift selection that “dragging definitely doesn’t feel as natural” and one of them asked “is it ok if I just keep tapping?” once it was understood that lift selection could be used the same way as touch selection. Some older participants also expressed a similar sentiment. One person described their experience while filling out the survey by saying that “dragging wasn’t used because it wasn’t needed” and another who noticed that dragging wasn’t required to complete selection commented during the lift selection trials that “it’s easier to just touch it.” Comments like these from smartphone owners support the theory that the difference in usability ratings was related to experience using a smartphone. These comments illustrate the idea that individuals who own smartphones quickly acclimate to the current market software which uses predominantly touch selection for target selection, (though one participant showed me an app they had downloaded that used what they described as a “hybridized touch” which allowed for touch selection, but lift cancellation by moving the finger into a neutral area of the screen similar to lift selection in this
thesis) and then are resistant to changing to a target selection method that differs from what they are used to.

While few in number, 4 of the 6 participants who did not own smartphones commented on lift selection. Most of what they had to say was quite positive, for example, “I think I like that better than touch right away.” One participant eagerly demonstrated how they were using lift selection, saying “my strategy is [my] finger [is] already here – I just put it down again,” before moving the finger over to the target and selecting. The majority of participants in the study owned a smartphone, and there was no difference in usability ratings amongst those who did not own a smartphone, so it is possible that a study with more participants without smartphones would yield different usability results. Furthermore, the average age of participants who did not own smartphones was 63.6, whereas the average age of the participants who experienced some form of accuracy improvement from lift selection was 68.6, a five-year difference. Usability ratings may differ based on age as well as previous smartphone experience, however the results of this experiment did not find any evidence that touch selection was perceived as less usable than lift selection by older adults.

6.4 RQ4: Is selection speed related to the usability ratings of either selection method?

In the analysis of selection speed and usability, the two selection methods and the two participant groups were compared. Contrary to expectations, younger adults did not perform either touch selection or lift selection faster than older adults. The lack of a significant difference in speed is likely a result of the older sample being largely made up of university professors or employees with many of them owning and having regular experience with smartphones. Of the older adults
in the study, three quarters (76%) reported owning a smartphone and three quarters of older smartphone owners (74%, N=14) reported using their smartphone every day, suggesting that the regular practice using smartphones may have counteracted age-related reductions in selection speed.

As was to be expected based on previous literature (Potter et al., 1988; Wacharamanotham et al., 2011), touch selection was significantly faster than lift selection (approximately five times faster for older adults and approximately three and a half times faster for younger adults). The difference in time required to complete lift selection as compared to touch selection was what inspired this research question, and the difference in speed was significant. As was previously mentioned, touch selection scored higher on usability in all categories compared to lift selection and was also significantly faster, however it is unclear if these observations are related. Anecdotally, one participant said that “dragging wasn’t used because it wasn’t needed and would have slowed [them] down” but most negative feedback was unrelated to the slowness of lift selection. Furthermore, in the implementation of lift selection that was used in this thesis, participants could use lift selection in an identical way to touch selection. Since the initial location of the finger was irrelevant, participants could touch the screen and then remove their finger without moving it to select the target. The ability to use lift selection in a faster way was made clear to participants from the beginning, and some elected to use lift selection in this way. Despite this ability, participants were no more likely to rate lift selection usable when they performed selection faster as compared to when they performed selection slowly. Previous research found that older adults prefer to take more time when interacting with technology (Keates et al., 2005). Lacking a correlation between ratings of usability and lift selection speed suggests that how quickly lift selection can be performed is either not a major influence on
ratings of overall usability, or that a fifth of a second is not slow enough to evoke a strong reaction in older adults.

When examining the relationship between touch selection and usability, no relationship was found between selection speed and usability overall, but there was a weak, negative relationship found between selection speed and ratings of ease of use. This relationship could indicate that participants who found the touch selection easier to use were able to complete selection faster. Alternatively, participants who had more experience with smartphones may have been both faster and more likely to rate touch selection as easier. There were no other relationships between speed and usability for touch selection, implying that participants who were able to perform touch selection faster were no more likely to rate its usability higher than those who performed it slower.

Both the difference between usability scores and selection speeds were different between the two selection methods and there is anecdotal evidence that at least some participants felt the reduction in speed made lift selection unsatisfying to use. This information coupled with the fact that selection speed was not a significant predictor within each selection method suggests that speed is a factor that influences usability for some, but not all participants. Furthermore, previous literature suggests that this influence decreases as individuals age (Keates et al., 2005). It is likely that speed is one factor of many that influence ratings of usability and a more robust test of self-report and captured measures would likely reveal that speed does contribute to ratings of usability overall, but that it does not out-contribute other factors such as the ease with which the selection method is understood or the ease with which it can be accurately performed, and that this relationship would be especially true with advancing age.
Chapter 7 Limitations, Future Work & Conclusions

7.1 Study Limitations

When interpreting the results of the current research, it is important to understand them within the context of the limitations of the thesis. To begin, the lift selection paradigm is a comparatively recent one with several alternative implementations that may have performed better than either the lift implementation used during the experiment or the implementation of touch selection. In the current study, the implementation of lift selection was to grey out the background of the target to provide visual confirmation of contact when contact was made with a target and perform the selection when contact with the screen was ended. Several other implementation choices could have been made for confirming contact with a target, however, and should be investigated for their usability potential. Some additional lift implementations include providing haptic feedback when contact is made with a target, providing a magnification window near the contact point to show what is being occluded by the finger, playing a low-frequency tone or sound when contact is made with a target or any combination of these as well as the visual confirmation strategy already presented.

Secondly, the older adults in the study were all either highly educated individuals or friends and family of highly educated individuals and younger adults from the study were all participating in higher education. One younger participant even reported having completed an undergraduate degree prior to completing the experiment and was currently working towards a Master’s degree. When generalizing the results of the current study, it is therefore important to consider that the participants all had some level of higher education, and many had a substantial amount. The
results from this experiment, therefor, may not generalize as well to populations that do not share
the academic characteristics of this sample.

Moreover, there was a distinct difference in the context in which older and younger adults were
asked to complete the experiment. Younger adults were asked to participate in the noisy and
lively University Center during a time of high traffic to maximize participant exposure.
Individuals were approached by the researcher and asked to participate, then participated
immediately if they agreed. Older adults, however, were invited by email, sent an email reminder
if desired, selected a time that would work for their own schedule to complete the experiment
and generally performed the experiment in a private office or other quiet location where they
were comfortable and relaxed. Furthermore, younger adults were approached during some of the
last weeks of the semester as final exams were quickly approaching. Some younger participants
may have been stressed due to the time of the semester, the time of day (for example, some
individuals declined to participate saying they had to catch a bus or were on their way to a
scheduled meeting), the environmental factors of the University Center or other factors that
would not have influenced the older adults who completed the experiment. Moreover, many
younger adults completed the experiment while standing up, some while carrying a backpack or
other bag on their shoulder, even when offered the opportunity to sit down. In comparison, all
older adults completed the experiment in a comfortably seated position with no physical
interference from other sources (e.g. a hand bag). This difference in contexts might have meant
that younger adults performed slightly worse than they would have in the context of the older
adults (i.e. comfortable, quiet location at a time of their choosing) and older adults likely
performed better than they would have in the context of the younger adults (i.e. busy, loud
environment after being asked on the spot).
In addition, measures of smartphone usage and ownership were both self-report measures and measures that forced participants to group themselves into categories instead of measuring these concepts discretely. For example, the smartphone ownership question asked participants whether they owned a smartphone or feature phone currently, but did not ask about how long the participant’s currently used device had been owned or about previous devices the participant may have owned before the current one. Relationships between ownership and other variables such as accuracy, speed and usability perceptions would have been easier to find evidence for with more dynamic information about the participants’ smartphone ownership. Something similar can be said for the measure of smartphone usage. Smartphone usage is a multi-dimensional concept which encompasses measures of frequency and duration as well as qualitative measures such as tasks done, apps used, sites visited and others. More information about smartphone usage would likely have helped to clarify findings related to accuracy, usability and speed. Moreover, the collected measures were self-report measures which are less reliable than captured measures. The ability to correlate accuracy, speed and usability ratings with captured user data from a smartphone or service provider would likely have been particularly interesting in the context of exploring how participants rated the usability of touch and lift selection.

Lastly, the study included only three measures of usability, and some participants were not clear about what the difference was between some items. A few of the older participants also reported that the usability survey did not adequately capture their feelings about either touch or lift selection and one participant was confused that there was no open comments box on the survey for providing additional feedback. A more robust usability survey including more questions comparing the two selection methods would have provided more information about the
perceptions participants had and would have allowed for a more thorough exploration of factors predictive of participants’ usability ratings for both touch and lift selection. Moreover, a usability survey such as the PSSUQ (Lewis, 2002), or the ISO 9241 (Miranig, Meschtscherjakov, Wurhofer, Meneweger, & Tscheligi, 2015) which have been used and validated in the industry would have yielded more reliable and generalizable results. Both the PSSUQ and the ISO 9241, have also been used in similar research in the field (Hwangbo et al., 2013; Wacharamanotham et al., 2011). A comment box would have also been beneficial for soliciting additional feedback from all participants, not just participants who volunteered the information during the experiment.

7.2 Future Research

Based on the current study and state of the literature, several avenues for further research would be beneficial to the field of smartphone target selection usability for older adults. One important topic is the establishment of the effects of aging on the accuracy of both touch and lift selection at all ages. Many studies compare older and younger adults, but very few studies include adults from across a spectrum of ages, particularly those in the 25 – 49 age bracket, making it difficult to make assertions about how accuracy changes over time across all ages. That being said, even a study of this design would not provide the same strength of evidence as compared to longitudinal data examining the progression of selection method accuracy over time in the same individuals. Determining how different selection methods are affected by age is important for designers of usable interfaces for older adults.

Additionally, research focusing on selection accuracy and usability perceptions of alternative lift selection implementations would likely find that one of these alternatives provides a marked
improvement in selection accuracy and usability for older adults. For example, in a study of 22 older adults over the age of 65 that examined haptic and auditory feedback during touch selection, the authors found that performance increased significantly when either auditory or a combination of auditory and haptic feedback was provided, but that haptic feedback alone decreased performance and even caused some participants to lose their grip on the phone (Hwangbo et al., 2013). A similar study about lift selection would be beneficial. Moreover, including more participants who do not currently own smartphones or do not have substantial previous experience with smartphones would also likely yield valuable results. The current study also found that if lift selection provides an improvement in accuracy it is most likely experienced among those who are approaching the age of 70 and, therefor, those who are experiencing more symptoms of age-related decline. Research focusing on older adults aged 70 or older that compares touch and lift selection would, therefor, also likely be fruitful.

Similarly, some participants alluded to the idea that lift selection helped them to focus on what target they needed to select instead of the act of making the selection. It would be worthwhile to determine if lift selection could ease cognitive load during selection tasks by reducing task interaction between target searching (i.e. identifying the correct target) and target selection (i.e. making contact with the correct target). A simple experiment where the number of targets increases with each condition could be performed with both touch and lift selection and younger and older participants to determine if a similar implementation of lift selection improves accuracy in conditions of high target volume. A significant difference in accuracy between target volume conditions when using a similar implementation of lift selection would support that lift selection reduces cognitive load in older adults by reducing the need to focus on two challenging tasks simultaneously. A similar study design can be found in the second “Swabbing” experiment,
where participants completed the task with 16, 25 and 36 possible targets (Wacharamanotham et al., 2011). The described study focused on older adults suffering from tremor, so repeating a similar study with older adults suffering from a wider range of age-related decline, and particularly cognitive decline, would be needed to establish whether improvements in accuracy can, in part, be attributed to reduction in task competition between finding and selecting a target.

Another critical step for advancing research in the usability and benefits of lift selection for older adults is to test the selection method within the context of actual tasks that an older adult might expect to complete on a smartphone. Some tasks could include dialling a phone number, checking the time, locating contact information, opening a text message or answering a ringing phone. It is important to test this alternative selection method in the broader context of completing real tasks because it is likely that other factors and technical limitations will need to be addressed for a practical implementation to be offered as a legitimate alternative. Moreover, a select few gestures resemble lift selection and would have to be modified to support the change in selection paradigm. Slow dragging or scrolling (i.e. when reading a long message), dragging and dropping (i.e. when customizing the phone’s layout) and single contact panning (i.e. when looking at a map) all resemble lift selection since they involve measuring the speed and/or direction of a digit that remains in contact with the screen. Alternatives to these important gestures would have to be studied as well.

7.3 Conclusion

In conclusion, lift selection has the potential to improve accuracy for smartphone use among older adults the more they experience age-related decline, but not necessarily older adults who experience these symptoms to a lesser degree. While there was no significant difference found in
accuracy between touch and lift selection for older adults selecting similarly sized targets to those commonly found on the market currently, this study also found that experience with smartphones had the ability to buffer declines in accuracy related to age. It makes sense that practice improves performance, and that older adults committed to using a smartphone already would have developed strategies for increasing their own accuracy when selecting targets, since they are required to do so in order to complete any task. With so much investment in learning to perform touch selection, it is not particularly surprising that smartphone owners were more likely to rate lift selection lower in usability than those who were not smartphone owners. However, a quarter of the older adults in the study did show some form of accuracy improvement when using lift selection, and touch accuracy was lower for older adults than younger adults. The findings of this study, when taken together, support that lift selection is a good alternative to offer older adults who are suffering from age-related decline to support their use of smartphone technologies. Further research, however, is needed to determine which implementation of lift selection would benefit older adults the most as well as to verify how lift selection works in a practical smartphone context like dialling a phone number, opening a text message or checking the time. A solution would be to allow gestures to be customized so that older adults who would benefit from lift selection can have access without causing disruption to those who prefer not to use it.
References


Statistics Canada. (2017). *Age and sex, and type of dwelling data: Key results from the 2016 Census.*


Appendices

Appendix A Recruitment Script for Younger Adults

Hello, my name is Gwendolyn Witecki, and I'm doing research with the School of Computer Science at the University of Guelph. I'm researching how seniors use smartphones, and would like to invite you to participate in my study.

If you agree to participate, I will ask you to complete some simple tasks on a smartphone. While you are completing these tasks, I will measure your performance and take notes. Afterwards I'll ask you a couple of questions about your reactions. The whole study should take about 10 to 15 minutes of your time. Would you be interested in participating in this research project?
Appendix B Recruitment Email for Older Adults

Subject: Participants Needed - Smartphone Use by Older Adults

Dear Dr. [First Name] [Last Name],

I am emailing you to invite you to participate in a smartphone usability interview. I am a graduate student of the School of Computer Science at the University of Guelph and I am studying smartphone accessibility for older adults. The goal of these interviews is to understand how smartphone use can be improved for adults as they age, and your participation would be very helpful.

Interviews will take approximately **20 minutes and can be completed in your office or another location on campus of your choice.** During the interview, you will be asked to complete a short task on a smartphone and a brief survey. You do not need to own a smartphone to participate.

Participation in this study is voluntary and there will be no compensation. However, your participation would be valuable to the research and could contribute to improving smartphone usability for older adults.

If you are interested in participating in this study please reply to this email with a date and time that would be convenient for you, if you have a preference, and I will arrange to visit your office for an interview. If you have any questions, please feel free to contact me by email or by phone at 519-400-1689, or my advisor by email at nonnecke@uoguelph.ca.

Thank-you for your time and consideration, I hope to hear from you!

Sincerely,

Gwendolyn Witecki
Appendix C Informed Consent Document

CONSENT TO PARTICIPATE IN RESEARCH

Touch Interface Designs for Older Adults

You are about to participate in a study conducted by Gwendolyn Witecki who prepared this experiment and survey as part of her Graduate thesis for Computer Science (Human Computer Interaction) at the University of Guelph. Any questions or comments about this experiment, or the research may be directed to Blair Nonnecke (Research Advisor) by email: nonnecke@uoguelph.ca.

Purpose of the Study

The purpose of this research is to assess the viability of target selection using a drag and lift design as an effective alternative to commonly used “tap” designs. The study will ask you to select targets in a number of different locations on the phone using both the lift and tap methods. Afterwards, you will be asked to complete a survey asking you questions regarding your experiences with the two interfaces.

Procedures

If you choose to participate in this research, the experimenter will demonstrate the lift and tap methods of target selection, and you will be given the opportunity to practice using a phone provided by the researcher. During the experiment you will be asked to use the phone to select specific targets using both methods, which will take approximately 15 minutes of your time. After the experiment, you will be asked to respond to a short survey comparing the two methods of interaction, which will take approximately five minutes of your time. The entire experiment should not exceed 20 minutes of your time.

Potential Benefits to Society

By helping explore alternative interface designs for older phone users, you will help inform the design of touch screen interfaces designed to be used by older adults. The current study is meant to determine if there are easier ways for older users to interact with smartphones and, by extension, if there are ways to extend the benefits of smartphones to more older adults. Should the current research be used in marketable designs, older adults would greatly benefit from the increase in independence and security associated with easy and intuitive access to smartphones.
Confidentiality and Anonymity

You will be asked to provide a name so as to identify yourself should you choose to withdraw your information at a later date. No other personally identifying information will be recorded, maintained or used by the researcher and your name will not be used for any purpose other than that stated previously. Other information recorded will be your speed, accuracy and precision of selection during the experiment as well as your responses to the UI evaluation survey.

Participation and Withdrawal

Your participation in this research is voluntary. Older participants must be 55 years or older to be included in the current research, and control participants must be between 18 and 35 years of age. You may withdraw from the study at any time without consequence. Should you wish to withdraw your participation after the study has been completed, you may email Gwendolyn Witecki at gduffey@uoguelph.ca or Blair Nonnecke at nonnecke@uoguelph.ca with your name and desire to withdraw your participation.

Potential Risks and Discomforts

Any interaction with public devices incurs a risk of acquiring communicable illnesses/viruses as many individuals may have touched or interacted with the device before you. To minimize this risk, the phone you will be using in the experiment has been cleaned and sanitized between each use to ensure your safety and health as a participant. There is no penalty for withdrawing your participation at any point during the study.

Rights of Research Participants

Your agreement to participate in this study does not waive any of your legal rights. All data collected will be kept confidential. You have the right not to answer any question in this survey and to withdraw your participation at any time. If you are interested in receiving the final results of the study, please email either Blair Nonnecke at nonnecke@uoguelph.ca or Gwendolyn Witecki at gduffey@uoguelph.ca and results will be sent to you by email.

Questions or concerns regarding your rights as a research participant may be directed to:

Research Ethics Coordinator Telephone: (519) 824-4120, ext. 56606
University of Guelph E-mail: sauld@uoguelph.ca
437 University Centre Fax: (519) 821-5236

Consent to Participate in Research

Should you decide to participate in the current research, please sign below to indicate your willingness to proceed with the survey. In doing so, you grant permission for the researchers to use your data in the current research.
Thank-you for your co-operation,
Gwendolyn Witecki
School of Computer Science
University of Guelph
gduffey@uoguelph.ca

Having read the informed consent introduction above, sign below if you give permission for your data to be used for the purpose of the current research study.

Participant Signature: _____________________________________________________________
Appendix D Informed Consent Introduction Script

This study is completely voluntary, and if you decide you don't want to continue, we can stop at any time. Your information, including your performance on the tasks and answers to survey questions, will be kept confidential at all times. Your name will be recorded so you may withdraw your information from the study at a later date. This study involves minimal risks, and to further minimize these risks, the phone you will be using has been cleaned and sanitized before the start of the study. If you have any questions about the study, please feel free to ask me. You can contact either myself or Dr. Nonnecke after the study is finished by phone or by email. If you have any questions about your rights as a research subject, you can contact the Research Ethics Coordinator by phone or by email.
Appendix E Experiment Instructions

Experiment Instructions

1. You have agreed to participate in a mobile usability study.
2. The goal of each task is to select a given shape
3. You will be asked to either touch the shape or drag your finger over the shape to select it
4. You will be asked to select large, medium and small shapes
5. You will be able to practise touching the shape and dragging your finger over the shape
6. Afterwards you will be asked to answer a few questions

Touch Instructions

1. Touch the screen on the shape to select
2. You will practise touch selection on the next screen

Drag/Lift Instructions

1. Touch the screen without lifting your finger
2. Drag your finger over the shape and lift it to select
3. If you touch the shape initially, you can simply lift your finger to select
4. If you don't touch the shape initially, you can correct by dragging your finger to the shape
5. You will practise lift and drag selection on the next screen
Appendix F Post-Experimental Survey

**UI Evaluation Post Survey**

<table>
<thead>
<tr>
<th>Age:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Difficult</strong></td>
<td><strong>Difficult</strong></td>
<td><strong>Neutral</strong></td>
<td><strong>Easy</strong></td>
<td><strong>Very Easy</strong></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1. On a scale from 1 to 5, rate how easily you were able to select a shape **by touching**?

2. On a scale from 1 to 5, rate how easily you were able to select a shape **by dragging and lifting**?

<table>
<thead>
<tr>
<th>Really Not Satisfied</th>
<th>Not Satisfied</th>
<th>Neutral</th>
<th>Satisfied</th>
<th>Really Satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

3. On a scale of 1 to 5, rate how satisfied you were with selecting a shape **by touching**?

4. On a scale of 1 to 5, rate how satisfied you were with selecting a shape **by dragging and lifting**?

<table>
<thead>
<tr>
<th>Very Difficult</th>
<th>Difficult</th>
<th>Neutral</th>
<th>Easy</th>
<th>Very Easy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

5. On a scale of 1 to 5, how easy was it to learn selection **by touching**?

6. On a scale of 1 to 5, how easy was it to learn selection **by dragging and lifting**?

<table>
<thead>
<tr>
<th>Yes, A Feature Phone</th>
<th>Yes, A Smartphone</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>I’ve never used a smartphone</td>
<td>I’ve used a smartphone once or twice.</td>
<td>I’ve used a smartphone occasionally.</td>
</tr>
<tr>
<td>I use a smartphone semi-regularly.</td>
<td>I use a smartphone every day.</td>
<td></td>
</tr>
</tbody>
</table>

7. Do you own a cellular/mobile phone? Yes, A Feature Phone Yes, A Smartphone No

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I’ve never used a smartphone.</td>
<td>I’ve used a smartphone once or twice.</td>
<td>I’ve used a smartphone occasionally.</td>
<td>I use a smartphone semi-regularly.</td>
<td>I use a smartphone every day.</td>
</tr>
</tbody>
</table>

8. How much experience have you had using a smartphone?
Appendix G Experimental Procedure Beta Test Results

Older Adults

The results from the beta test with an older adult are summarized in Table 2 below. The most important finding was that the instructions for lift selection were not as effective or clear as they should have been. Other notable findings included confusion having both the paper and mobile instructions simultaneously at the beginning, confusion at how far along through the experiment the participant was and a preference for completing the final survey on paper. The participant commented on a preference for paper instructions and a paper survey, however due to the results of the beta test with a younger participant, the mobile instructions were not removed altogether. The decision was made to conduct the survey on paper, however, as it was easier and faster for the participant to complete in this way. Changes made in response to the beta test results are also summarized in the Table below.
Table A-1 Beta testing results for older tester by screen

<table>
<thead>
<tr>
<th>Screen</th>
<th>Comment/Note</th>
<th>Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructions</td>
<td>“Should I touch next or continue?”</td>
<td>Selection method instructions modified</td>
</tr>
<tr>
<td></td>
<td>“It’s unclear what ‘continue’ is referring to”</td>
<td>Selection method instructions modified</td>
</tr>
<tr>
<td></td>
<td>Skipped selection method title</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Unclear that instructions were appearing once more because a new selection method was being introduced</td>
<td>Progress through experiment display increased Selection Method complete screen introduced</td>
</tr>
<tr>
<td></td>
<td>Having the paper instructions first and the on-screen instructions second was confusing</td>
<td>Paper instructions only given after Participant told that paper gives no new information</td>
</tr>
<tr>
<td>Demo</td>
<td>Selection method instructions were insufficient to explain how to correctly perform selection</td>
<td>Selection method instructions modified Selection method demo added</td>
</tr>
<tr>
<td></td>
<td>Tried passing the finger through the target instead of ending in the target area</td>
<td>Selection method instructions modified Selection method demo added</td>
</tr>
<tr>
<td>Target Selection</td>
<td>The reminder shape was not clearly labelled and the participant started lift selection on the reminder shape</td>
<td>Reminder shape labelled</td>
</tr>
<tr>
<td>Survey</td>
<td>Paper survey preferred over phone survey</td>
<td>Paper survey implemented Smartphone survey removed</td>
</tr>
</tbody>
</table>

Younger Adults

The results from the beta test with a younger adult and changes made as a result are summarized in the Table below. The most important finding was that the instructions for lift selection, the selection method the interface was designed to test, were not as effective or clear as they should have been. The finding that these instructions were unclear for both older and younger adults was particularly bad. The instructions were revised and a demo of both selection methods was added. Other findings of note included that the younger participant became frustrated with how many instruction screens there were, and that the paper instructions were not wanted at all. Since the
younger and older beta testers had differing opinions about the medium in which the instructions were presented in, the decision was made to allow participants to choose between paper and electronic instructions.

<table>
<thead>
<tr>
<th>Screen</th>
<th>Comment/Note</th>
<th>Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructions</td>
<td>Spent more time on the press continue instruction page than other pages</td>
<td>Selection method instructions modified</td>
</tr>
<tr>
<td></td>
<td>“There are too many instruction screens”</td>
<td>Instructions condensed to remove screens</td>
</tr>
<tr>
<td></td>
<td>Did not need the paper instructions</td>
<td>None</td>
</tr>
<tr>
<td>Demo</td>
<td>Long pressed on the target instead of using lift to select the target</td>
<td>Selection method instructions modified</td>
</tr>
<tr>
<td></td>
<td>Needed verbal directions to clarify lift selection</td>
<td>Selection method demo added</td>
</tr>
<tr>
<td>Target</td>
<td>Did not relate instruction regarding continue button to this screen where it is relevant</td>
<td>Instructions modified</td>
</tr>
</tbody>
</table>
Appendix H Summary of Experimental Procedure

The following is a summary of the experiment phases:

1. Introduction
2. Selection Method Demonstration
3. Target Selection
4. Self-Report Usability Survey

Introduction

At the start of the experiment, the researcher introduced the study and requested the participant sign the informed consent form (See Appendix C). Before each experiment, the researcher recorded the participant's participant ID on the blank post-experimental survey (See Appendix F). Each participant completed the target selection task using both selection methods to select targets of all three sizes before being asked to fill in the survey. All participants were told they could take a break at any time during the experiment and were given multiple opportunities to ask questions. The participant was asked to hold the device in portrait mode during the experimental trials. Participants were not given further direction on how to hold the phone and were allowed to hold the device according to personal comfort and preference. The hand or hands used by the participant and a description of his or her preference for holding the device was recorded by the researcher during the experiment. The hand or hands as well as the digit or digits used by the participant to select targets and interact with the phone was also recorded by the researcher at the same time.
Selection Method Demonstration

Before using a particular selection method, the method was described and participants practised it. Each practice session consisted of three successful target selections in a practice setting where no data was recorded for the participant. A single target was presented to the participant who was asked to select the target. Participants had to successfully select the target to proceed in practice sessions. If the participant did not correctly select the target, the practice session was not complete. Participants were given infinite attempts to select the target using the correct selection method. Once the target was correctly selected, a check mark was displayed to indicate to the user that they had successfully completed a practice trial, and then progressed to the next practice trial automatically. Three practice trials were completed for each selection method before the experimental trials began. In this way, the researcher ensured that the participant could successfully perform the selection method before the experimental trials began and data was collected. During the practice session, the target's colour and shape did not change and only the small target size was used.

Target Selection

Each participant completed six conditions covering every combination of selection method with target size (see Section 3.3.2 for a list of selection method and size combinations). For each selection method, all three size conditions were completed before the other selection method was introduced. Which selection method the participants completed first was alternated with each participant. The size conditions were presented in a random order for both selection methods to avoid ordering effects within participants.
Every size condition contained the same six targets arranged in the same locations every time
with the only difference between the conditions being the size of the targets. Each size condition
contained a series of twelve trials. All trials consisted of the same steps, given in the Table
below, repeated 12 times (i.e. once per trial). Each trial required the participant to select a
specific target, identified by the both shape and colour to make the targets as easily identifiable
as possible.

Table A-3 Target selection trial steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired Target Displayed</td>
<td>A screen is displayed with instructions to select a coloured shape. Only a single coloured shape is shown to indicate the target to select.</td>
</tr>
<tr>
<td>Readiness Confirmed</td>
<td>The participant touches the “Continue” button to indicate readiness to begin the trial. The “Continue” button is on the same screen as the coloured shape shown as the target.</td>
</tr>
<tr>
<td>Selectable Targets Displayed</td>
<td>New screen displayed with six selectable areas, each marked with a coloured shape</td>
</tr>
<tr>
<td>Selection Completed</td>
<td>Participant performs either touch or lift selection</td>
</tr>
<tr>
<td>Trial Completed</td>
<td>Participant is shown trial complete screen and progress through the experiment</td>
</tr>
</tbody>
</table>

Which target the participant was required to select was randomly generated. Each trial was
completed one at a time, and the trial concluded with the first selection location captured from
the participant. Participants were not required to successfully select a target to complete the trial,
and participants were not told if the target was successfully selected or not after each trial (in
contrast to the demo trials discussed previously). After twelve attempts to select targets of the
same size, the condition was complete, and the next size condition began. After all the size
conditions were completed for a single selection method, the next selection method was
presented to the participant, and the same procedure was used again for the second selection
method. Once all size conditions had been completed for both selection methods, the results were
saved in an excel file.
Self-Report Usability Survey

Once the participant completed the selection method evaluation portion of the experiment, he or she was asked eight questions about the interfaces and selection methods. Participants were given the paper questionnaire and asked to circle the appropriate answer on their copy of the survey. The survey also included questions about the participant’s experience with smartphones. The participant’s age and sex were also recorded at the same time. The participant was then thanked for his or her time and the experiment was completed. The survey used in the experiment is shown in Appendix F.