Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Evaluating Mobile Apps Designed for the Elderly People Based on Available Usability and Accessibility Guidelines

Elenia Cristina Carrasco Almao

A research paper submitted in partial fulfilment of the requirements for the degree of Master of Science Interactive Digital Media

2018

Declaration

I have read and I understand the plagiarism provisions in the General Regulations of the University Calendar for the current year, found at: http://www.tcd.ie/calendar

I have also completed the Online Tutorial on avoiding plagiarism 'Ready, Steady, Write', located at http://tcd-ie.libguides.com/plagiarism/ready-steady-write

I declare that the work described in this research Paper is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

Signed: ___________________

Elenia Cristina Carrasco Almao

11/05/2018

Permission to lend and/or copy

I agree that Trinity College Library may lend or copy this research Paper upon request.

Signed: ___________________

Elenia Cristina Carrasco Almao

11/05/2018

Acknowledgements

Thanks to all of those who supported me though this journey, especially my beloved José Monreal, for his patience, love, and constant support; and Fatemeh Golpayegani for her guidance.

Abstract

Smartphones have become indispensable devices in people's everyday life facilitating many activities, such as taking pills on time, monitoring blood pressure, and socializing with other people. As the global population is rapidly ageing, it is necessary to design mobile interfaces that focuses on elderly people's needs, considering that they use their phones as an assistive technology through their mobile applications. Such needs are related to cognitive, perceptual, and psychomotor changes that take place in the ageing process, which affect the way older people interact with a mobile device. However, most of the mobile interfaces are not designed optimally for older people. To address this issue, some usability and accessibility guidelines, such as having a big enough font size, are suggested to design and evaluate age-specific mobile interfaces. However, there is no evaluation on how and to what extent the industry is implementing these guidelines in the mobile app's design process.

This paper aims to assess the application of these guidelines in industry-built apps. Thus, 18 specific mobile apps have been selected because they address different age-related issues, like visual aid or health support. These apps will then be evaluated on the basis of available guidelines, to better understand how the industry is taking into account the usability and accessibility requirements of older people in the app's design process. As a result, it will be revealed if there is any specific usability and accessibility issue that could be better addressed by the industry to design more appropriate mobile applications for the elderly people.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Introduction

Over time, with technological advancement, making technology accessible for people with impairments has turned into an important topic. However, there still a lot of work to be done on this subject to truly make technology accessible for this group of people. Elderly people, who experience age related impairments, are one of those who constantly have issues interacting with technology. For instance, in the mobile technology context elderly people face these issues, as the size of a mobile phone is reduced, the menu is more complex, and it requires to be operated via difficult touch-based gestures. Now that, it has been predicted that the ageing population will rapidly grow worldwide, making mobile devices accessible for the elderly people is even more necessary than ever. Based on that, this chapter will briefly introduce the research undertaken, considering the context of the topic, the current available work and the importance of the research. At the end of this chapter, the research question will be stated, along with a brief description of the structure of this study.

1.2 Background

Mobile phones, specially smartphones, are an important technology in people's everyday life. The use of such technologies is rapidly increasing around the world. As reported in Statista, in 2017 approximately 2.4 billion people were smartphone users [1]. By 2020 it is forecast that there will be 2.9 million people using smartphones, that is a 20% growth. Smartphones have become indispensable for many, almost like a basic service like electricity. Since the emergence of smartphones, a great number of useful functionalities have been developed. These have made daily routines such as daily chore organization; text and voice communication; and socialization, easier. In some cases these functionalities are built-in apps; in other cases they are external apps that can be downloaded and installed by the users. So, as life gets busier and faster mobile apps in smartphones assist people, from small kids to older people, in daily activities.

The United Nations reported, in its World Population Prospect 2017, that the population aged 60 and over is expected to grow rapidly. In 2017, the number of individuals aged 60 and over was approximately 962 million people, equivalent to 13% of the global population. While by 2030 the number of older people will reach 1.4 billion people, and 2.1 billion by 2050. This means that the elderly population will be doubled by 2050 [2]. Additionally, the number of older people using a smartphone is growing [3] [4], not only for communication purposes, but also for its help as assistive technology through mobile applications. This allows an ageing person to feel more secure and carry out a more autonomous life. However, many still find interacting with a mobile interface difficult. As people grow older they experience certain age related changes in their vision, hearing, motor skills, and cognitive skills, which affect the way they interact with mobile phone interfaces. Therefore, it is important to consider elderly people's impairments in the design process of mobile apps. Thanks to the advancement in technology, developing a mobile app has been constantly improving which is a great benefit for general users. Unfortunately, mobile interfaces remain relatively inaccessible as they are not specifically designed for the ageing population.

1.2.2 Ageing

Aging is a complex process, at a biological level the human body experiences a progressive accumulation of diverse molecular and cellular damage [2]. Over time, this damage in the human body leads to a progressive decline in physiological functioning, more chances of diseases, and a decline in functional skills of a person. This general decline of a person while ageing, is reflected in the common change of vision, hearing, mobility and cognition experienced by elderly people. With increasing age, issues with mobility are triggered by a decline in muscle mass, which causes problems in coordination, speed and strength. While, there is also a gradual loss of vision and hearing which limits how older people interact with their environment. For example, hearing loss affects communication, and can cause isolation and loss of autonomy, as a person with hearing loss is not appreciated by people with normal hearing. In the case of visual impairment it might limit mobility, affect social interactions, limit the access to information, and increases the risk of accidents. While, cognitive loss is marked by a decline in memory and the speed at which older people process information.

All these age-related changes, have an important impact on different aspects of an elderly people's everyday life, such as the way they interact with a mobile phone. As a result, they often need support in carrying out tasks and activities [5]. For example, in the mobile phone context, to be able to perceive the interface they require larger UI elements than the average user. Which is one of the many reasons why accessibility should be a required part of the mobile interface design process, putting a special emphasis on making an interface usable for the elderlies. The problem is that there are still not as many accessible websites and applications for the elderlies as there should be. Which is even more concerning in the context of mobile phones, as they are rapidly growing and constantly changing, making it hard to properly address accessibility.

How a person experiences age related changes is influenced by the environment of the person, which might take many forms. For instance, policy making, economic sustainability, society's position on ageing, infrastructure, social relationships, and even the assistive technology available for elderly people. The evolution of mobile technologies has supposed an enormous social change. It is even opening new opportunities for people with different levels of impairment through the assistive technology apps installed in the device. However, if interfaces still remain inaccessible for people with impairments, then they cannot take advantage of the technology. Abascal, as referenced by Bossini, suggests that what an older adult wants from a mobile phone is not too different from what the generic user wants from it: "fully reliable personal communications and services to improve, as much as possible, safety and quality of life." [5]. Based on that and as pointed in [6] and [2], mobile phones for elderly people should meet the following requirements:

- Enhance the chance of personal communication for elderlies to help them maintain and build relationships with more people. Relationships are an important aspect in their life for a healthy ageing.
- Offering security to older people who run risk of accidents. In case of an emergency mobile phones should be a quick and effective communication medium.
- Allowing for social integration through services that promote access to remote activities like education, work, entertainment, health, among others. These activities promote abilities that are regarded as important for older people, like the ability to build and maintain relationships and the ability to learn, grow and make decisions.

- By including the first 3 requirements, give elderly people the opportunity to live an autonomous way of life that they can enjoy.

As it can be observed, by addressing accessibility in the mobile app development process, it is possible to improve the quality of life of the elder population in many ways. As a consequence and as it will be discussed in the following subsection, many have tried to create a set of guidelines specially aimed at the elderly people. Guidelines are important because they are a useful tool to be able to design and evaluate age friendly mobile interfaces.

1.2.3 Current work

Because of the age related changes experienced by older people, many have recognized the importance of designing age friendly products. Guidelines along with heuristic evaluation are considered efficient tools for assessing products design. Which is why, enormous research have been carried out to develop design and usability guidelines specifically intended for older people [7] [8] [5] [9]. Developing a set of standard guidelines to design a product for elderly people solves an issue that has been regarded as challenging by many. Which is recruiting, retaining, and working with elderly people during heuristic evaluation [9]. More important, guidelines help facilitate the interaction between an older adult and a mobile phone. Petrovčič, Taipale, Rogelj, & Dolničar [9] performed a review of the published design guidelines and checklist for mobile phones aimed at older people. The findings were encoded into a coding scheme including 38 usability guidelines grouped within seven usability dimensions. In this coding scheme, for example, buttons are suggested to be an important interaction element for an age friendly interface. As easy to understand buttons make elderly's interaction with a mobile device easier. So for example, older people favour large buttons with clear feedback because with age it is harder for them to see. Additionally, with age their motor skill declines so it is important for them that the buttons have a prudent time of responsiveness to avoid incidents like pressing a button by mistake. Furthermore, the World Wide Web Consortium (W3C), the main web standards organization, is also putting a major effort into developing guidelines for designing usable and accessible mobile interfaces. In [7], they offer informative guidance to interpret and apply their already stable Web Content Accessibility Guidelines 2.0 (WCAG), to web and non-web mobile content and applications. Their focus is on making mobile interfaces accessible for people with disabilities, such as the visual, cognitive and motor impaired. Impairments that, as discussed earlier, are the most important limitations that affect the UI design for older people, which is why this study is being considered in this research. Based on the WCAG 2.0 categorization [10], the W3C divides the guidelines for the mobile interfaces into four principles related to barriers experienced by people with impairments. The principles are: perceivable, operable, understandable, and robust. W3C suggest that in order for a mobile device to be accessible, they should meet those principles. In a perceivable interface the content and interaction elements are presented in such a way that can be easily recognized by people with all skill levels. If a text is displayed in a small font size, then elderly people will not be able to perceive it. Meantime, an operable interface offers navigation and interaction components that can be easily used, avoiding interactions that users cannot perform. For example, if an interface asks an elderly person make a complex gesture to perform an action, it is possible that he will face difficulties due to lack of coordination. An understandable interface, encompasses information and interaction elements that are easily comprehensible by all. If an interface requires custom gestures, but does not provide instructions on how to achieve those gestures, then it is probable that for an elderly people it is going to be harder to interact with that interface. Finally, a robust mobile interface means that its content is always going to be available even if the technologies evolve. So, if today a fully customized app is developed for elderly people, and it cannot respond to new technologies, then it will eventually be outdated and the user will not be able to access it anymore.

1.3 Aim of the study

Despite all the research carried out in the development of age-friendly UI design guidelines for mobile phones, there has been no study exploring how, and to what extent, these guidelines are being implemented in already launched mobile applications for the ageing population. So, the aim of this research is to better understand how the industry is taking into account the usability and accessibility requirements of older people in the mobile app's design process. For this, 18 up to date mobile apps, which address age related changes, have been selected. To assess how these industry-built apps consider older adult's usability and accessibility needs, they will be evaluated based on Petrovčič et al. findings [9] on published guidelines, along with the W3C standards [7] for accessibility.

The rest of this paper is organized as follows: chapter 2 reviews the available guidelines for designing usable and accessible mobile phone devices for the elderly people. Chapter 3 describes the procedure and method of the evaluation, including the selection criteria for the apps and the selection criteria for the parameters. Chapter 4 presents the results of the apps evaluation, on the basis of the usability and accessibility checkpoints identified in the provided guidelines. Chapter 5 discusses the results of the evaluation. Chapter 6 provides the conclusion of this work, including the problem addressed, the importance of the research, the limitations, and the possible recommendations for future research.

Chapter 2 – Usability and accessibility guidelines of mobile interfaces for the elderly people

2.1 General overview

In an early stage, a search was conducted among the available relevant literature to retrieve all of those that included guidelines for evaluating and/or designing mobile phone interfaces aimed at elderly people. To select the appropriate work the following criteria has been applied:

1) The guideline should focus on older people.
2) The guideline should deal with touchscreen-based mobile phones and/or smartphones.
3) The guideline should have been developed for expert inspection.
4) The selected work should come from different sectors such as the industry and the academia.

In the search it has been discovered that currently it is more common to include people with disabilities in the design of mobile interfaces. For instance, major operative systems include built-in functionalities, such as Voice Over in iOS or TalkBack in Android, that make the interface accessible. More specifically, both features allow to turn the interface into text to speech for people with visual disabilities. Additionally, there is a wide variety of research-based work [5] [8] [9] [11], as well as standards organization efforts [7], trying to develop a set of guidelines that allow to design usable and accessible mobile interfaces for the ageing population.

Research-based guidelines and standard's guidelines are important concepts in this research. Research-based guidelines are the ones developed in the academic context, which are published in indexed conferences and journals. While, standard's guidelines are the ones developed in standards organizations like ISO or W3C. It is important to consider guidelines from different sectors to be able to evaluate the apps from different perspectives. This will tell how both spheres of influence are coinciding or differing, and even if there is any contradiction between each other. From the reviewed literature, two sets of guidelines, that met all the criteria, have been selected. One is a research-based guideline [9], and the other is from a standards organization [7]. On the next sections, both sets will be reviewed in more detail.

2.2 Research-based guidelines

2.2.1 Guidelines based on usability aspects of mobile-phones for older people

Based on eight published guidelines [12] [13] [14] [15] [16] [5] [17] [18], Petrovčič, Taipale, Rogelj, and Dolničar [9] coded a set of 38 senior friendly usability guidelines. These guidelines are grouped within seven different dimensions associated with various interaction elements of mobile phones. As it can be observed in Table 1, the dimensions are: **screen**, **touchscreen**, **keypad**, **text**, **menu**, **exterior**, and **content**. In the following subsection, these dimensions will be described.

Table 1 – Complete version of the research-based guidelines

Dimension	Guideline
Screen	Display size
	High contrast
	Colors
	High resolution
	Slower dimming
	Zooming and magnification
Touchscreen	Touchscreen gestures
	Feedback
	Target/Icon properties
	Content layout
	Animation
Keypad	Button type
	Button shape
	Button size
	Button feedback

	Button responsiveness
	Labelled buttons
	Button positioning Number of buttons
Text	Ease of text entry
	Font size
	Font type
Menu	Simple menu
	Consistent menu
	Minimized nesting
	Ease of navigation
	Current location in the menu
Exterior	Device size
	Shape
	Material
	Battery charging
	External volume buttons
	Hearing aid compatible
Content	Terminology
	Function labels
	Additional languages
	User help and/or manual
	Error messages

2.2.1.1 Screen

The screen dimension considers five aspects:

1) Display size

   Elderly people prefer larger screen for better readability [19].

2) Color

   It is suggested that older people favour conservative colors with high contrast between the foreground and the background [19]. This allows elderly people to better understand and recognize the interactive elements. Since there is no agreed definition of conservative colors in the provided guidelines, the following definitions will be considered: “marked by moderation or caution” [20], and “sober and conventional” [21]. With that in mind, the colors that will be regarded as conservative are black; white; grey; blue; beige; and various shades, tones, or tints of one color. As well as, any color palette with a mix of neutral and highlight colors, where the neutral color appears in the biggest amount.

3) High resolution

   There is not enough context on what this guideline means, thus it will not be discussed in this study.

4) Slower dimming

   Screens should have slower dimming to allow older people to have sufficient time to understand and execute the necessary actions [22].

5) Zooming and magnification

   Fonts and screens should have the option to be magnified, that way if an elderly people cannot see a content well enough, at least they can zoom in or increase the font size. [23] [24] [25]

2.2.1.2 Touchscreen

The touchscreen dimension deals with:

1) Touchscreen gestures

   Gestures can create difficulties for elderly people since they are not familiarized with tapping on the screen. As a result, they need more time to comprehend and learn the movements required for gestures [26] [27] [28]. Thus, it is highly recommended to keep gestures simple.

2) Feedback

   It is common that in digital interfaces elderly people face problems trying to distinguishing whether if a button or target was pressed or not. Therefore, they constantly make mistakes by tapping for too long or not pressing the right buttons [9].

That is why, it is suggested to include auditory and tactile signals that give distinctive feedback to the user [29]. This feedback, help improving the performance of older people in touch-based interfaces.

3) Target/icon properties

   Icons should be simple and clear, properly designed for elderly people's mental models [30].

4) Content layout

   There is not enough explanation in the provided guidelines to what this guideline entails.

5) Animation

   There is not enough explanation in the provided guidelines to what this guideline entails, only that elderly people dislike animations in an icon [19].

2.2.1.3 Keypad

The keypad dimension involves eight aspects focused on buttons usability and accessibility:

1) Button type

   As mentioned before, older people prefer large buttons with clear and immediate feedback that allows them to be more accurate when pressing the buttons. This is especially useful for older people when they are dialling or witting a text.

2) Button shape

   It is recommended to differentiate buttons visually from other elements so they look as buttons. This helps older people to easily recognize buttons [23].

3) Button size

   Make buttons big enough so elderly people can perceive them [23] [22] [31].

4) Button feedback

   Include immediate visual, tactile, and/or auditory feedback, to help elderly people to avoid mistakes [32].

5) Buttons responsiveness

   Since it is common that elderly people press the wrong buttons, they should not be too sensitive, and there should be enough space between them. This gives elderly people time to react and avoid that kind of mistakes [31].

6) Labelled buttons

   Buttons along with icons should include self-explanatory labels and textual explanation [33]. That way elderly people are able to easily comprehend what they are pressing.

7) Button positioning

   The keypad should be placed at the bottom of the interface so while typing the user does not hide the rest of the screen [9]. It is suggested that older adult's pointing performance is better with: large buttons; a wider spacing between buttons; and a target size between 14 and 17.5 mm [34]. In addition it is suggested that the pointing performance among elderly people also increases by placing the buttons in the upper right direction from the centre point [29].

8) Number of buttons

   There is not enough explanation in the provided guidelines to what this guideline entails. It could be assumed that since older people face cognitive skill issues, for them it is harder to focus in too many things at the same time. Which means, that to many buttons should be avoided.

2.2.1.4 Text

This dimension encompasses three factors:

1) Ease of text entry

   Because older people are slower at working with a mobile device, they also find it difficult to type with virtual keyboards. Thus, it is recommended to provide easier ways for them to input data [27] [28].

2) Font size
   With age the visual skill starts degrading, that is why elderly people require a bigger font size. This gets worst, in the mobile context as the screen size is reduced. Thus, it is necessary provide a suitable font size for elderly people.

3) Font type
   There is not enough explanation in the provided guidelines to what this guideline entails, it could be assumed that there are certain family fonts that are more suitable for elderly people.

2.2.1.5 Menu

As the features and services in mobile devices increased, also did the complexity of the menu. As a result, elderly people constantly experience problems understanding the menu. This gets worst with the small display size of mobile phones, which does not allow to view the complete menu. That is way why, a menu should:

1) Be simple
2) Be Consistent
3) Have Minimized nesting
4) Be easy to navigate
5) Show the current location in the menu

It is suggested that a one-level menu navigation is easier to manage for elderly people because they do not always have a hierarchical mental model [28].

2.2.1.6 Exterior

The aspects that the exterior dimension contemplates are:

1) Device size
2) Shape
3) Material
4) Battery charging
5) External volume buttons
6) Hearing aid compatible

Something to keep in mind about this specific dimension is that it considers more aspects related to ergonomic characteristic of a mobile device, and less to UI elements. Some studies have reveal that for older people mobile devices should: be big, facilitate an ergonomic grip, be lightweight, and have the shape of a bar [30] [23][24]. Also, it is advisable to include audio adjustment, preferably from an external button, with a wide number of volume levels. As well as, supporting hearing aids to enable quality sound for the ageing population.

2.2.1.7 Content

The content dimension includes five factors:

1) Terminology
   Function labels have a fundamental role in the UI design for elderly people, who do not know what to do while navigating a menu [9]. Which is why the terminology used in a function label should be simple, consistent, self-explanatory, and non-ambiguous. It is also recommended to avoid foreign expressions, abbreviations, and technical terms as it might be confusing for an older adult [31].

2) Function labels
   Self-explanatory labels simplify memorizing icons, their location within the menu, and the required steps for accomplishing certain tasks [31].

3) Additional languages
   There is not enough explanation into what is important about this specific guidelines, which is why it will not be possible to consider it.

4) User help and/or manual
   Help is an important aspect in interfaces for the elderly people. As it has been mentioned before, they require more time to comprehend smartphones, thus it is necessary to include easy to understand help that is always available.

5) Error messages
   It is common that elderly people make mistakes while interacting with a mobile interface. That is why, it is fundamental to include clear error messages that give them a clear feedback in case they make a mistake.

2.3 Standards organizations guidelines

2.3.1 Overview

The W3C is the main standard's organization for the web. Within all their work, they already published "Web Content Accessibility Guidelines" (WCAG), and now they are working on providing guidance on how to apply those guidelines to the mobile device context [7]. The WCAG was created thinking on web technology. However, in terms of UI elements like buttons, hyperlinks, and paragraphs, mobile interfaces are similar to web technologies. So, the same elements that are applicable in the web are also applicable in the mobile context.

The W3C offers a set of adaptations and recommendations, not specific guidelines. Nevertheless, in this research they will be regarded as guidelines, because they were developed considering the same barriers that people with any type of impairment face while interacting either with the web or a mobile interface. Additionally, it is important to point out that the W3C focuses on creating guidelines for people with disabilities. That includes all of those who have a temporary or permanent type of impairment, like the elderly people who are the target of this study. With that in mind, in the following section the W3C guidelines will be reviewed in more depth, and later it will be identified which guidelines can be part of this study.

2.3.2 Guidelines based on barriers experienced by people with disabilities

According to the W3C there are certain barriers that are common to mobile device users with disabilities and they group them on the basis of four principles: **perceivable**, **operable**, **understandable**, and **robust** [11]. These principles are the required foundation to develop any accessible web and mobile content. Thus, as it will be explained below, the W3C provides its set of guidelines based on those principles (Table 2).

Table 2 – Complete version of the W3C Mobile accessibility guidelines

Principle	Dimension	Guideline
Perceivable	Small screen size	Minimizing the amount of information displayed as the space is limited

		Providing a reasonable default size for text and touch controls
		Adapting the length of link text to the viewport width
		Positioning form fields below their labels
	Zoom/magnification	Allow customization of default text size, preferably on page controls
		Allow for magnification of entire screen
		Allow for magnifying lens view under user's finger
	Contrast	Provide high contrast text to assist people with low vision problems
Operable	Keyboard control for touchscreen devices	Allow interfaces to be operated by external physical keyboards or other on-screen keyboards
	Touch target size and spacing	Touch targets should be at least 9 mm high by 9 mm wide. Touch targets close to the min. Size should be surrounded by a small amount of inactive space
		Allow for reasonable spacing between buttons
	Touchscreen gestures	Gestures in apps should be as easy as possible to carry out
		Activating elements via the mouse up or touch end event
	Device manipulation gestures	To manipulate a device always provide touch and keyboard operability
	Placing buttons where they are easy to access	Provide button positioning alternatives based on different scenarios: people with one hand, and left and right handed
Understandable	Changing screen orientation (portrait/landscape)	Support both orientations
	Consistent layout	Repeated interaction elements should be displayed consistently across diff. pages, including screen size and screen orientations. Consider navigation and identification
	Positioning important page elements before the page scroll	Positioning important page elements so it is visible without scrolling
	Grouping operable elements that perform the same action	Group a link and an icon that go to the same destination
	Provide clear indication that elements are actionable	Provide visual feedback to differentiate actionable elements from non-actionable ones
	Provide instructions for custom touchscreen and device manipulation gestures	Provide instructions explaining gestures that can be used, and if there are alternatives
		Instructions should be easily discoverable and accessible
		Instructions should be available anytime

Robust	Set the virtual keyboard to the type of data entry required	For forms automatically trigger the type of keyboard that meets the data entry required (email, numeric, character, etc.)
	Provide easy methods for data entry	Reduce the amount of text entry. Include select menus, radio buttons, check boxes, and auto-filling known information
	Support the characteristic properties of the platform	Support the platform's accessibility feature

2.3.2.1 Perceivable

When information and user interface components are perceivable, it means that all the elements are presented in such a way that everyone can be aware of them. To make an interface perceivable three aspects should be considered:

1) Small screen size

   Mobile devices are usually smaller than desktop, as a result the amount of information that can be displayed is more limited. The W3C recommends the following for mobile phones:

   - Reduce the amount of information displayed in the viewport. This could be achieved by hierarchizing the information and including what is truly necessary. In that way a person does not get lost and knows what to do next.
   - Provide a reasonable by default text size to minimize the use of zoom. An elderly people might find it hard when there is too much information, which gets worst if the font size is too small.
   - Extend the width of a text link to the same width of the viewport to increase visibility.
   - Position form fields below their labels to increase the size of input elements, and as result improve visibility.

2) Zoom/magnification

   Magnification and zooming is a major concern as visual degrading is one of the changes that affect elderly people. Thus to help them it is recommended to allow the following:

   - Customize the text size. Preferably through on page controls that are visible and recognizable.

- Magnify the entire screen. This allows older people with visual impairment to be able to better read and understand the content.
- Magnifying lens view under user's finger which is something normal in mobile platforms and can be triggered from the settings of the platform.

3) Contrast

   This guideline refers to checking if the text size and color over the desired background color meets the criteria to be visible enough. This can improve the visibility on screens, especially under certain environments where there is glare.

2.3.2.2 Operable

An operable content means that all the user interface and navigation can be easily controlled by the user without requesting to perform an interaction that is not possible. An operable interface encompasses five factors:

1) Keyboard control for touchscreen devices

   This involves allowing users to access the interface with alternative external physical keyboards. Considering that mobile phones have a digital keyboard that is not available at all times, some people might prefer to connect an external keyboard.

2) Touch target size and spacing

   For touch target size and spacing, the W3C recommends:

   - Setting the touch target to at least 9mm high by 9mm wide. If the elements are close to the minimum value then they should have an inactive space around them. This makes the touch target bigger and makes it easier to interact with the elements.
   - Allowing a prudent separation between the interaction elements. This helps to avoid common accidents among elderly people like pressing a button by mistake.

3) Touchscreen gestures

   Intrinsically, a mobile phone touch-based interface can be confusing for an older adult. Thus, a way to make an interface operable for them is by:

- Avoiding complex gestures like pinch and spread, which is a standard gesture for zooming in and out [19].
- Allowing to trigger actionable elements via the mouse up or touch end event. This event takes place when a person taps on an actionable element, and keeps up pressing while moving the finger away, and then releases in a non-actionable area. What happens is that the tapped elements will not get triggered. This allows to reduce the chances of clicking something by mistake, which is normal among the elderly who have reduced motor and visual skills.

4) Device manipulation gestures
Besides touch and keyboard manipulation, there are other possible methods for manipulating a mobile phone like shaking or tilting. If these are going to be part of the interface, they should not be the only way to operate the interface. Always provide the traditional touch and keyboard manipulation.

5) Placing buttons where they are easy to access
This involves providing button placement alternatives for people with only one hand, and a left and right handed.

2.3.2.3 Understandable

This refers to an interface where everyone is able to comprehend all the information and operations in it. To design an understandable mobile interface, it is recommended to consider the following six points:

1) Changing screen orientation
Mobile phones can be viewed in portrait and landscape orientation. The W3C suggests supporting both of them, without forcing anyone to change their orientation if they don't want to. It might be disorientating for an elderly people if an app only supports landscape, when the common orientation is portrait.

2) Consistent layout
For a consistent layout it is recommended to display repetitive elements across the interface in the same way, even in different screen sizes and orientations. It is specially easier for an elderly people to interact with an interface that they know how

to manipulate, they normally prefer to know what something does before clicking on it.

3) Position important page elements before the page scroll
   This allows the user to view the important content at once without the need to scroll.

4) Group operable elements that perform the same action
   Group operable elements, like a link and an icon, that share the same destination. Since both do the same, they should be grouped to increase the touch target size and benefit people with dexterity.

5) Provide clear indication that elements are actionable
   Provide visual hints that differentiate actionable from non-actionable elements. An elderly people benefits by this because they are generally used to physical interaction elements. Feature phones, for example, have buttons that allow to feel that there is a pressing, but the buttons in a flat digital screen don't have the same sensorial feedback. That is why a digital actionable element can give more feedback through the use of color, shape, iconography, positioning, and/or text label.

6) Provide instructions for custom touchscreen and device manipulation gestures
   As it is hard for elderly people to understand gestures, it is necessary to include instructions that are discoverable and available at any time. Instructions help elderly people to learn how gestures work and when to use it.

2.3.2.4 Robust

Not everyone uses the same technology, due to different preferences and also because overtime technology evolves. However, despite the differences in operative system or the software version everyone expects a mobile app to work. When they use a mobile app that uses methods not supported by their technologies, then they will feel frustrated and probably not use the app. Thus, an interface should be robust enough to support the evolution of technology, as well as different user agents, including assistive technology like external magnifiers or screen reader. Some considerations for a robust interface are:

1) Set the virtual keyboard to the type of data entry required

This involves automatically triggering the type of keyboard that matches the data entry required in a form. So for example, if only numbers are required, then enable only the numeric keyboard. This, helps elderly people to focus and reduce the time of data input, as it saves them from having to find the numeric keyboard and then coming back to the alphabetical one.

2) Provide easy methods for data entry
   Similarly, to facilitate the data entry in forms it is important to provide easy methods to do it. A convenient way to do so is including select menus, radio buttons, check boxes, and even auto-complete acquainted information.

3) Support the characteristic properties of the platform
   To make an interface robust enough it is necessary that it supports the platform's accessibility features. In this way if an app does not include any of the mentioned guidelines, at least the platform can help the elderly users to interact with the app.

2.4 Comparison between research-based guidelines and standard's guidelines

This section provides an analysis of the reviewed set of guidelines. More specifically, it outlines how the two different spheres of influence (academia and standards organizations) address the development of age friendly usability and accessibility guidelines for mobile interfaces. From the review of the research-based guidelines and the standard's guidelines, it has been observed that there are similarities and differences between both sources. On the one hand, some of the similarities lay within aspects that are important for perceivability. For instance, providing high contrast content, allowing a suitable font size for elderly people, allowing users to resize the text, and even allow them to magnify the entire screen. To make the interface operable for elderly people, both guidelines also make an emphasis on including gestures that are simple, as well as allowing for a suitable target size and spacing to avoid wrong pressing of buttons. Additionally, they also agree on providing feedback for actionable elements, along with including instructions that make the interface easily understandable for an elderly people. Finally, both guidelines coincide on the importance of facilitating text entry by reducing the amount of data to be input and the number of actions to input that data.

In terms of structure, both guidelines are completely different, as the standard's guidelines are categorized according to the barriers that impaired people face while using a mobile device, and the research-based guidelines are categorized according to general usability aspects of mobile phones and smartphones for older people. This does not mean that one is better than the other, they just have different approaches to categorize each guideline. Additionally, it was observed in some cases that both guidelines give importance to the same element but in different ways. For example, both consider the small screen size of mobile devices as a usability aspect for age-friendly mobile interfaces. The research-based guidelines review the screen size from the perspective of how elderly people prefer bigger screens, but the standard's guidelines reviews it from the perspective of the limited amount of information that can be displayed on mobile-phone screen. Meaning that, the first one is more focused in physical features of the device itself, which is not the focus of this study, and the second one on the UI design. Also, in the standard's guidelines consistency is reviewed from a more general perspective, like consistency across different pages, while the research-based guidelines only addresses the consistency in menus. Button properties for elderly people, are also approached differently in both guidelines. In the standard's guidelines buttons are addressed from a more generic point of view, like actionable elements, while research-based guidelines are more detailed, as they have several guidelines only for buttons. As a result regarding buttons, the standard's guidelines are open for interpretation, because an actionable element might be a link, an icon, an image, or an input. Which could share some properties.

Another difference between both guidelines is how each cover their own unique interaction elements. For instance, in the research-based guidelines there is a complete set of guidelines specifically aimed at menus, which is not addressed in the standard's guidelines. Similarly, in the research-based guidelines there is a complete section that deals with written content, including the importance of simple and effective terminology, simple labels, and error messages. Research-based guidelines emphasize on the type of buttons, the responsiveness of buttons and the labelling of buttons, which is not part of the standard's guidelines. Additionally, for visual characteristics, it is suggested to use conservative colors, and plain icons. On the other hand, the standard's guidelines emphasize on the screen orientation, which is not considered in the research-based guidelines. Also, standard's guidelines covers more on forms than research-based guidelines, by advising to locate a field below its label, and automatically setting the virtual keyboard to the type of data entry required. The most interesting aspect in standard's guidelines, not included in the research-based guidelines, is the emphasis on supporting the platform's built-in accessibility settings. This turns a non-accessible app into an accessible app, allowing any person with disabilities to use it. Other aspects addressed in the standard's guidelines and not in the research-based guidelines are the touch end event for avoiding tapping mistakes, the alternative positions of buttons for people with only one hand or left/right handed, positioning important elements before the page scroll, and grouping operable elements performing the same action.

Despite that research-based guidelines and standard's guidelines have a lot of differences, they both share the same goal: facilitating the interaction of an elderly people with a mobile interface. Thus, both could complement each other by filling the gap the other one has. That is why, later the apps will be evaluated based on both guidelines. The following chapter explains the evaluation method, the selected list of checkpoint from each guideline, and introduces the apps to be evaluated.

Chapter 3 – Procedure and Method

The aim of this research is to assess how and to what extent the industry is taking into account the usability and accessibility needs of the ageing population in the design process of mobile apps. Which is why 18 age-specific mobile apps are selected and evaluated on the basis of the standard's and research-based guidelines, reviewed in chapter 2. This chapter explains the procedure and method applied to evaluate the apps, including the selection criteria of the apps and the selection criteria of the parameters applied on the evaluation of the apps.

3.1 Apps Systematic review

3.1.1 Apps Search Strategy

To find the appropriate mobile applications for the evaluation, a systematic review of the market was performed. The review was carried out using Google's browser, the Apple App Store for iOS apps, and the Google Play Store for Android apps. Moreover the following selection criteria was applied:

- The functionality of the apps must address age-related needs.
- The app should be up to date, meaning that it is still in use and developers still support it.
- The app should be for iOS and/or Android.
- The app should be free or at least should have a demo version.

The first step of the review was to define certain keywords to ensure that all the relevant apps for the ageing population was detected. Therefore, the following combination of keywords in English were used: best, elderly, app, senior, elder, older people. Every hit was reviewed in terms of its relevance and specific relation to the elderly people. The basis for the systematic market review was defined by categories and their respective specifications outlined in Table 3. To collect the information for all categories and specifications, all the available information given by both the stores and the app developer were considered.

Table 3 – Categories and subcategories/specifications retrieved from each app

Category	Specifications
General information	• App name • App language • Date of latest update • Operating system availability
Operating system	• App exclusively for the iOS operating system • App exclusively for the Android operating system • App for both operating systems available
Developer information	• Name of the developer • Link to website (if available)
Acquisition costs	• Free • Exact price • Availability as "demo" version (paid apps sometimes offer free or cheaper demo versions with limited functionality)
Popularity/user ratings	• User rating • Number of user ratings
Range of functions (multiple selection possible)	• Apps addressing any age-related need such as: health monitoring, hearing aid, social network, emergency, visual aid, reminders, games, location, etc.

3.1.2 Sample app's

The search resulted in a total of 48 applications. From this original sample, 13 apps were excluded as they did not meet the criteria. The remaining 35 apps were grouped by their functionality, such as health and fitness or hearing support, to facilitate their assessment. However, from theses apps 17 were also excluded from the study because of the following reasons:

- The app was a built-in application
- The functionality of the app was repeated more than twice and had lower ratings than its peer
- The app was too generic, meaning that it was also aimed at other type of users, like the case of Netflix
- The app was addressed at people with more severe disabilities

- The app was not free and did not have a demo version
- The app was not found on the Irish App store

As a result, only the following 18 apps were selected for examination. They all address an important need for elderly people:

- Red Panic Button [35]
- Fade: fall detector [36]
- Magnifying Glass With Light [37]
- Magnifying Glass Flashlight [38]
- Usound (Hearing Assistant) [39]
- MyEarDroid - Sound Recognition [40]
- Live Caption [41]
- Wiser - Simple Senior Launcher [42]
- Nova Launcher [43]
- MindMate - Healthy Aging [44]
- WebMD [45]
- Pocket Physio [46]
- Blood Pressure Monitor [47]
- Pill Reminder by Medisafe [48]
- Lumosity - Brain Training [49]
- Skype [50]
- Stitch Companionship [51]
- Find My Family, Friends, Phone Safe365 [52]

Red Panic Button & Fade: fall detector

These are useful apps in case of an emergency, like falling. Accidents of different nature often occur to elderly people who start experiencing a decline in their motor and visual skills, as well as their health.

Magnifying Glass With Light & Magnifying Glass Flashlight

These applications address the visual decline common among the elderly people. They particularly magnify and light external text through the use of the phone’s camera.

Usound (Hearing Assistant), MyEarDroid - Sound Recognition & Live Caption

These apps consider the loss in hearing among the ageing population. In a high level, Usound and MyEarDroid amplify external environmental sounds. While Live Caption processes external conversations and displays captions on the screen in real time.

Wiser - Simple Senior Launcher & Nova Launcher

These applications turn the mobile interface accessible for the elderly people. Among their features it is possible to customize the size of the icons, the text and label. In general, this apps simplify the use of an interface for elderly people.

MindMate, WebMD, Pocket Physio & Blood Pressure Monitor

All of these apps focus on health and fitness. As it was already mentioned, ageing is associated with a gradual decrease in health, and as result a decline in motor and cognitive skills. In response to that, these four apps have tips for a healthy living, set of physical and mental exercises, monitoring of blood pressure, symptom checkers, among other functionalities.

Pill Reminder by Medisafe

Elderly people generally have to take a wide variety of pills for different reasons and they sometimes forget. As a response, Pill Reminder by Medisafe assist older people keeping a record and reminding them to take their medication on time.

Lumosity - Brain Training

This app provides a set of games designed for elderly people to enhance their memory, cognitive abilities, and dexterity issues.

Skype and Stitch Companionship

One of the things that older people identify as important in their life is relationships. In fact, it is believed that one of the thigs that influence life span and functional abilities in older people, is social interaction [2]. Skype and Stitch Companionship are application that allow to maintain and built relationships. Particularly, Stitch Companionship is an app that allows elderly people to make friends, plan activities with people their own age, and even date.

While Skype is a telecommunication app that has been suggested to help older people to stay in touch with their loved ones, especially when there is any type of movement impediment.

Find My Family, Friends, Phone Safe365

This is an app that helps locate elderly people with the additional feature of sending emergency alerts. It is especially helpful for when older people experience dementia, Alzheimer or any other condition that increases the chance of older people getting lost.

3.2 Parameters: from guidelines to a list of checkpoints

As the parameters to evaluate the selected apps, the research-based guidelines and the standard's guidelines were turned into two lists of checkpoints (Table 4 and 5). To turn the guidelines into checkpoints, some items have been renamed and others have been excluded from this study. Additionally, to facilitate the evaluation process, a codename is assigned to each checkpoint. RBG for research-based guidelines and SG for standard's guidelines, which is followed by a number which represents the positions of the guideline on the table.

3.2.1 List 1: Checkpoints retrieved from research-based guidelines

Some items from the research-based guidelines on Table 1 have been excluded from this study as they go beyond the scope of this study. For example, the exterior dimension and its guidelines have been excluded because it mostly addresses physical characteristics of a mobile device, and not UI elements. The excluded guidelines for the exterior dimension include: device size, shape, material, battery charging, external volume buttons, and hearing aid compatibility. Other guidelines were excluded from the study because it is not described in the respective literature. Thus, there was not a clear clue for what was supposed to be measured. These items are: additional languages, font type, number of buttons, animation, and content layout. From the prevailing items four –display size, high resolution, and slower dimming– were excluded as well because they do not address UI elements. While the last item –high contrast– was also omitted because there were not enough resources available to be able to evaluate it. So, from the original set of 38 guidelines, only 23 have been selected and turned into one of the lists of checkpoints to evaluate the apps (Table 4).

Table 4 – Selected list of checkpoints from the research based guidelines

Dimension	Checkpoint	Code
Screen	Colors conservativeness	RBG-01
	Zooming and magnification	RBG-02
Touchscreen	Touchscreen gestures	RBG-03
	Feedback	RBG-04
	Target/Icon properties	RBG-05
Keypad	Button type	RBG-06
	Button shape	RBG-07
	Button size	RBG-08
	Button feedback	RBG-09
	Button responsiveness	RBG-10
	Labelled buttons	RBG-11
	Button positioning	RBG-12
Text	Ease of text entry	RBG-13
	Font size	RBG-14
Menu	Simple menu	RBG-15
	Consistent menu	RBG-16
	Minimized nesting	RBG-17
	Ease of navigation	RBG-18
	Current location in the menu	RBG-19
Content	Terminology	RBG-20
	Function labels	RBG-21
	User help and/or manual	RBG-22
	Error messages	RBG-23

3.2.2 List 2: Checkpoints retrieved from the standard's guidelines

Similarly to the research-based guidelines, some of the W3C guidelines on Table 2 have been renamed or excluded. On the one hand two items from this table –contrast, and touch target size and spacing– have been excluded from this study due to resource limitations. Whereas, keyboard control for touchscreen devices, and device manipulation gestures have been also excluded, because they go beyond the scope of this study. Allowing for magnifying lens under user's finger, and adapting link text width to the viewport width was also excluded because there was not enough context in the respective literature about their importance for older people. Hence, from the original 26 guidelines on Table 2, 20 will be considered for the final evaluation. The complete list of guidelines and their corresponding checkpoint is listed on Table 5. Some changes have been applied to some of the guidelines to facilitate the evaluation process. First, from the complete list of checkpoints two –supporting the platform's accessibility features, and consistent layout– have been divided into more modules. However, for the final result they will still count as one. Then, to facilitate the reading of each checkpoint their names have been shorten. So for example, instead of "provide reasonable default size for content and touch controls" (Table 2), the name of the checkpoint is "suitable font size" (Table 5).

Table 5 – Selected list of checkpoints from the standard's guidelines

Principle	Dimension	Checkpoint	Code
Perceivable	Small screen size	Reduce information	SG-01
		Font size	SG-02
		Form field below label	SG-03
	Zoom/magnification	Text resizing	SG-04
		On-screen control to change text size	SG-05
		Zoom	SG-06
Operable	Touchscreen gestures	Easy	SG-07
		Touch-end event	SG-08
	Buttons	Accessible	SG-09
Understandable	Screen orientation	Support both	SG-10
	Consistent layout	Multiple pages Screen orientations	SG-11
	Important page elements before page scroll		SG-12
	Group operable elements performing same action		SG-13
	Visually differentiate actionable elements		SG-14

	Instructions	Available	SG-15
		Easily discoverable and accessible	SG-16
		Available anytime	SG-17
Robust	Set virtual keyboard to the type of data entry required		SG-18
	Reduce amount of text entry required		SG-19
	Support characteristic properties of platform	Zoom Font size Captions	SG-20

3.3 Usability Evaluation

To assess the usability and accessibility of the selected applications for elderly people, an expert-based usability evaluation has been performed. This method involved one expert, reviewing the apps in terms of usability and accessibility on the basis of the defined list of checkpoints retrieved from the provided guidelines. This guideline-based approach of usability evaluation is based by the one proposed by Nielsen with some variations [53]. Throughout the evaluation, each individual checkpoint was tested manually for every app. To grade each checkpoint, a scale system that goes from 0 to 2 has been employed. In this system, 0 points are given to null or no-included checkpoints, 1 point is given to checkpoints not entirely considered, and 2 points are given to checkpoints fully included. For each list of checkpoints there were individual preliminary results, and the final score of each app was the average between these preliminary scores. As observed in Table 6, the preliminary and final results were categorized based on a 5 point rating scale system raging from high to low. Where, high is given to scores equivalent to 81% and above, high-moderate is given to scores equivalent to 71-80%, moderate is given to scores equivalent to 61-70%, low-moderate is given to scores equivalent to 51-60%, and low is given to scores equivalent to 50% and below. From this grades, a ranking of the most and least accessible apps will be retrieved. The percentage of accessible versus non accessible apps is what will show how the industry is taking into account older people's needs in the design of mobile interfaces.

Table 6 – Rating scale system used to categorize the score of the apps

Qualification	(%)	Research-based	Standard's	Average
High	81-100	37-46	32-40	34.9-43
High-moderate	71-80	33-36	28-31	30.6-34.8
Moderate	61-70	28-32	24-27	26.3-30.5
Low-moderate	51-60	23-27	20-23	21.6-26.2
Low	0-50	0-22	0-19	0-21.5

The analysis has been performed using two different devices: an iPhone 5s with iOS 11.3, and a Moto G 2014 with Android 7.1.1. In both cases, the platform's built-in accessibility settings were disabled.

Chapter 4 – Results

The aim of this study is to assess how and to what extent is the industry considering the usability and accessibility needs of the elderly people. To do that, 18 age-specific industry-built mobile apps are selected and systematically reviewed. These apps are reviewed on the basis of two available usability and accessibility guidelines to design age-friendly mobile interfaces.

This chapter presents the results obtained during the evaluation of each app. Section 4.1 reviews the apps in terms of how many apps include a specific checkpoint. Section 4.2 shows the preliminary score of each app for each set of checkpoints. Section 4.3 present the final result of each app and shows on average which are the most and least accessible apps.

4.1 How many apps include each checkpoint?

This section presents the results collected in Figure 1 and Figure 2, in terms of how many applications fully include a specific checkpoint. The structure of this section is as follows: subsection 4.1.1 provides a description of the results from Figure 1. Subsection 4.1.2 provides a descriptions of the results from Figure 2.

... continue on next page

Figure 1: Checkpoints under evaluation scores (research-based guidelines)

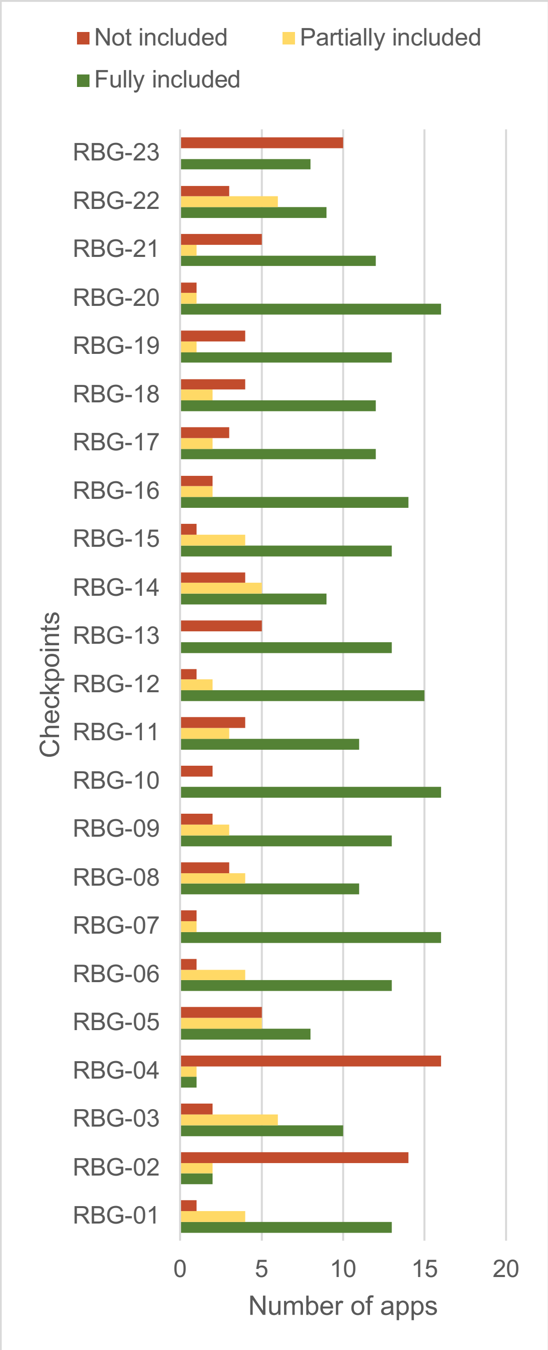
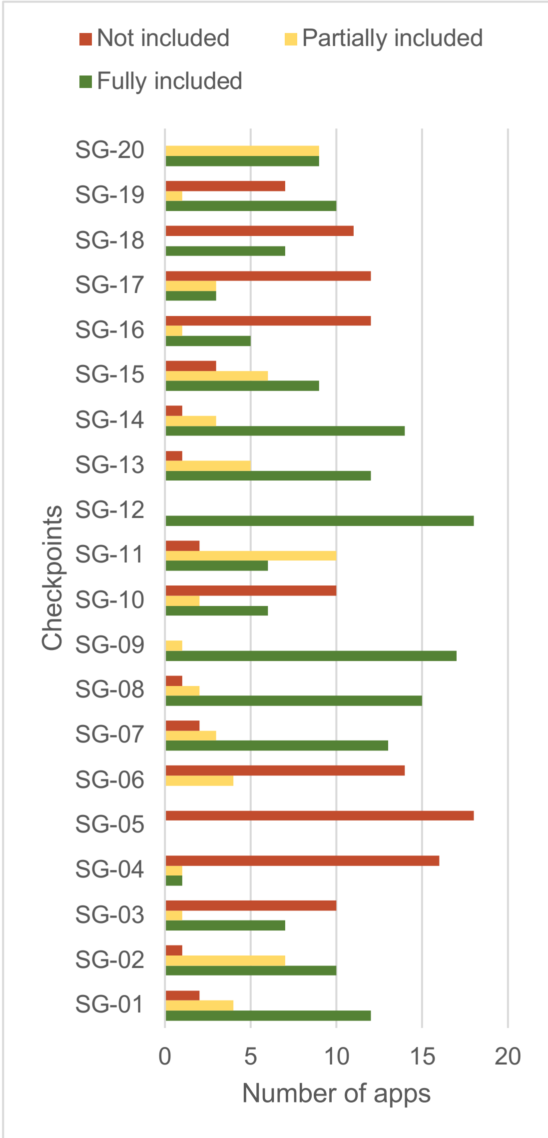


Figure 2: Checkpoints under evaluation scores (standard's guidelines)



4.1.1 List 1: checkpoints retrieved from the research-based guidelines

The results obtained in the evaluation of the apps on the basis of the research-based guidelines are summarised in Figure 1. On average, it was observed that all the applications include 70% of the checkpoints. However, there are 7 checkpoints with results below expectations. First, it was surprising to see that there are 2 checkpoints fully included in less than 11% of the apps. They, have a relevant impact on how the elderly people interact with a mobile interface, and have been recurrently mentioned in several guidelines since 2004 [9]. These checkpoints are zooming and magnification (RBG-02) and feedback (RGB-04). The remaining 5 checkpoints below expectations, included in between 44% and 55% of the apps, are: error message (RBG-23), target/icon property (RBG-05), help (RBG-22), font size (RBG-14), and touchscreen gesture (RBG-03). Help, error messages and an appropriate target property are important aspects in an age-friendly interface because they allow to avoid mistakes commonly made by the elderly people. While font size and simple touchscreen gestures are basic usability and accessibility aspects for the elderly people who experience visual, and motor impairments.

An interesting finding is that none of the checkpoints were included in a 100% of the apps. The maximum amount of apps, including three of the checkpoints, was 88.8%. These 3 checkpoints included in 88.8% of the apps are: button shape (RGB-07), terminology (RGB-20), and button responsiveness (RGB-10). They are immediately followed by button positioning (RGB-12) included in 83.3% of the apps. The next most included checkpoints are colors (RGB-01), button type (RBG-06), consistent menu (RBG-16), button feedback (RBG-09), current location in the menu (RBG-19), simple menu (RBG-15), and ease of text entry (RBG-13); which are fully included in 72.2% of the apps. The remaining checkpoints – minimized nesting (RBG-17), ease of navigation (RBG-18), button size (RBG-08), and labelled buttons (RBG-11)– are fully included in between 61.1% and 66.6% of the apps.

In Figure 1 it was observed, on average, that all the applications include 70% of the checkpoints, thus it is evident that there is a significant effort to consider the usability and accessibility aspects associated with the research-based guidelines. However, considering that 30.4% of the checkpoints are included by less than half of the apps, it means that there is still work to be done to. A special weakness was observed in guidelines that allow an effective interaction between the elderly people and their mobile phones, like zooming and magnification, font size, touchscreen gestures, and help.

4.1.2 List 2: checkpoints retrieved from the standard's guidelines

Figure 2 shows the results obtained from the evaluation of the applications based on the checkpoints retrieved from the standard's guidelines. From the data collected it was interesting to see that, unlike the overall results from Figure 1, the overall results from Figure 2 are below expectations. This is reflected on the average of all applications including only 49% of the checkpoints. Additionally, it was observed that more than half of the checkpoints had results below expectations, that is more than the results below expectation in Figure 1. As shown in Figure 2, one checkpoint –on screen controllers to change text size (SG-05)– was not included in any of the applications. While in Figure 1, all the checkpoints were included by at least one app. From the remaining 11 checkpoints, zoom (SG-06) is only partially included in 22.2% of the apps, text resizing (SG-04) is fully included in 5.5% of the apps, and instructions available anytime (SG-17) is included in 16.6% of the apps. From the remaining 8 checkpoints, there are five that are fully included in between 25% to 39% of the apps: form field below label (SG-03) and easily discoverable and accessible instructions (SG-16) fully included in 25%; consistent layout (SG-11) and support both screen orientations (SG-10) fully included in 33.3%; and setting virtual keyboard to the type of data entry required (SG-18) included in 38.8%. The remaining 3 apps with results below expectations are: instructions available (SG-15) and font size (SG-02) fully included in half of the applications, and easy methods for data entry (SG-19) fully included in only a bit more than half of the applications (55.5%).

Figure 2 reveals that from the 20 evaluated checkpoints, only 44.4% had high results. Additionally, a surprising finding from the results is that the checkpoint important page elements before page-scroll (SG-12) is the only one to be fully included in 100% of the apps. Even compared to the research-based guidelines this is the only checkpoint to be fully included by all the applications. An additional checkpoint that did well within the standard's checkpoints, was support characteristic properties of platform (SG-20), which was partially included in 50% of the apps and fully included in 50% of the apps. Meaning that, to some degree this checkpoint was considered by all the apps. The next group of checkpoints with satisfactory results are accessible buttons (SG-09) fully included in 88.8% of the apps, touch end event (SG-08) fully included in 83.3% of the apps, and visually differentiating actionable elements (SG-14) fully included in 77.7% of the apps. Finally, from the remaining three checkpoints, two –group operable elements performing same action (SG-13), and reduced information (SG-01)– are included in 66.6% of the apps, and one –easy touchscreen gestures (SG-07)– is included in 72.2% of the apps.

From the results above, it is surprising to see that the checkpoints with results below expectations allow to make an interface perceivable, understandable and robust for older people. That is 3 of the 4 principles necessary for making a mobile interface accessible for older people. Among this checkpoints, the most concerning checkpoints are: on screen controllers to change the text size, allowing text resizing, and allowing zoom. These checkpoints, are relevant to make an interface perceivable to older people with visual impairment. It was also surprising to observe that, from the checkpoints with results below expectations, there are many related to making the data entry process easier, like including easy methods for data entry and setting the virtual keyboard to the type of data entry required. However, there is one positive result worth highlighting from this set of checkpoints. While, the checkpoints zoom and font size are fully included in less than half of the applications, it was observed that all the apps support the characteristic properties of the platform. This properties, allow to magnify the screen and adjust the size of the fonts.

The most concerning finding from this results is that more than half of the standard's checkpoints obtained a result below expectations (65% of the checkpoints). Revealing that the industry is not taking into account the usability and accessibility aspects for elderly people related to the standard's guidelines.

4.2 Preliminary app's score

The previous section showed the results of the evaluation in terms of how many apps include a specific checkpoint. This section presents the preliminary scores of every app for each list of checkpoints provided in chapter 3. First, the scores of the reviewed apps based on the research-based checkpoints will be described, then the scores of the reviewed apps based on the standard's checkpoints.

4.2.1 Research-based checkpoints

Table 7 (a) and (b) present the partial score for each application based on the research-based guidelines. For the evaluation, it is important to point out that the highest score that an app could get is 46 points, as there were 23 research-based checkpoints and each could get a maximum of two points. As mentioned in Table 6, the scores were categorized as follows: scores 22 and below were qualified as low, scores between 23 and 29 were qualified as low-moderate, scores ranging from 30 to 34 were qualified as moderate, scores from 35 to 39 were qualified as high-moderate, and scores 40 to 46 were qualified as high.

As it can be observed in Tables 7 (a) and (b) the application with the highest score (above 86.6% of the full score) was Usound with 42 points, followed by Lumosity and Wiser with 40 points. Then, comes the apps with between 73% and 85% of the full score: Safe365 with 39 points, Pocket Physio with 37 points, Live caption and Pill Reminder with 35 points, and Stich with 34 points. Then, there are 5 apps with a moderate score, with between 60% and 69.5% of the full score: Magnifying Glass Flashlight and MindMate with 32 points, Red panic Button with 31, WebMD with 29, and Nova launcher with 28. Conversely, the application that obtained the lowest score of the research-based guidelines was MyEarDroid with 22 points. The remaining 3 apps had a low-moderate score, between 50% and 56.5% of the full score. The apps with the lowest score from this group was Blood Pressure Monitor with 23 points, followed by Magnifying Glass With Light and skype with 26 points.

The data from Table 7 (a) and (b) show that, according to the rating scale system (Table 6), 44.4% of the apps qualified as high and high-moderate, 33.3% of the apps qualified as moderate, and 22.2% qualified as low-moderate and low. Meaning that less than half of the app's sample (44.4%) acceptably address accessibility and usability issues for the elderly people. Although, there is a 33.3% of the apps that moderately address these issues, but not highly enough. The good thing about the results, is that the percentage of apps that barely or not at all address accessibility and usability issues for the elderly people is smaller (22.2%) than the percentage of apps that do address these issues.

Table 7(a) – preliminary score of the apps evaluated on the basis of the research-based checkpoints (part a)

	Red Panic Button	Fade	Magnifying Glass With Light	Magnifying Glass Flashlight	Usound	MyEar Droid	Live Caption	Wiser	Nova Launcher
RBG-01	2	1	2	2	2	2	2	2	0
RBG-02	0	0	1	1	0	0	2	0	2
RBG-03	1	1	0	2	2	2	2	2	1
RBG-04	0	0	0	2	0	0	0	1	0
RBG-05	2	0	1	2	2	0	2	2	2
RBG-06	2	1	2	1	2	1	2	2	2
RBG-07	2	2	2	2	2	0	1	2	2
RBG-08	2	2	1	2	2	1	1	2	2
RBG-09	2	2	2	0	2	1	2	2	2
RBG-10	0	2	2	2	2	2	2	2	2
RBG-11	1	0	0	0	2	0	1	2	2
RBG-12	2	2	1	2	2	2	2	2	2
RBG-13	2	2	0	0	2	0	0	2	0
RBG-14	0	2	1	2	2	1	0	2	2
RBG-15	2	2	0	2	2	2	2	2	0
RBG-16	2	2	2	2	2	2	2	2	2
RBG-17	1	2	2	2	2	2	2	2	0
RBG-18	2	1	2	2	2	0	2	2	0
RBG-19	2	0	2	2	2	1	2	2	2
RBG-20	2	2	2	2	2	2	2	2	0
RBG-21	0	0	0	0	2	0	2	2	2
RBG-22	2	1	1	0	2	1	2	1	1
RBG-23	0	2	0	0	2	0	0	0	0
TOTAL	**31**	**29**	**26**	**32**	**42**	**22**	**35**	**40**	**28**

Table 7(b) – preliminary score of the apps evaluated on the basis of the research-based checkpoints (part b)

	MindMate	WebMD	Pocket Physio	Blood Pressure Monitor	Pill Reminder	Lumosity	Skype	Stitch	Safe365
RBG-01	1	2	2	2	2	1	1	2	2
RBG-02	0	0	0	0	0	0	0	0	0
RBG-03	2	0	2	2	1	2	1	2	1
RBG-04	0	0	0	0	0	0	0	0	0
RBG-05	1	0	0	2	1	1	1	0	2
RBG-06	2	2	2	0	2	2	1	2	2
RBG-07	2	2	2	2	2	2	2	2	2
RBG-08	2	0	2	0	0	2	1	2	2
RBG-09	1	1	2	2	2	2	2	2	0
RBG-10	2	2	2	2	2	2	2	0	2
RBG-11	2	2	2	2	2	2	1	2	2
RBG-12	2	2	2	0	2	2	1	2	2
RBG-13	2	2	2	2	2	2	2	2	2
RBG-14	2	0	1	0	1	2	1	2	2
RBG-15	2	1	2	0	2	2	0	2	2
RBG-16	2	1	2	0	1	2	2	0	2
RBG-17	2	1	2	0	1	2	0	2	2
RBG-18	2	1	2	0	2	2	0	2	2
RBG-19	0	2	2	0	2	2	0	2	2
RBG-20	2	2	2	1	2	2	2	2	2
RBG-21	1	2	2	2	2	2	2	2	2
RBG-22	0	2	2	2	2	2	2	2	2
RBG-23	0	2	0	2	2	2	2	0	2
TOTAL	32	29	37	23	35	40	26	34	39

4.2.2 Standard’s checkpoints

The data collected in Table 8 (a) and (b) correspond to the scores of each selected app based on the list of checkpoints retrieved from the standard’s guidelines. In this case, since there were twenty checkpoints and each could get a maximum of 2 points, the highest score was 40. Again, to evaluate the apps the scores were grouped according to the qualifications in Table 6. Where, 19 below means low, 20 to 23 means low-moderate, 24 to 27 means moderate, 28 to 31 means high-moderate, and 32 above means high.

As it can be observed in Tables 8 (a) and (b), overall the apps have a higher number of low moderate and low results (66.6% of the apps) than high-moderate results (11.1% of the apps). Furthermore, none of the apps got a high score, the highest qualification is high-moderate. The apps with this qualification are: Live Caption with 30 points and Lumosity with 29. Then, four apps with a moderate result are: Skype with 27 points, Usound with 26, and Stitch and Safe365 with 24. An interesting phenomenon from these results, is that in the evaluation of the research-based checkpoints, Usound and Safe365 have the highest score, while for the evaluation of the standard’s checkpoints, their score is lower, with a moderate qualification. In the case of Skype in the evaluation of the standard’s checkpoints its score was higher, with a moderate qualification, instead of a low-moderate. More than half of the apps (55.5%) have low-moderate result. The apps that scored highest in this group were MindMate and Magnifying Glass with 23 points, followed by Magnifying Glass Flashlight, WebMD, Pocket Physio, and Pill Reminder with 22. Next, Red Panic Button with 21 points, and Wiser, Blood Pressure Monitor, and Nova Launcher with a total of 20 points. The remaining two apps – MyEarDroid and Fade– had the lowest score with 18 and 16 points respectively.

These results reveal that, from the standard’s checkpoints, only 11.1% of the apps have a high-moderate score, 22.2% of the apps have a moderate score; 55.5% have a low-moderate score; and 11.1% have a low score. Meaning that, from the standard’s checkpoints only 11.1% of the apps acceptably address usability and accessibility issue for the elderly people. Although, there is another small percentage of apps (22.2%) that moderately address this issues, but not enough to be fully accessible. The most concerning result from the standard’s checkpoints is that more than half of the apps (66.6%) do not address usability and accessibility issues for the elderly people. Compared to the research-based guidelines, the apps become less accessible when evaluated against the standard's guidelines.

Table 8(a) – preliminary score of the apps evaluated on the basis of the standard's checkpoints (part a)

	Red Panic Button	Fade	Magnifying Glass With Light	Magnifying Glass Flashlight	Usound	MyEar Droid	Live Caption	Wiser	Nova Launcher
SG-01	2	2	2	2	2	2	2	2	0
SG-02	2	2	2	2	2	1	1	2	2
SG-03	0	0	2	0	2	0	2	0	2
SG-04	0	0	0	0	0	0	1	0	2
SG-05	0	0	0	0	0	0	1	0	0
SG-06	0	0	1	1	0	0	0	0	0
SG-07	2	1	1	2	2	2	2	2	0
SG-08	2	2	1	2	2	1	2	2	2
SG-09	2	2	2	2	2	1	2	2	2
SG-10	0	0	1	2	0	0	2	0	0
SG-11	1	1	2	1	1	0	2	1	1
SG-12	2	2	2	2	2	2	2	2	2
SG-13	2	2	2	2	2	1	2	2	2
SG-14	2	0	2	2	1	1	2	2	2
SG-15	0	0	2	0	2	1	2	2	1
SG-16	0	0	0	0	1	2	2	0	0
SG-17	0	0	0	0	0	2	2	0	0
SG-18	0	0	0	0	2	0	0	0	0
SG-19	2	0	0	0	2	0	0	0	1
SG-20	2	2	1	2	1	2	1	1	1
TOTAL	**21**	**16**	**23**	**22**	**26**	**18**	**30**	**20**	**20**

Table 8(b) – preliminary score of the apps evaluated on the basis of the standard's checkpoints (part b)

	MindMate	WebMD	Pocket Physio	Blood Pressure Monitor	Pill Reminder	Lumosity	Skype	Stitch	Safe365
SG-01	2	1	1	0	1	2	1	2	2
SG-02	2	0	1	0	1	2	2	2	2
SG-03	2	0	0	0	1	0	2	0	0
SG-04	0	0	0	0	0	0	0	0	0
SG-05	0	0	0	0	0	0	0	0	0
SG-06	1	1	0	0	0	0	0	0	0
SG-07	2	1	2	2	0	2	2	2	2
SG-08	2	2	2	2	2	2	2	0	2
SG-09	2	2	2	2	2	2	2	2	2
SG-10	0	0	2	1	2	2	2	2	0
SG-11	1	1	2	0	2	0	2	2	1
SG-12	2	2	2	2	2	1	2	2	2
SG-13	2	2	0	2	1	2	1	1	1
SG-14	2	2	2	2	1	2	2	2	2
SG-15	0	1	1	2	1	2	2	2	1
SG-16	0	2	2	0	0	2	0	0	0
SG-17	0	1	1	0	0	2	0	0	1
SG-18	0	0	0	2	2	2	2	2	2
SG-19	2	2	0	2	2	2	2	2	2
SG-20	1	2	2	1	2	2	1	1	2
TOTAL	23	22	22	20	22	29	27	24	24

4.3 Final results of the applications

This section presents the data in terms of the least and most accessible applications for elderly people on the basis of the two list of checkpoints provided in section 3. Tables 7 (a) and (b) and Tables 8 (a) and (b) show the preliminary score obtained by each app for each list of checkpoints, while Table 9 shows the final score obtained by each app. This final score was calculated making an average between the preliminary score of the research-based checkpoints and the preliminary score of the standard's checkpoints.

In table 9, the highest score an app could get was 43. According to the rating scale system in Table 5, the apps are categorized as follows: the apps with a score between 30.6 and 43 are the most accessible apps for elderly people, and the apps with a score between 26.3 and 30.5 are the least accessible for elderly people. The remaining apps with a score between 26.3 and 30.5 address usability and accessibility for older people only partially, but not enough to be considered accessible for older people.

Table 9 shows interesting results about the apps. First, on average only 22.2% of all the apps acceptably addressed usability and accessibility issues for the elderly people, and 38.8% of all the apps moderately address these issues. While, the remaining 38.8% of all the apps barely or did not address at all the necessary usability and accessibility issues of the elderly people. Thus, the most accessible apps are Lumosity with 34.5, Usound with 34, Live caption with 32.5, and Safe365 with 31.5. Conversely, the least accessible apps are MyEarDroid with 20, Blood Pressure Monitor with 21.5, Nova Launcher with 22, Fade with 22.5, Magnifying Glass With Light with 24.5, WebMD with 25.5, and Red Panic Button with 26. The remaining apps, 38.8% of all the apps, certainly make an effort to include accessibility issues for the elderly people but only moderately. These apps are: Skype with 26.5, Magnifying Glass Flashlight with 27, MindMate with 27.5, Pill Reminder with 28.5, Stich with 29, Pocket Physio with 29.5, and Wiser with 30.

From the collected data in table 9, It was expected that at least 81% of the sample successfully included most of the checkpoints, however as it was already mentioned, on average only 22.2% of the apps fully included most of the checkpoints. So, as it can be observed less than half of the industry is implementing age-friendly guidelines in the design of mobile apps for older people. Although, there is a 38,8% of the apps that moderately include the checkpoints, which can be joined to the 22.2% of the apps that fully include most of the checkpoints. These, two together show that there is a low effort from the industry-built apps to address usability and accessibility issues for the elderly people. Despite this low effort, there is still a lot of work to do in order to design usable and accessible mobile apps for older people. In fact, the percentage of non-accessible apps was even higher (38.8%) than the amount of accessible apps (22.2%).

Table 9 – Scores of the average between research-based and standard's checkpoints.

	Red Panic Button	Fade	Magnifying Glass With Light	Magnifying Glass Flashlight	Usound	MyEar Droid	Live Caption	Wiser	Nova Launcher
RBG	31	29	26	32	42	22	35	40	28
SG	21	16	23	22	26	18	30	20	16
SCORE (media)	**26**	**22.5**	**24.5**	**27**	**34**	**20**	**32.5**	**30**	**22**

	MindMate	WebMD	Pocket Physio	Blood Pressure Monitor	Pill Reminder	Lumosity	Skype	Stitch	Safe365
RBG	32	29	37	23	35	40	26	34	39
SG	23	22	22	20	22	29	27	24	24
SCORE (media)	**27.5**	**25.5**	**29.5**	**21.5**	**28.5**	**34.5**	**26.5**	**29**	**31.5**

Chapter 5 – Discussion

This aim of this study is to assess how and to what extent is the industry is taking into consideration the existing age-specific usability and accessibility guidelines for designing mobile apps for older people. To assess the industry, 18 age-specific industry-built mobile applications are selected and evaluated on the basis of two set of checkpoints retrieved from two available usability and accessibility guidelines for designing mobile interfaces especially aimed at older people. On Chapter 2, this two usability and accessibility guidelines for designing mobile interfaces especially aimed at older people where reviewed: the standard's guidelines and the research-based guidelines. On Chapter 3, the methods for evaluating the mobile apps are presented, including the selection criteria for choosing the proper apps for evaluation, the selection criteria for retrieving the checkpoints from the research-based and standard's guidelines to evaluate the apps, and the description of the usability evaluation method used to assess the apps on the basis of the two set of checkpoints. On Chapter 4, the results of the evaluation of the apps are presented in a 3-steps process. First, the results are presented in terms of how many industry-built app include a specific checkpoint for both list of checkpoints. Second, each app is given a preliminary score for each set of checkpoints. Third, the average between these two sets of preliminary scores is calculated, to give the apps a final score. This Chapter presents the discussion of these results, which will give an idea of how and to what extent is the industry implementing the usability and accessibility guidelines in the design of mobile apps for older people. Along with the results, the limitation and possible future work will also be discussed in this chapter.

In terms of how many apps include a specific checkpoint, the data collected in Figures 1 and 2 show some important results. First, it was observed that overall the apps had a weakness in all the usability and accessibility principles, as referred to by the W3C [10], that make an interface perceivable, operable, understandable and robust for the elderly people. From these weaknesses, the most concerning checkpoints were the lack of text resizing, zoom, and an adequate font size in more than 50% of the apps. Although, something good discovered regarding these checkpoints during the apps evaluation on the basis of the standard's guidelines, is that most of the apps (75%) support the platform's settings, which allow to zoom and adjust the font size. An issue with this is that the applications are asking older people to find such settings in the platform's adjustment menu, which generally represents a complexity for older people. Which means, that elderly people will still keep on facing difficulties interacting with those applications, because their weakness in perceivability. In terms of operability the most surprising finding was that the touchscreen gestures are not easy enough for the older people in at least half of the apps. Simple touchscreen gestures are suggested as necessary, because often older people experience difficulty manipulating a touchscreen, specially due to motor and cognitive skill decline [26] [27] [28]. Furthermore, another relevant weakness observed in the apps is the inefficiency of the instructions, which if available are not easily understandable, nor discoverable or available at all times. Without the proper instructions the interface turns incomprehensible for older people.

Another interesting finding from the study was the relevant difference between the results from the research-based guidelines and the standard's guidelines. A tendency was observed between Figures 1 and 2, and Tables 7(a) and (b) and Tables 8(a) and (b), where the results corresponding to the standard's guidelines (Figure 1 and Tables 7(a) and (b)) was more below expectations than those corresponding to the research-based guidelines (Figure 2 and Tables 8(a) and (b)) which had better results. Regarding Figures 1 and 2 it was observed that in Figure 1 on average all applications include 70% of the checkpoints, while in Figure 2 on average all applications include only 49% of the checkpoints. As for the comparison of the results between Tables 7 (a) and (b) and Tables 8 (a) and (b), in Tables 8 (a) and (b) the score of the apps were lower than the results from Tables 7 (a) and (b). This difference in scores is directly correlated to the results in Figures 1 and 2, that measure how many apps fully include a specific checkpoint. The observed difference between the results from the research-based checkpoints and the standard's checkpoints, can be explained because at least half of the checkpoints, from each list, measured different usability and accessibility aspects. Clearly, this difference had an important impact on the average score of each app. However, from this difference, it was revealed that the industry is considering more usability aspects related to the research-based guidelines than the standard's guidelines. Although it is not justifiable, a reason for this might be that the research-based guidelines are easier and cheaper to implement, than the standard's guidelines. However, there is no sufficient evidence to proof this theory.

The final scores of the applications in Table 9, also show some important results. It was expected that at least 81% of the apps successfully included most of the checkpoints.

However, it was revealed that only 22.2% of the apps fully included most of the checkpoints, meaning that only this percentage of apps are the most accessible for older people. So, according to the average scores less than half of the industry is implementing age-friendly guidelines in the design of mobile apps for older people. From the remaining percentage of apps, 38.8% moderately include the checkpoints, which is not enough to be regarded as accessible apps. However, if this percentage is added to the 22.2% of apps fully including most of the checkpoints, then it is possible to say that there is an effort from the industry to implement the age-friendly guidelines in the design of mobile apps for older people. But, this effort is still too low, in fact the percentage of least accessible apps is even higher (38.8%) than the accessible apps (22.2%). Thus, despite the effort, there is still a lot of work to do in the industry to design usable and accessible mobile apps for older people.

This study is subject to some limitations and could be improved in future work. One of the greatest limitations is that the evaluation of the apps was not performed by the end-user (the elderly people), which would have been more desirable and beneficial to obtain more accurate results. So for future work, it is recommended to include the elderly people. Another limitation is that the study was performed using free apps, which might have a lower usability and accessibility standard than paid apps. Thus, for future work it would be a good idea to evaluate paid apps and compare with the result of this study, that way there is a wider range of samples. Additionally, not all the guidelines could be evaluated due to resource limitations, and these could have an impact on the final results. So, to improve this study in the future, the evaluation should be performed including all the guidelines from the research-based and standard's work. An additional limitation of this study is the grading system applied to review each apps, where 0 was applied to checkpoints not included and to checkpoints that were null. The issue with this is that sometimes null meant that a checkpoint was not applicable to the app, because the usability aspect being evaluated was not part of the app. For example, for the checkpoint set virtual keyboard to the type of data entry required, a form is necessary, however sometimes the apps did not include a form. So, in some specific cases giving 0 points to null checkpoints might have had an impact on accurately assessing which are the most and least accessible apps for elderly people. In this regards, for future work the method should be improved to avoid affecting the scores of apps where a certain checkpoint does not apply. Finally, for future work with more resources it is suggested to evaluate more apps in other languages, more apps with other functionalities, as well a testing a bigger amount of apps, since 18 might not be enough to represent the whole spectrum of available apps.

Despite of the limitations, the study provided useful information to use available usability and accessibility guidelines for the evaluation of age-specific mobile applications. Thus, it can be used as a framework for future development. More specifically, this study gave an insight into how and to what extent is the industry implementing age-specific guidelines in the design of mobile apps for older people.

Chapter 6 – Conclusion

Today, smartphones have turned into a useful device in people's every-day life, which facilitate many activities, like socializing with more people, making bank transactions, and monitoring a person's health. In fact, thanks to technology advancements, smartphones now offer assistive technology for older people through their mobile apps. The issue is, that mobile apps are still relatively inaccessible for older people. As the global population is rapidly ageing, and is expected to more than double by 2030, now than ever is necessary to design mobile interfaces that focuses on elderly people's needs. Such needs are related to the changes a person experiences while ageing, such as motor, visual and cognitive skills. This is why, many times older people need assistance carrying out different tasks. In the mobile context, these age-related changes have an impact on how older people interact with their mobile devices. For example, to be able to see the screen of a mobile phone, older people require a bigger font size or higher contrast colors [9]. This is why, this age-related changes, should be considered when designing a mobile interface aimed at the elderly people. However, mobile interfaces are not always properly designed for older people, who want to have a satisfactory interaction with their mobile phones. It has been suggested that guidelines are a useful tool to design and evaluate mobile interfaces especially aimed at the elderly people [5]. Thus, enormous research have been carried out to develop design and usability guidelines specifically intended for older people [7] [8] [5] [9]. But there is not much research available that evaluates how and to what extent is the industry implementing these guidelines in the mobile app's design process.

The aim of this study is to assess the application of the available guidelines in industry-built apps. Which is why, 18 specific mobile apps have been selected because they address different age-related issues, like hearing aid or health monitoring. These apps are evaluated on the basis of two set of checkpoints, retrieved from two guidelines previously reviewed: the research-based guidelines [9] and the standard's guidelines [7]. These evaluation allows to assess how and to what extent is the industry taking into account the usability and accessibility requirements of older people in the design of age-specific mobile apps.

The results of the evaluation show that, although there is an effort from the industry to address usability and accessibility issues for the elderly people, there is still a lot of work to be done to design appropriate mobile applications for the elderly people. On average, it was observed that only 22.2% of the apps properly address the requirements of elderly people for usable and accessible mobile interfaces. More specifically, it was observed that there is a weakness in the apps in the four principles, that according to the W3C, make a mobile interface accessible for older people (perceivability, operability, understandability and robustness). The most concerning of all the usability issues is in terms of perceivability, as it was observed that a prudent font size, allowing to zoom the screen, and allowing to modify the font size was only possible in less than half of the apps. These aspects, have been recurrently addressed as important for older people in different age-specific guidelines since 2004 [7] [9] [13] [22] [23] [24] [25] [31], however industry-built apps are not considering these aspects. In terms of operability, the weakest aspect was that in 50% of the apps touchscreen gestures are too difficult for older people, and this affects the way an older person manipulates an app. This is an aspect that has been mentioned as important for the elderly people in different guidelines since 2012 [7] [9] [26] [32] [27], but still is not being considered in the design of age-specific mobile apps. In terms of understandability, the major issue was with instructions, which if available in the apps, they were not clear enough, nor easily accessible, or available at all times. Finally, in terms of robustness, more than half of the apps had issues with aspects related to making the process of typing or inputting data easy.

In conclusion, industry-built apps are not implementing age friendly guidelines. So a major effort should be put into improving the design of mobile apps for older people by truly focusing in their needs. Which is why more apps should be constantly scrutinized and validated, to try to push the industry into implementing the necessary usability and accessibility guidelines for appropriate mobile app for the elderly population. For future work, more evaluations of age-specific apps should be performed performed in a wider variety of apps, including more app’s functionalities, apps in other languages, a higher number of apps, and paid apps. More importantly, future evaluations should be performed including older people to have more accurate results. This was one of the major limitations of this study.

References

[1] Statista, "Number of smartphone users worldwide from 2014 to 2020 (in billions)," June 2016. [Online]. Available: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/. [Accessed 15 December 2018].

[2] World Health Organization, "World report on Ageing And Health," World Health Organization, Luxembourg, 2015.

[3] Pew Research Center, "Tech Adoption Climbs Among Older Users," 2017.

[4] A. Berenguer, J. Goncalves, D. Ferreira, T. Anagnostopoulos and V. Kostakos, "Are Smartphones Ubiquitous? An in-depth survey of smartphone adoption by seniors. By Anabela Berenguer, Jorge Goncalves, Simo Hosio, Denzil Ferreira, Theodoros Anagnostopoulos, and Vassilis Kostakos Digital Object Identifier 10.1109/MCE.2016.2614524 Date," *IEEE Consumer Electronics Magazine,* vol. 6, no. 1, pp. 104-110, 2017.

[5] J.-M. Díaz-Bossini and L. Moreno, "Accessibility to mobile interfaces for older people," *Procedia Computer Science,* vol. 27, no. 2014, pp. 57-66, 2013.

[6] J. Abascal and A. Civit, *Mobile communication for older people: new opportunities for autonomous life,* 2001.

[7] W3C, "Mobile Accessibility: How WCAG 2.0 and Other W3C/WAI Guidelines Apply to Mobile," 26 February 2015. [Online]. Available: https://www.w3.org/TR/mobile-accessibility-mapping/. [Accessed 20 January 2017].

[8] W. Husain, A. Ibrahim and A. Mohamed Shahiri, "User Interface Design for Elderly Mobile Assistive Systems," *ISICO,* vol. 2015, 2015.

[9] A. Petrovčič, S. Taipale, R. Ajda and D. Vesna, "Design of mobile phones for older adults: An empirical analysis of design guidelines and checklists for feature phones and smartphones," *International Journal of Human–Computer Interaction,* vol. 34(3), pp. 251-264, 2018.

[10] W3C, "Introduction to Understanding WCAG 2.0," 7 Octobe 2016. [Online]. Available: https://www.w3.org/TR/UNDERSTANDING-WCAG20/intro.html. [Accessed 20 March 2018].

[11] C. W. H. &. B. L. Stößel, *Gestural interfaces for elderly users: help or hindrance?,* Berlin: Springer, 2009.

[12] M. Pattison and A. W. Stedmon, "Inclusive Design and Human Factors: Designing Mobile Phones for Older Users," *PsychNology Journal ,* vol. 4, no. no. 3 , pp. 267-284, 2006.

[13] M. Massimi, *Participatory design of mobile phone software for seniors,* Toronto, Ontario: University of Toronto, 2007.

[14] M. S. Al-Razgan, H. S. Al-Khalifa, M. D. Al-Shahrani and H. H. AlAjmi, "Touch-based mobile phone interface guidelines and design recommendations for elderly people: A survey of the literature," in *In International Conference on Neural Information Processing*, Berlin, Heidelberg, 2012.

[15] T. van Dyk, H. Gelderblom, J. Van Biljon and K. Renaud, "Mobile Phones for the Elderly: a design framework In Steyn. Public and private access to ICTs in developing regions," in *Proceedings of the 7th International Development Informatics Conference (IDIA2013)*, Bangkok, Thailand, 2013.

[16] P. Calak, "Smartphone evaluation heuristics for older adults," 2013.

[17] P. A. Silva, P. Jordan and K. Holden, "Something old, something new, something borrowed: Gathering experts' feedback while performing heuristic evaluation with a list of heuristics targeted at older adults. In Proceedings of the 2014 Workshops on," in *In Proceedings of the 2014 Workshops on Advances in Computer Entertainment Conference*, New York, NY, 2014.

[18] N. Mi, L. A. Cavuoto, K. Benson, . T. Smith-Jackson and M. A. Nussbaum, "A heuristic checklist for an accessible smartphone interface design," *Universal Access in the Information Society,* vol. 13, no. 4, p. 351–365, 2014.

[19] Q. Gao, D. Ebert, X. Chen and Y. Ding, "Design of a mobile social community platform for older Chinese people in Urban Areas," *Human Factors and Ergonomics in Manufacturing & Service Industries,* vol. 25, no. 1, p. 66–89, 2015.

[20] Merriam-Webster, "Conservative," [Online]. Available: https://www.merriam-webster.com/dictionary/conservative. [Accessed 15 April 2018].

[21] Oxford, "English Oxford: Living Dictionaries," [Online]. Available: https://en.oxforddictionaries.com/definition/conservative. [Accessed 15 April 2018].

[22] H. Hassan and M. H. N. Nasir, "The use of mobile phones by older adults: A Malaysian Study," *SIGACCESS Access Computation,* vol. 92, p. 11–16, 2008.

[23] N. Caprani, N. E. O'Connor and C. Gurrin, *Touch screens for the older user,* Rijeka, Croatia: InTech, 2012.

[24] Q. Wang, "The effects of interface design about mobile phones on older adults' usage," in *In 2008 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM*, 2008.

[25] A. Olwal, D. Lachanas and E. Zacharouli, "OldGen: Mobile phone personalization for older adults," in *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2011.

[26] K. Furuki and Y. Kikuchi, "Approach to commercialization of Raku–Raku smartphone," *FUJITSU Scientific & Technical Journal,* vol. 49, no. 2, p. 196–201, 2013.

[27] L. G. Motti, N. Vigouroux and P. Gorce, "Interaction techniques for older adults using touchscreen devices: A literature review," in *In Proceedings of the 25th IEME Conference Francophone on L'Interaction Homme-Machine*, New York, NY, 2013.

[28] J. Zhou, P.-L. P. Rau and G. Salvendy, "Use and design of handheld computers for older adults: A review and appraisal.," *International Journal of Human-Computer Interaction,* vol. 28, no. 12, p. 799–826, 2012.

[29] H. Hwangbo, S. H. Yoon, B. S. Jin, Y. S. Han and Y. G. Ji, "A study of pointing performance of elderly users on smartphones," *International Journal of Human-Computer Interaction,* vol. 29, no. 9, p. 604–618, 2013.

[30] S. Boustani, *Designing touch-based interfaces for the elderly,* Sydney, Australia: University of Sydney, 2010.

[31] H. Kim, J. Heo, J. Shim, M. Kim, S. Park and S. Park, "Contextual research on elderly users' needs for developing universal design mobile phone," in *In Proceedings of the 4th International Conference on Universal Access in Human Computer Interaction: Coping with Diversity*, Berlin: Springer, 2007.

[32] S. Harada, D. Sato, H. Takagi and . C. Asakawa, "Characteristics of elderly user behavior on mobile multi-touch devices," in *Human-computer interaction – INTERACT 2013*, Berlin, Germany, 2013.

[33] F. H. Abdul Razak, N. A. Razak, W. A. Wan Adnan and N. A. Ahmad, "How simple is simple: Our experience with older adult users," in *In Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction*, New York, NY, 2013.

[34] R. Leitao and P. A. Silva, "Target and spacing sizes for smartphone user interfaces for older adults: Design patterns based on an evaluation with users," in *Presented at the Conference on Pattern Languages of Programs*, Tucson, Arizona, 2012.

[35] "Red Panic Button," Ultimate Communication Software LTD, [Online]. Available: http://redpanicbutton.com/. [Accessed 14 November 2017].

[36] "Fade: fall detector," ITER S.A., [Online]. Available: https://play.google.com/store/apps/details?id=com.iter.falldetector&hl=es. [Accessed 14 November 2017].

[37] "Magnifying Glass With Light," Falcon In Motion LLC, [Online]. Available: https://itunes.apple.com/us/app/magnifying-glass-light-digital/id406048120?mt=8. [Accessed 14 November 2017].

[38] "Magnifying Glass Flashlight," Bzing, [Online]. Available: https://play.google.com/store/apps/details?id=com.IdanS.magnifyingglassflashlight&hl=en. [Accessed 2014 November 2017].

[39] "Usound (Hearing Assistant)," Newbrick S.A., [Online]. Available: https://www.usound.co/. [Accessed 14 November 2017].

[40] "MyEarDroid - Sound Recognition," Tecnalia - Salud, [Online]. Available: https://www.tecnalia.com/en/myeardroid/what-is-myeardroid.htm. [Accessed 14 November 2017].

[41] "Live Caption, Wiser – Simple Senior Launcher," RyFly, [Online]. Available: http://www.livecaptionapp.com/. [Accessed 14 November 2017].

[42] "Wiser Launcher," UIU LTD., [Online]. Available: http://www.wiser.site/. [Accessed 2014 November 2017].

[43] "Nova Launcher," TeslaCoil Software, [Online]. Available: http://novalauncher.com/. [Accessed 14 November 2017].

[44] "MindMate - Healthy Aging," MindMate LTD, [Online]. Available: https://www.mindmate-app.com/. [Accessed 14 November 2017].

[45] "WebMD," WebMD Health Corporation, [Online]. Available: https://www.webmd.com/mobile. [Accessed 14 November 2017].

[46] "Pocket Physio," Care Uk, [Online]. Available: http://www.careukhealthcare.com/pocketphysio. [Accessed 14 November 2017].

[47] "Blood Pressure Monitor," Taconic System LLC, [Online]. Available: http://www.taconicsys.com/. [Accessed 14 November 2017].

[48] "Pill Reminder by Medisafe," MediSafe Inc., [Online]. Available: https://medisafe.com/. [Accessed 14 November 2017].

[49] "Lumosity - Brain Training," Lumos Labs, Inc., [Online]. Available: https://www.lumosity.com/. [Accessed 14 November 2017].

[50] "Skype," Skype Communications S.a.r.l, [Online]. Available: https://www.skype.com/en/. [Accessed 14 November 2017].

[51] "Stitch Companionship," Stitch Holdings Pty Ltd, [Online]. Available: https://www.stitch.net/. [Accessed 14 November 2017].

[52] "Find My Family, Friends, Phone Safe365," Alpify, [Online]. Available: http://www.safe365.com/. [Accessed 14 November 2017].

[53] J. Nielsen, Usability engineering, San Francisco, California: Morgan Kaufmann, 1993.

[54] United Nations, Department of Economic and Social Affairs, Population Division, "World Population Prospects: The 2017 Revision, Key Findings and Advance Tables," n/a, New York, 2017.

[55] A. Dickinson, J. Arnott and S. Prior, "Methods For Human - Computer Interaction research With Older Adults," *Behaviour & Information Technology ,* vol. 4, no. 26, pp. 343-352, 2007.