AN ERGONOMICS ANALYSIS OF REDUNDANCY EFFECT IN TOUCH SCREEN DESIGN FOR THE AGED POPULATION

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ABSTRACT

An Ergonomics Analysis of Redundancy Effect in Touch Screen Design for the Aged Population

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Touch screen technology is rapidly increasing, and at the same time there is a shifting, aging population. As the percentage of the population over the age of 65 increases, adults of the age group are adopting smartphones and tablets more now than ever before. Although older adults are adopting touch screen devices, they face many challenges when interacting with said devices, such as not knowing how to navigate between pages, not knowing where to click for an action to occur, and the touch screen interface is often too sensitive or the buttons are not big enough. Furthermore, the challenges of aging, specifically sensory and cognitive decline resulting from aging affect comprehension and spacial processing, which are critical when navigating through an interface.

The purpose of this thesis was to better understand redundancy effect applied to females and males between the ages of 65 and 84. There were two tasks of different lengths, and for each task there were two designs. The first design included text only buttons, and the second included symbol + text buttons, the latter being the redundant interface. Quantitative results yielded no significant results for time for either task. Qualitative results included ratings for ease of navigation, general satisfaction, overall understanding, and button design preference. Preferences between text only buttons were statistically significant; for the task of online grocery shopping and booking a cruise, females prefer text only buttons and males prefer symbol + text buttons ($p = 0.0068$ and $p = 0.0024$). Although button design had no significance in completing a task, significant preference results indicate likelihood to return to a given website. Furthermore, although quantitative results were not significant, gender did influence average times per task and average ratings across categories. Further research could be conducted with larger sample sizes, other forms of redundancy, and larger tasks, however it is evident through this experiment that gender has an impact on how adults between 65 and 84 perceive and navigate through touch screen interfaces given the constraints of the symbols used, ages, and task designs. Therefore, concluding recommendations based on the qualitative data suggest that designers should create gender specific interfaces based on gender favored websites, or design based on the ability to customize the interface upon entering a website.

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Chapter 1: Introduction

As the world becomes more technology focused at a growing rate, there is a larger percentage of the population that has not grown up using these devices and is therefore left at a disadvantage when it comes to adopting new technology. Touch screens are an example of this. Touch screen smartphones and tablets allow users anywhere in the world to easily access the internet, play games for entertainment, read, online shop, and communicate with family and friends. How though, does a user learn what a button is, or learn the scroll function if they have never touched a touch screen device before? How does this person know that touch screens are convenient, easy to adopt, and have multiple adjustability features to fit everyone's needs? The benefits and even the many activities that can be done on a touch screen are foreign to many older adults and therefore motivation to learn a new technology may prevent device adoption. When researching how older adults interact with touch screen technology, contradicting findings by multiple sources on whether or not redundant interfaces increase or decrease ease of navigation led to the development of an experiment testing between text only buttons and symbol + text buttons. The symbol + text button is a redundant interface. The purpose of this current research is to test whether or not redundancy in button design for adults between the ages of 65 and 84 and between males and females is helpful. This is in order to better understand whether or not there is a way to practically design touch screen interfaces that will not only benefit the aging population, and potentially for everyone.

Chapter 2: Literature Review

The purpose of this Literature Review is to provide an understanding on the sensory, cognitive and physical aspects of aging as it applies to older adults using touch screen devices, in addition to the design and feasibility of touch screen devices for older adults. A brief background on how adults age, followed by characteristics of modern day touch screens provide a framework on the two factors that influence the challenges older adults experience when interacting with touch screen devices.

2.1 Background

Digital literacy, or in other words, "the ability to use and understand information from various digital devices" must first be understood before addressing how older adults adopt touch screen technology [20]. Not only does obtaining this digital literacy have multiple benefits for the aging population, but doing so has been a United States policy goal in order to narrow the digital divide [20]. The benefits of digital literacy include an improved overall quality of life, better communication with family and friends, and increased cognitive engagement in every-day activities [20]. Increasing communication with family and friends via technology could reduce feelings of isolation and loneliness that older adults may experience upon retirement or as ability to interact with loved ones decreases, and cognitive stimulation provides insight into one's own problems in addition to world problems [3, 20]. Furthermore, many healthcare providers are offering applications for patients to be more engaged in information, appointments, and other medical needs that otherwise could not easily be answered unless physically at a healthcare facility [3, 20]. This has the potential to be extremely beneficial due to the increased healthcare needs typically required as people age. As for touch screens themselves, they are becoming more and more prevalent in everyday operations such as mobile devices (smartphones and tablets), information kiosks and displays, ATM machines, and healthcare and security controls [9].

Touch screens were introduced by E.A. Johnson in 1965, with the concept of public touch screen introduced by Elographics Inc. in 1971, followed by the introduction of a personal touch screen device in 1983 by Hewlett-Packard [3]. The most recent touch screen revolution, however, "is largely due to the release of the Apple iPhone and iPad that was quickly followed by similar offerings from competitors" [3]. The importance of the advancement in touch screen devices and digital literacy wouldn't be as important if it weren't for the major demographic shift affecting our world as we speak; people are living longer, the older population is gradually increasing, and the overall population is expected to shrink [3].

In a study completed by Mamolo and Scherbov in 2009 regarding population projections in Europe, one person out of every four is projected to be 65 or older by 2030 [3]. As seen in Table 1 below from the U.S. Census Bureau International Data Base, Europe has the highest percentage of adults over the age of 65 compared to all other regions (23.5% in 2030), followed closely behind by North America [10].

Table 1: Percentage of Population by Region Across Generations, [10]

Percent of Population in Older Ages by Region, 2000, 2015, and 2030

Region	Year	65 years or older	80 years or older
Asia	2000	5.9	0.9
	2015	7.8	1.4
	2030	12.0	2.3
Europe	2000	14.7	3.0
	2015	17.6	4.7
	2030	23.5	6.4
Latin America/Caribbean	2000	5.6	1.0
	2015	7.6	1.5
	2030	11.5	2.5
Middle East/North Africa	2000	4.4	0.6
	2015	5.5	0.9
	2030	8.4	1.4
North America	2000	12.4	3.3
	2015	14.7	3.9
	2030	20.0	5.4
Oceania	2000	10.1	2.3
	2015	12.4	3.1
	2030	16.3	4.4
Sub-Saharan Africa	2000	2.9	0.3
	2015	3.1	0.4
	2030	3.6	0.5

According to the U.S. Department of Health and Human Services, in 2013 there were 44.7 million people 65 years or older in the United States [19]. This represents 14.1% of the U.S. population, and is a 24.7% increase in people aged 65 years or older since 2003 [19]. Of this 44.7 million Americans 65 years or older, 25.1 million were women and 19.6 were men [19]. The ratio of women to men 65 years or older is 128.1:100, and the ratio of women to men 85 or older is 195.1:100 [19]. This can possibly be attributed to the differing average lifespans between females and males; the life expectancy of females in the United States is 81 years of age, whereas for males it is 76 years of age. To put this into perspective, there were 67,347 persons aged 100 or more in 2013, which is more than double the number in 1980 of 32,194 [19].

Currently, smartphones are among the most popular touch screen devices available.

The top two functions of smartphones are browsing the internet and social networking, followed by playing games, listening to music, and making phone calls [12]. Because of this, smartphones are being designed with the central features being internet and social networking applications, which increases the difficulties older adults deal with when learning the basic functions of touch screen devices because these are not among the top activities performed by older technology users [12].

These statistics, combined with the fastest growing group of internet users being older adults, greatly emphasizes the need for adjusted technology designs that both supports and encourages technology use by older adults [3].

2.2 Characteristics of Aging

Regardless of demographics, lifestyle, and history, older adults generally have similar biological, psychological, and social characteristics as aging occurs [3]. After the age of 65 years old, a substantial reduction in sensory, motor, and cognitive functions occur [18]. According to Tenneti et al. (2011), sensory capabilities include vision and hearing, motor capabilities include dexterity, locomotion, reach and stretch, and cognitive capabilities include memory, learning, and comprehension all decline. As this development into aging adulthood occurs, some skills improve while other skills decline, and these changes have implications on how older adults interact and adapt to technology [3].

Sensory changes are most commonly related to the decline in vision, which can begin around the age of 40, and decline in hearing, which affects approximately thirty percent of women and fifty percent of men over the age of 53 [3]. Cognitive decline in older adults affects working memory, attention, and information processing, and typically results from lack of cognitive demanding activities. Although most adults experience a decline in cognitive abilities, maintaining or increasing the quality of life can be directly linked to decreasing mental decay through cognitive stimulation, which as discussed previously can be achieved via touch screen devices [20]. This can also affect the ability to interpret and understand perceptual feedback [15].

In terms of physical abilities, a side effect of aging is an overall slowness of movement, potentially due to a decline in muscle mass and/or flexibility. The decline in manual dexterity most often affects spatial aiming, pointing movements, and slower reaction times [9]. These together with cognitive decline increase difficulty in keeping information active, making small, precise selections, pressing buttons, and understanding what is being asked of them when using touch screen devices [3]. These changes due to aging make it such that older adults, when compared to younger adults, take longer to complete similar movements and lack ability to maintain continuous, coordinated movements - this is best described as having more "noise" in motor control skills [15]. These findings on how aging affects touch screen interaction is congruent to the findings by Smith and Chapparo [17].

In addition to the sensory, cognitive, and physical changes discussed above, educational levels, socioeconomic status, motivation to learn a new technology, self-efficacy, and confidence all influence an older adult's ability to become digitally literate [20]. Different psychological states also have the potential to directly influence a person's capability when using new technology, with evidence showing that emotional state can influence a persons perception, thoughts, and behavior when interacting with something such as a touch screen device [18]. Self-esteem, optimism, perceived mastery, beliefs and attitudes also play a role in an individual's ability to successfully interact with a touch screen device [18].

Despite the decline in many cognitive and physical characteristics, research has shown that older adults are interested in trying new technologies, including touch screen devices. In general, older users of touch screen devices tend to be more patient and accepting of the difficulties associated with learning a new task [20]. Regardless, older adults still find using touch screen devices frustrating due to being educated in a time when touch screens were not present. Therefore advanced technologies may not be a common everyday occurrence for them [12]. The challenges and difficulties older adults experience when interacting with touch screen devices will be discussed further in a future section: *Challenges faced by Older Adults using Touch Screen Devices.*

2.3 Touch Screen Design & Feasibility

As new technology progresses faster than ever before, touch screen devices are becoming more and more prevalent in today's society. One of the major discrepancies between older adults and the digital literacy of touch screen devices is the minimal amount of inclusive design features in touch screens [18]. Inclusive design means that the design process includes and achieves goals created to make the product better for a wider range of users [18]. In this case, inclusive design suggests that the design of touch screen devices should take into account the cognitive and physical changes adults experience as they age. This is especially important as product operations and user interfaces continuously change as well [4]. Simple interface designs with minimal extraneous features and elements grouped logically will also help reduce distractions given older adults reduced attention span as a function of aging [3]. It is also recommended to display all menu items on one page whenever possible, as this will minimize confusion between tasks at hand [3]. According to Page [12], the success of the mobile application is highly correlated with the end-user interface design.

2.3.1 Button Size & Spacing

In studies conducted to test for the differences in direct (e.g. touch screens) versus indirect devices (e.g. physical keyboard), it was concluded across ages that touch screen keypads were preferred by participants over physical keyboards in terms of ease of use [4]. Jin, Plocher, & Kiff [9] conducted two experiments, the first one testing for speed and accuracy given a single button touch test. Results concluded that reaction time increased as button size decreased, with a p-value <0.001. The second experiment consisted of a multiple button touch test, and button size, button spacing, and accuracy given button size was significant. Reaction time decreased as the button size increased ($p < 0.001$), Reaction time decreased as spacing decreased ($p < 0.001$), and accuracy increased with a button size up to 19.05 mm ($p < 0.001$). Subjective preferences conclude that subjects preferred a button size of 16.51 mm and 19.05 mm ($p < 0.001$), and there was a significant difference between preferred button spacing ($p < 0.001$) for 3.17 mm, 6.35 mm, and 12.7 mm [9]. This is supported by other researchers who recommend a keypad with 20 mm buttons and 3 mm between each button per line [4]. The larger the button sizes and spacing between buttons, the higher the accuracy in touch screen usage [9]. In sum, there is a tradeoff between accuracy and speed, which directly correlates to button spacing [9]. This is similar research suggesting the value in increased screen size to increase accuracy for older adults [3].

In terms of decline in motor control, large targets for improved accuracy, reduction in scrolling and swiping, and an allowance for slower response times will increase older adults success in adapting to touch screen technology [3].

2.3.2 Vertical versus Horizontal Alignment

Several studies have also been conducted on vertical versus horizontal alignment when looking at menu structures and navigation. According to research conducted by Snowberry, Parkinson and Sisson on the organization of menus, visual eye scanning is predictive of performance [22]. The organization of menus, either by column or row, had an effect on search time. Based on their research, menus organized by column were searched faster than menus organized by row [22]. These results are similar to an experiment conducted on visual scanning, where participants were given an item to locate in a list of either vertically or horizontally aligned items either in a single list or groups of listings [11]. Here the scanning rate of horizontally aligned items varied with organization produced the slowest search when an item was searched for within multiple groups of horizontally aligned items in a random order [11]. Furthermore, participants were 42% faster when scanning items in a vertical orientation when patterns such as alphabetical order were detected, compared to 11% faster given a horizontal orientation [11]. Conclusions from this experiment suggest that the vertical alignment of data is preferable, and that data items within a group should be close together [11].

2.3.3 Intuitive Use

According to Blackler, Popovic and Mahar [1], who are researchers in the field of intuitive interface design, there are three principles that have been developed to help designers develop interfaces that are intuitive to use. There principles are as follows:

1. "Use familiar symbols and/or words for well-known functions, put them in a familiar or expected position, and make the function comparable with similar functions users have seen before." This involves utilizing existing features, labels or icons that users

have seen before in similar products that perform the same function. This is the simplest level of applying intuitive use [1].

2. "Make it obvious what less well-known functions will do by using familiar things as metaphors to demonstrate their function." This requires the use of metaphor to make something completely new familiar by relating it to something already existing [1].

3. "Increase consistency so that function, location and appearance of features are consistent between different parts of the design and throughout each part," in other words increase consistency between screens and features. This allows users to apply the same knowledge and metaphors across all parts of the interface [1].

It is difficult to design an interface to be intuitive, especially for older users, because intuitive by nature is personal to the user, therefore making it challenging when designing a universal product [5]. However, it is possible to increase potential intuitiveness by presenting information in a recognizable symbology, as this facilitates communication which is an important aspect of usability [7].

2.3.4 Use of Symbols

An icon is "a small picture or graphical symbol, which provides an illustration of a function or file on the system," and "such icon should transmit information about its underlying function in an abbreviated, simplified form and should not depend on letters or words" [2]. When designing for aging users, it is said that icons can be used in an interface to reduce complexity because when designed appropriately, they decrease the mental workload [2]. An experiment was designed to evaluate two different icon sets: Icon Set A included simple icons low in complexity and concreteness, consisted of only three colors, and were designed in a two-dimensional space, whereas Icon Set B had a more realistic appearance, were more colorful, depicted in a three-dimensional space, and were high in complexity and concreteness [2]. Results from the experiment revealed that older adults made less errors and had short execution times with Icon Set A [2]. These findings are similar to research by Qian and Wendao, who suggest icon color design should have no more than five kinds of color, especially for users over the age of fifty who may experience visual degradation [13]. In order to build concise, simple icons, it's best to use grayscale or calm colors with high contrast against the background [13]. Furthermore, according to Horton [8], there are give degrees of detail and realism, as seen in Figure 1 below, and the best approach is to select a primary style and use it as much as possible throughout the menu to create consistency [8]. Another consideration is to include only the details necessary for the icon to be recognized as it is intended, often the less detailed the better [8].

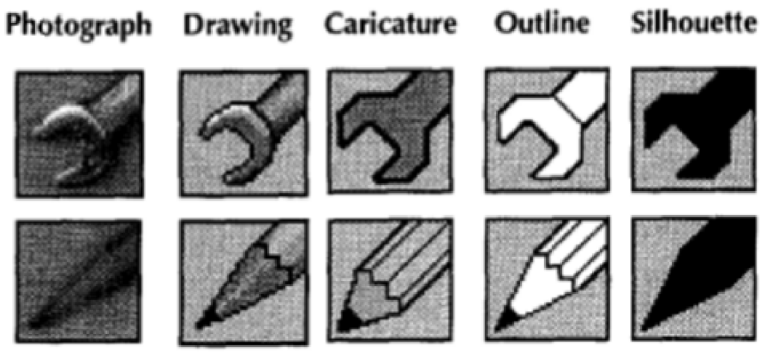


Figure 1: Icon Types by Style, [8]

In a study on redundancy in interface design and its impact on intuitive use for older users, Blackler, Popovic and Mahar [1] worked with Gudur [6] to design an experiment to investigate the effect of redundancy and intuitive use. The experiment had three interface designs: one with text only navigation, one with a symbol and text navigation, (the redundant interface), and one with symbol only navigation [6]. Results indicated that there was a negative relationship between technology familiarity and time to complete the task, and there was a significant time between young (xbar = 4.33 minutes) and older users (xbar = 7.33 minutes) when completing the task on the redundant interface [6]. However, redundancy did have a positive impact for users with moderate to high technology familiarity in using the product faster and more accurately [6]. This is contradicted in research by Kalyuga, who conducted a study and found that redundant textual descriptions along with diagrams were essential for novice users, and once the user gained additional expertise this redundant information impeded learning [21].

2.3.5 Current Human Factors Research & Development Efforts

There are several instances where companies have taken products one step further to enable improvements better suited for older adults. VibeTonz technology, an immersion corporation, has touch screen devices with tactile feedback, and mobile phones now have a feature that emits a vibration and/or sound as items are selected on screen [4]. Improving user interfaces enables older users to more easily navigate and explore, which not only makes them more skillful at using touch screens, but also boosts their confidence [20]. Apple iPhones and iPads also offer background color reversal as one of many accessibility options for users with sensory, cognitive, and physical decline. It is also important to note that the concept of designing a product for all users is unrealistic, and therefore, like the products listed, allowing for greater flexibility will improve the ease of which users can adopt a given product [3].

2.4 Challenges Faced by Older Adults Using Touch Screen Devices

Now that an understanding on the cognitive and physical changes of aging and the design and feasibility of touch screen devices has been established, it is necessary to discuss the challenges older adults face when interacting with touch screen devices. Results of past studies related to the interaction of older adults and touch screen devices will be discussed, and any aspects of touch screen devices that older adults find useful and beneficial when using these devices be included.

A study was completed on the usability of touch screen mobile devices and older adults, which discusses assumptions made on how older adults perceive technology and more specifically touch screen devices [12]. As a matter of fact, older adults do indeed want to interact with technology for the purpose of engaging in a form of modern day communication and staying in touch with society [12]. Page (2014) also brings to light a good point, that older users of touch screen devices are more likely to get frustrated due to having been "educated during a time where advanced technologies were not prominent in everyday tasks, unlike today's society." Like mentioned previously, level of education plays a role in the success of technology involvement among older adults, however even so older adults tend to feel that modern touch screen devices are not designed to suit their needs.

Multiple studies have been conducted to test the significance of various input devices such as touch screen keyboards versus physical keyboards, multiple forms of text entry, or using a touch screen device to test different variations of the same design feature between younger and older adults. All of the tests conducted indicate that older adults are slower, less accurate, and have much more variable results (higher error rates) than younger adults when using touch screen devices [15, 4]. In a study on input device used in context, which included testing the performance between indirect and direct devices by the type of control being performed, in was concluded that the degree of accuracy and the speed of which tasks were completed varies between individuals, and this is heightened as adults age [15].

In an experiment conducted to test for optimal button size and spacing for the interaction of touch screen device user interfaces and older adults, subjects felt that although larger buttons were less convenient due to the space they take up, they did however make the touching operation easier, more comfortable, and more convenient [9]. Additionally, a recurring theme found in an experiment on touch screen usability suggested that navigating through multiple menu pages caused additional confusion when asked to complete a certain task [12]. Both swiping and scrolling are foreign operations that were required in order to travel throughout the user interface, which further reduced the efficiency of the task being completed.

As cognitive functions decline and motor behaviors change, older adults are more challenged with navigation related tasks and also may take longer to complete like tasks than younger adults [12]. Complicated touch screen interface designs, and the size reduction in many touch screen devices increases the challenges for older adults who experience any kind of sensory, cognitive, or physical changes related to aging. These features may cause anxiety or frustration for older users, and therefore improved user interface design further plays a role in an older adult's responsiveness to trying new technologies [12].

Tsai et al. (2015) bring to light the importance of experimentation and confidence in the exploration stages of learning a new technology for older users, which can be elevated by having a support system. This however is often a challenge for older adults who are retired and living on their own. Even more so, before being comfortable with learning how to use new technologies, the personal benefits of this new skill must exceed the effort needed to develop this new skill [20]. Committing to learn how to effectively use touch screen devices is a major challenge in itself, especially for older adults who may fear computers or lack perceived competency.

A qualitative study was conducted to receive feedback on how older adults felt about their tablets [20]. A participant named Frank loved his iPad, and was very knowledgeable and comfortable using it as well as other technology. Both a participant named Bill and a participant named Grace expressed initial hesitation on using a tablet due to difficulties in using computers, and an inability to see the value given the cost, however both ended up loving their tablets once they got to know how to use them. This experience was similar for many participants who mentioned frustration with first using their tablets, but felt comfortable after support was found and/or trial and error was practiced [20]. It was also frequently mentioned that the tablets provided and unexpected comfort level due to the ability to sit anywhere with the tablet [20]. Of those who sought support, several discussed the difficulties of learning at the store where leaders or trainers spoke or moved too fast, which resulted in added frustration [20]. In another study, perceived self esteem and general optimism decreased with age, which can add yet another dimension to the challenges older adults face when adopting a new technology into their lives [18].

Intuition on what to do next to progress through a touch screen interface is lacking for older adults, not in terms of an incompetence, but as a side effect of the ever changing world in which we live. The rapidly changing touch screen technology is creating a digital divide, especially in conjunction to the growing aging population. As older adults make up a larger percentage of the population, it will become more and more beneficial not only for the society, but for their personal lives as well if they are able to stay knowledgeable on touch screen technology advancements. The challenges older adults face on a daily basis in learning to use touch screen devices such as smartphones, tablets, or information kiosks is something that can and should be minimized as best as possible, especially after the previous research has shown differences in design and feasibility between younger and older adults. Regardless, of these challenges, there are many reports on how the ways touch screen devices and adapting to these newer technologies have made a positive impact on older adults lives in terms of communication, the feeling of fitting into society, and entertainment.

From this literature review it is evident that there exists a gap in how to bridge the challenges older adults face with touch screen devices and the user interface design of these touch screen devices. Therefore, the purpose of this project is to address touch screen interaction among older users by looking at the redundancy effect of symbols in interface navigation. A realistic approach is taken to drive effectiveness and functionality, with the goal to be able to help redesign the definition of designing for the average user. By providing recommendations to better design a touch screen interface suited for all, this can help promote long term population sustainability through increased cognitive interaction in the shifting aging population.

Chapter 3: Design

According to the Pew Research Centers Internet & American Life Project, a non-profit fact-tank that provides information online regarding the issues, trends, and attitudes shaping America, adults over the age of 65 use technology primarily for games and entertainment, online shopping or browsing the internet and communication with family and friends [14]. Based on this information, two tasks were designed for the purpose of this experiment. Task one is online grocery shopping, and task two is booking a cruise online. Within each task were two designs, the first including text only buttons, the second including symbol and text buttons.

An iPad was chosen as the optimal device to test the application on because as learned when reviewing literature, older users of technology are adopting touch screen devices, and tablets more widely than smartphones [16]. The following sub-sections discuss the different design elements for each of the tasks and button designs for this experiment.

3.1 Task & Button Design

Both of the tasks were designed with Literature Review recommendations in mind. The menu structure followed a vertical, single column alignment, button clicking between pages, and had simple, high contrast buttons. For the redundant interface, the symbols were black and white and the primary style used throughout the interfaces was the outline style. The pages remained consistent and simple to promote the highest level of understanding, and all buttons were made larger with increased font to reduce potential visual and sensory errors. The same formatting, style, and design parameters were maintained across both tasks and between both designs in order to eliminate potential bias between tasks. The two tasks designed for the purpose of this experiment were designed with the top uses of technology among older adults in mind, that being online shopping and searching the internet for entertainment [14]. Booking a cruise was used as the task to represent searching the internet because travel is among the top activities of retired adults in the United States.

3.1.1 Task 1

The online grocery shopping task was designed as a shopping task since online shopping is among the top activities performed by adults over the age of 65 when interacting with technology. This task required participants to add two items to the shopping cart before checking out, and consisted of a total of 19 steps. The specific page by page interfaces by which the participant navigated through can be seen in Appendix E parts 1 and 2. Participants were not required to fill in any personal information in order to checkout. The framework and design for this task were based off of several online grocery shopping websites, and then modified to fit the recommendations for menu design from the Literature Review.

3.1.2 Task 2

The task of booking a cruise was designed to represent searching the internet, one of the top activities performed by adults 65 and over when using technology. This task required the participant to book a cruise based on whether a certain game was offered on the cruise ship, and this consisted of 12 total steps before the task was completed. The specific page by page interfaces by which the participant navigated through can be seen in Appendix E parts 3 and 4. Participants were not required to fill in any personal information in order to book a cruise. The pages in this task were based on several cruise websites, and like the first task this was modified to fit recommendations for menu design from the Literature Review.

Two tasks were designed for this project as a way to represent a more diverse set of online interactions. The first task of online grocery shopping was a path that required moving both forwards and backwards in the interface. Task two on the other hand, for booking a cruise, was a forward progression of steps and shorter than task one. Having two tasks that differed in navigation processes and of different lengths was used to further enhance the strength of potential results between button designs, age, and gender. Both button designs followed the same design elements other than the inclusion of the symbol in the second button design. Each of the two button designs will be addressed in the following two sections in more detail before the design of the experiment is discussed.

3.1.3 Text Only Buttons

The text only buttons were 12mm by 50mm and had black text in size 23 Arial font, and were set on a light gray background. An example of the button can be seen in Figure 2 below.

Figure 2: Text Only Button

3.1.4 Symbol + Text Buttons

The symbol + text buttons were the same size, color, and font as the text only buttons: 12mm by 50mm with black text in size 23 Arial font with a light gray background. The symbol was positioned on the left side of the button, and was approximately 10mm by 10mm depending on the overall shape of the symbol. An example of the button can be seen in Figure 3 below. The symbols were chosen by determining the most well adopted interpretation of the text, while also taking into consideration the simplistic style of the symbol.

Figure 3: Symbol + Text Button

For each of the button designs, whenever a the text was too long for the width of the button, the text was wrapped onto a second line and centered. This can be seen in Figure 4, with (A) representing the text only button and (B) representing the symbol + text button.

Figure 4: Wrapped Text in Button Designs

These two button designs, in addition to the two tasks described previously, were designed and made available to use on an iPad 2 using the program Xcode.

3.2 Technical Development

The two tasks were created on the Macintosh application Xcode. Xcode is an integrated development environment that contains software development tools developed by Apple for developing software for OS X, iOS, WatchOS, and tvOS. Through Xcode the applications were designed and made for each task and with each button design, and were then downloaded onto an iPad 2 for testing purposes.

Once the two tasks and each button design per task were built in Xcode, a total of four applications were then ready to be used on the iPad. In order to ascertain the best possible results, key decisions were made in regards to the design of experiment for the ordering of the task and button designs per participant. The decision to have each participant interact with both button designs before filling out the questionnaire was viewed as more important for comparing button designs, the primary focus of this experiment, rather than gathering individualized data based solely on one button design per participant.

Chapter 4: Methodology

The methodology section contains seven subsections that address the design of experiment, variables, experiment set-up and participants included, and procedure, in order to understand all parameters before discussing results. The final section discusses the pilot results before moving into the results for the experiment.

4.1 Design of Experiment

The design of experiment incorporates the variables, experiment set-up, and participants together to address the hypothesis, and here it was critical to determine the best mode of design in order to yield the best possible results for the purpose of this project. Again, the purpose is to determine whether or not there is an optimal way to design touch screen interface buttons for adults between the ages of 65 and 84 based both on time to complete the task and subjective survey results. Therefore, participants were randomly assigned a task and button design order given gender. This required an even number of males and females per cell in order to counterbalance the design and reduce the potential learning effect. A repeated measures approach was chosen as the best way to analyze the data because this allowed for a direct comparison between button designs. If a completely randomized approach was taken, there would have been more participants required to draw direct comparisons between the two button designs, which reduces the potential for powerful comparative results regarding optimal button designs for aged adults given gender.

4.2 Hypothesis

Given the Literature Review conducted on the interaction of touch screen tablets for the aging population, it is hypothesized that the redundant buttons will:

- Increase ease of navigation through the interface for both age groups and genders
- Result in faster task completion times for both age groups and genders

- Generate higher ratings for navigation, satisfaction, and understanding categories for both age groups and genders
- Have a higher percentage of preference ratings for both age groups and genders

Each of the variables taken into consideration were critical for testing the hypothesis for significance, and this includes the independent variables, dependent variables, and controlled variables. Set-up also played a crucial role for consistency of participant interaction due to multiple locations used to run the experiment.

4.3 Variables

The variables discussed in this section include independent variables, dependent variables, and controlled variables. It is important to note that each of the variables listed below pertain to *each* task. Participants will only interact with one of the tasks, either online grocery shopping or booking a cruise, not both.

4.3.1 Independent Variables

- Age: There were two age groups for the purpose of this experiment, 65 to 74 and 75 to 84, in order to assess potential differences in touch screen interaction across age ranges. Two age groups were used as opposed to more due to the time constraints to complete this project, and a decade was chosen as an appropriate grouping of ages to reduce potential difficulty in participant recruitment but not bigger to minimize potential chances for major differences in the characteristics of aging within age groups.

- Gender: Males and females were analyzed in this research in order to better understand gender differences in touch screen interaction.

4.3.2 Dependent Variables

- Time: The time to complete a task given each button design was recorded in seconds for every participant.

- Questionnaire Results: The questionnaire yields insight into touch screen use for each participant, includes a rating scale for comparison of the two button designs, and includes questions asking for specific attributes related to aging that may interfere with touch screen interaction. The specific questions included in the questionnaire can be referred to in Appendix D.

4.3.3 Controlled Variables

- Button Designs: Every participant used both of the button designs in the tasks, the text only button and the symbol + text button. This allowed for a comparison between the two designs in the questionnaire.

- Tablet: The same iPad 2 was used for all iterations of the experiment. It was positioned centered in front of each participant flat on the table and their dominant hand was used on the device.

- Introduction & Instructions: The same introduction was read to each participant, and the instructions for each task differed between tasks but remained constant for each iteration of the same task. The experiment introduction can be read in Appendix A and the experiment instructions per task can be looked at in detail in Appendix C.

4.4 Experiment Set-up

Each experiment took place in a separate room where noise and lighting was controlled. The rooms were quiet and if the room was too dim a desk lamp was provided. The desk lamp was not used in each scenario if already existing bright lighting was available, and was therefore only necessary at The Villages Independent Living Community. The setup at each of the three locations where data collection took place can be seen in Figures 5, 6 and 7 below.

(A) (B)

Figure 5: The Villages Experiment Set-up

(A) (B)

Figure 6: Paso Robles Senior Center Experiment Set-up

(A) (B)

Figure 7: San Luis Obispo Senior Center Experiment Set-up

4.5 Participants

All participants included in the research were between the ages of 65 and 84, and had used a touch screen device at least once prior to the experiment. The age range began at the age of 65 because 65 years of age is the standard age of retirement in the United

States. The participants were recruited from multiple locations between San Luis Obispo and Paso Robles, California. In order to be a valid participant, each volunteer had to be between the ages of 65 and 84, and had to have used a touch screen prior to the experiment. Two age brackets were examined in this study, ages 65 to 74, and ages 75 to 84. The age brackets were set at a decade each in order to provide enough age span to be able to recruit enough volunteers, but not larger in order to minimize the variability in ages and interaction abilities. Each volunteer was also pre-screened in order to validate prior touch screen experience. Any volunteer who had not used a touch screen before, or who was below or over the age brackets was not used for the purpose of this study.

Eight females and eight males were recruited for the pilot, and sixteen females and sixteen males were recruited for the experiment. Participants were randomly assigned a task and an order for each button design based on their gender and age upon arrival.

4.6 Procedure

The correspondence with each volunteer began with an informal greeting to get to know the participant briefly in order to make him or her feel comfortable and more relaxed. When ready, the participant was then read the instructions, as seen in Appendix A.

Following the introduction, the participant was asked to sign a consent form for the purpose of assuring confidentiality and providing contacts in the case that questions or concerns arise. This can be seen in Appendix B.

Upon signing the consent form, the participant was shown an example of the interface they would be looking at so that they could become familiar with what the button looked like before beginning. They were shown either Figure 8 image (A) below or Figure 8 image (B) below depending on which order they were completing the task designs in.

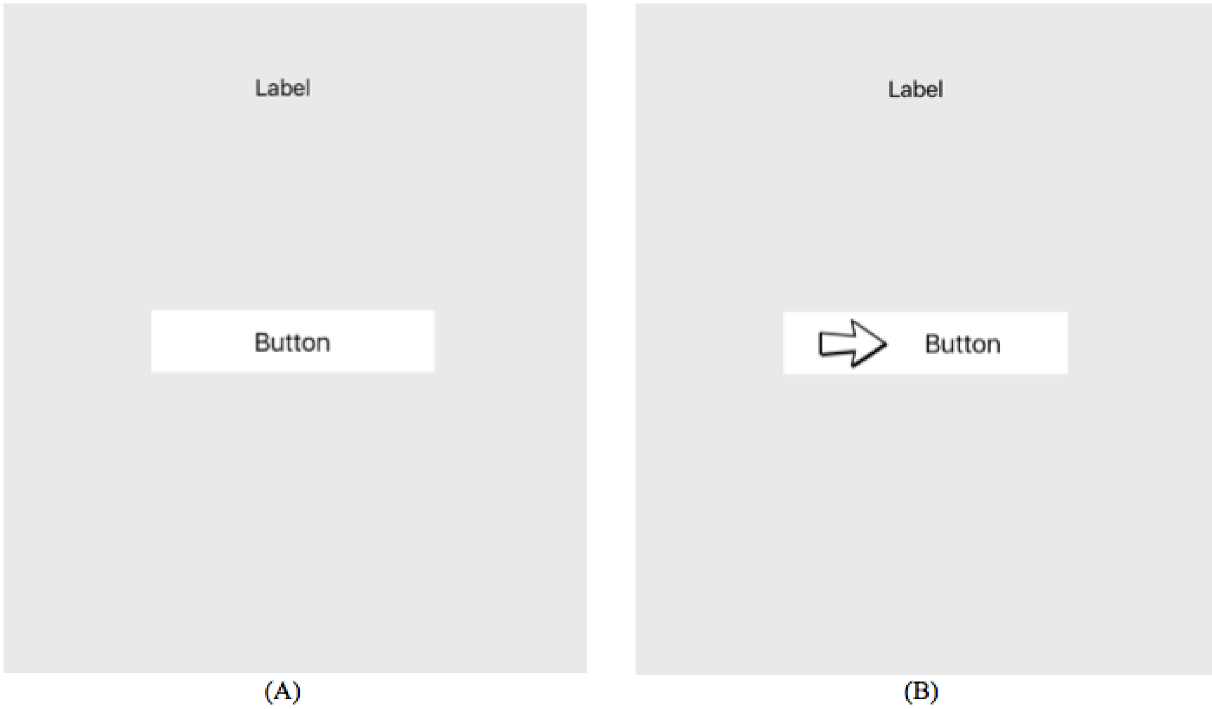


Figure 8: Interface Familiarity Example

In order to reduce the risk of a learning curve, there were equal numbers of participants between ages and genders to complete the experiment starting with opposite button designs. For example, female one may start with the text only interface and then move to the symbol + text interface, and then female two would start with the symbol + text interface before moving to the text only interface. Counterbalancing was used because repeated measures was chosen as the optimal design of experiment due to the importance of participants being able to compare and contrast button designs in the questionnaire.

Following the example of the interface, the participant was given the instruction sheet for the given task, and the iPad. The iPad was opened to the "Begin" button and the timer was initiated here. The instruction sheets per task can be viewed in Appendix C.

Once the last page was reached, the timer was stopped and the time was recorded.

The participant was introduced to the next interface based on which design they interacted with first. The start page to the second interface was opened and the timer was reset. The participant was given the instruction sheet again and asked to navigate through the given task. Once finished, the second time was recorded and the participant was given the questionnaire to fill it. The questionnaire can be seen in Appendix D.

After the questionnaire was filled out, the participant was thanked and given a thank you card and cookies. The participant was also asked if they would like a copy of the results, and if so, their first name and a form of contact was recorded.

Once the application was designed and running smoothly, the design of experiment was established, and the documents needed for testing and gathering results were created, contact was made between the pre-determined locations to collect volunteers and administer the experiment. The pilot took place at The Villages Independent Living Community and the Paso Robles Senior Center.

4.7 Pilot

The purpose of the pilot was to ensure that the testing procedures, including all instructions and questionnaires were well received and understood by participants when in use. The pilot also ensured that the application for which the experiment was tested on ran smoothly and without complications. Eight females and eight males were recruited for the pilot from *The Villages* Independent Living Community and the Paso Robles Senior Center. Half of these volunteers were between the ages 65 and 74 and the other half were between 75 and 84 years of age, with an equal distribution of females and males. Of this, there were two females and two males per age group per task. For each two participants per cell, they completed the tasks in opposite button design orders to counterbalance potential learning effect.

The pilot results were partially analyzed in JMP to test the significance of time against age, gender, and button design. The Task 1, online grocery shopping data did not pass the normality test, however by transforming the response time data using the Box-Cox transformation method the data did pass the normality test with a p-value increasing from 0.033 to 0.7751. This high p-value validated the data's consistency with normality, therefore a three-way ANOVA could be run on this task. The task of booking a cruise data did on the other hand pass the test of normality with a p-value of 0.5178.

Following normality validation, the significance was tested using a three-way ANOVA. For the task of online grocery shopping, there was a significant interaction between gender and age with a p-value of 0.0237. As females increased in age, the time to complete the task increased, however as males increased in age, time to complete the task decreased. Blocking decreased the significance of the interaction to $p = 0.0437$. For the booking a cruise task, there were no significant results, however age was noteworthy with a p-value of 0.14465. As both females and males increased in age, time to complete the task also increased. Blocking decreased the significance for all effects, and therefore will not be used in the analysis of the experiment results. The main takeaway from the quantitative results were that there was no significance between button design, the key difference between interfaces.

The qualitative data was not analyzed for the pilot, however it was obvious through observation that there was a big difference for preference of text only buttons versus symbol + text buttons between females and males. For the online grocery shopping task, 50% of females prefer text only buttons while 50% who prefer symbol + text buttons, and 100% of males prefer symbol + text buttons. For the task of booking a cruise, 75% of females prefer text only buttons compared to 25% who prefer symbol + text buttons, and 25% of males prefer text only buttons compared to 75% of males who prefer symbol + text buttons.

In summary, the time was tested for significance between age, gender and button design in JMP for the pilot, and results confirmed correctness of initial plan. Therefore, no revisions for parameters of the experiment were necessary. Because no revisions were necessary, the experiment was conducted with sixteen females and sixteen males. This allowed for four participants per cell, eight per task.

Chapter 5: Results

The results were comprised of three different sections: quantitative results, qualitative results, and observations. The first two sections, quantitative and qualitative results are broken up between tasks, and the age, gender, and button design effects are discussed within each section.

5.1 Quantitative Results

Both of the tasks required the same level of difficulty in order to complete each task, and the button designs did not change the time to navigate through the task much. This can be seen in Table 2 and Table 3 below, where the average time to complete each task by gender and by button design are summarized. Here it is important to note that males had an average faster completion time for online grocery shopping compared to females, and females had an average faster completion time for booking a cruise compared to males. The significance analysis of these results are discussed in the following two subsections.

Table 2: Average Time by Age and Gender for Online Grocery Shopping (seconds)

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	88.20	130.43	114.61	88.88
Symbol + Text Button	95.73	111.17	100.32	88.65

Table 3: Average Time by Age and Gender for Booking a Cruise (seconds)

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	91.12	89.82	71.32	128.30
Symbol + Text Button	93.09	98.13	83.15	121.72

5.1.1 *Task 1: Online Grocery Shopping*

The raw data for the task of online grocery shopping failed the initial test of normality, however transforming the data allowed for a three-way ANOVA analysis to proceed. The data was transformed using the Box-Cox transformation method, an approach that uses a logarithmic scale to manipulate data in a way that produces a normal distribution. This allows for the assumption of normality to be met before proceeding to assess the significance of the data, which can be seen in Figure 9 below. The transformation increased the p-value from 0.0011 to 0.3174, suggesting the data is normal and the assumptions to run an ANOVA are met.

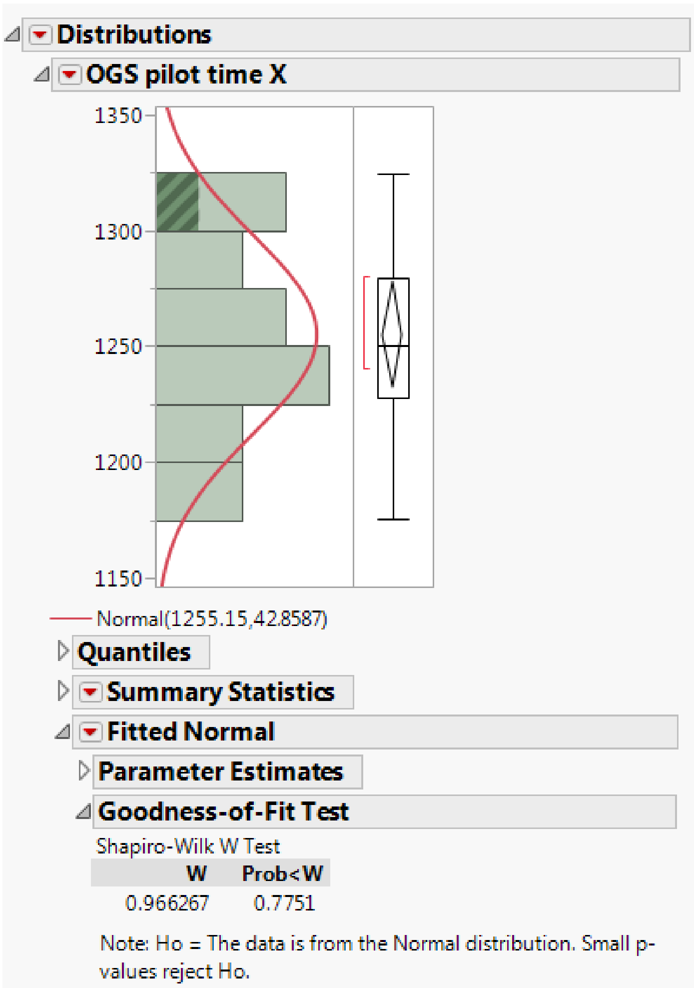


Figure 9: Normality Test for Time for Online Grocery Shopping

The three-way ANOVA results indicated no significant effects, as seen in Table 4 below.

However, the interaction effect of age and gender was noteworthy at a p-value of 0.15727. This is consistent with the pilot findings for this task, where as females increased in age, time to complete the task increased, and as males increased in age, time to complete the task decreased. Figure 10 below shows this interaction.

Table 4: P-values for Online Grocery Shopping Time Effects

Effect	**p-value**
Age	0.4274
Gender	0.8931
Button design	0.8374
Age*Gender	0.1573
Age*Button design	0.7505
Gender*Button design	0.6981
Age*Gender*Button design	0.7849

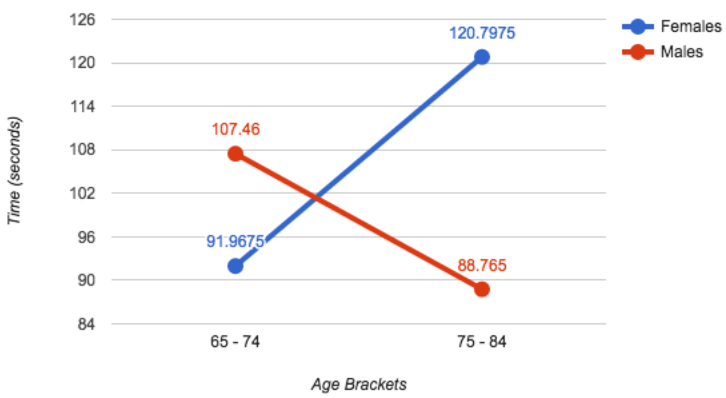


Figure 10: Interaction Plot between Age & Gender for Online Grocery Shopping

5.1.2 Task 2: Booking a Cruise

Similar to the raw data for online grocery shopping, the data for the task of booking a cruise failed the initial test of normality. The data was again transformed using the Box-Cox transformation method, which increased the p-value from 0.0036 to 0.8842. The normality test can be seen in Figure 11 below.

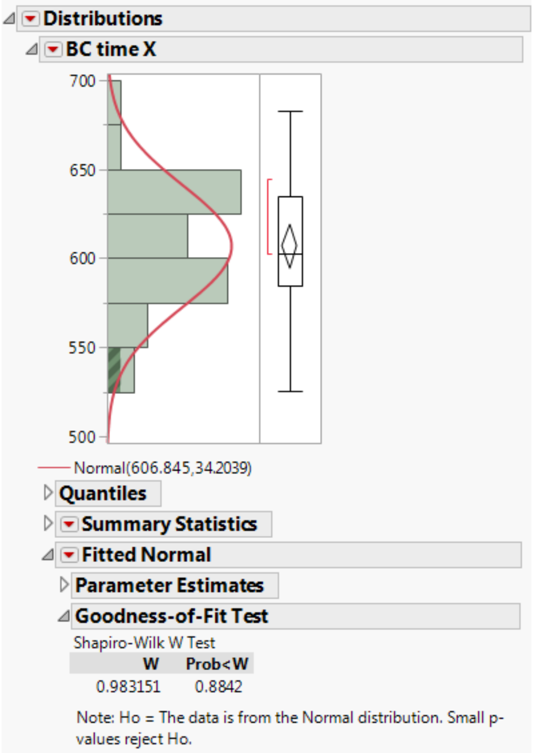


Figure 11: Normality Test for Time for Booking a Cruise

An ANOVA analysis concluded no significant results, which are listed in Table 5. However, age was noteworthy with a p-value of 0.18119. As both females and males increased in age, time to complete the task of booking a cruise increased. This can be seen in Figure 12 below.

Table 5: P-values for Booking a Cruise Time Effects

Effect	**p-value**
Age	0.1812
Gender	0.8266
Button design	0.5345
Age*Gender	0.5492
Age*Button design	0.8832
Gender*Button design	0.5731
Age*Gender*Button design	0.7176

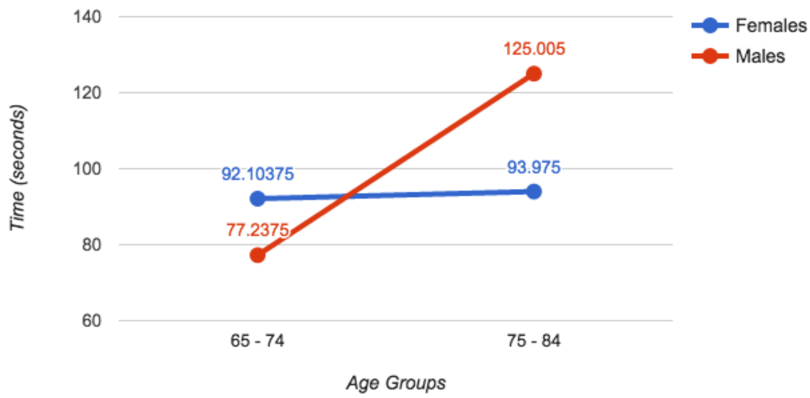


Figure 12: Average Time by Gender for Booking a Cruise

5.2 Qualitative Results

The qualitative results came from the questionnaires, and included four parts that could be analyzed statistically. The first three components were related to ease of navigation, general satisfaction, and overall understanding of the two button designs, where each participant had to rate each of the two buttons based on their experience using the interfaces. The rating scale ranged from one to five, with one being the worst score and five being the best.

The last part of the qualitative data to be analyzed was the preferences of the two buttons. This question was prefaced in disregard to the task, where the participant decided which type of button they would prefer if they were to get the choice in the future. The results are broken up by task and detailed in the following subsections.

5.2.1 Task 1: Online Grocery Shopping

The average ratings for navigation, satisfaction, and understanding are listed below in Table 6, Table 7, and Table 8. In terms of ease of navigation, general satisfaction, and overall understanding, none of the data followed a normal distribution, therefore the data had to be transformed. When looking at the normality test for the residuals, the satisfaction and understanding ratings were normal, therefore an ANOVA could be run on this data. The navigation data was much more normal when tested using residuals ($p = 0.0196$) compared to the original data ($p < 0.001$) and Box Cox transformed data ($p < 0.001$), therefore, it was chosen to run the ANOVA with the assumption of normality met based on the increase in p-value for normality. The p-values and the normality plots are summarized in Table 9.

Table 6: Average Navigation Ratings by Age and Gender for Online GroceryShopping

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	3.5	4.25	4	4
Symbol + Text Button	4	4.75	4	4.75

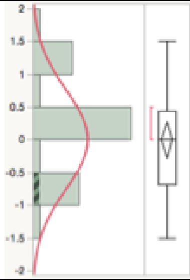
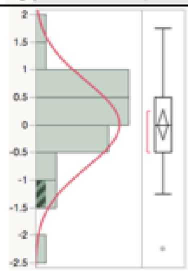
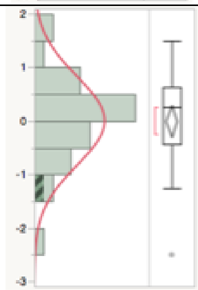
Table 7: Average Satisfaction Ratings by Age and Gender for Online GroceryShopping

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	3.25	4.25	4.5	4
Symbol + Text Button	4	4.25	4.5	4.75

Table 8: Average Understanding Ratings by Age and Gender for Online GroceryShopping

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	3.875	3.5	4.75	4.5
Symbol + Text Button	4.125	4.25	4.75	4.75

Table 9: Normality Test for Ratings for Online Grocery Shopping

Rating	Normality Plot	p-value
Navigation		0.0196
Satisfaction		0.2823
Understanding		0.1157

When a three-way ANOVA was run for each of the three ratings, there were no significant results. Table 10 summarizes the p-values for each each effect by rating category. This includes age, gender, button design, and each interaction effect for navigation, satisfaction, and understanding.

Table 10: P-values for Online Grocery Shopping Rating Effects

Effect	Navigation p-value	Satisfaction p-value	Understanding p-value
Age	0.0767	1.0000	0.4346
Gender	0.8389	0.0741	0.1250
Button design	0.0767	0.4623	0.2449
Age*Gender	0.5433	0.4623	0.2449
Age*Button design	0.3134	0.7120	1.0000
Gender*Button design	0.5433	1.0000	1.0000
Age*Gender*Button design	0.8389	0.2735	0.2449

Although there were no significant results, age and button design were noteworthy when looking at ratings for ease of navigation, as seen in Table 6 of the average ratings by age, gender, and button design. It is also interesting to note however that on average males rated each of these categories higher than females, which can be seen in Figure 13 below.

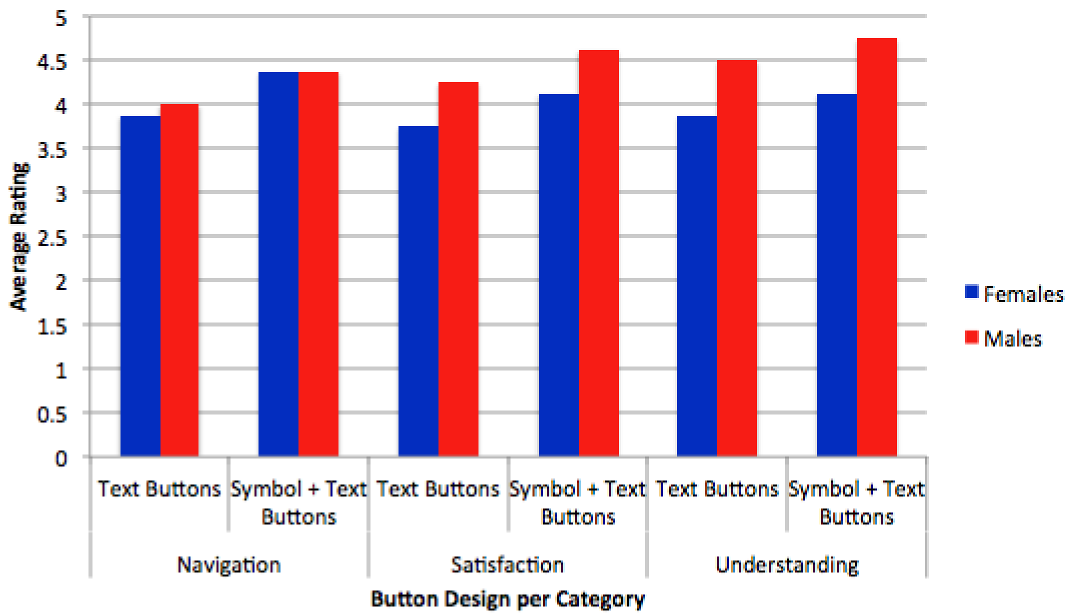


Figure 13: Average Ratings per Category by Gender for Online Grocery Shopping

The last portion of the qualitative data for this task is the user preference between button designs. Like mentioned previously, the participant was asked to give a preference on button type without the task in mind, as if for future interface interaction. This data was input into JMP using binary code, for which 0 stood for text only button and 1 stood for symbol + text button. Here a chi-square test of association was used to test the significance of the data, and it was concluded that there was a significant difference in gender. The p-value was 0.0068. In Figure 14 below it can be seen that 50% of females prefer text only buttons compared to the other 50% of females who prefer symbol + text buttons, whereas 100% of males prefer a symbol + text button.

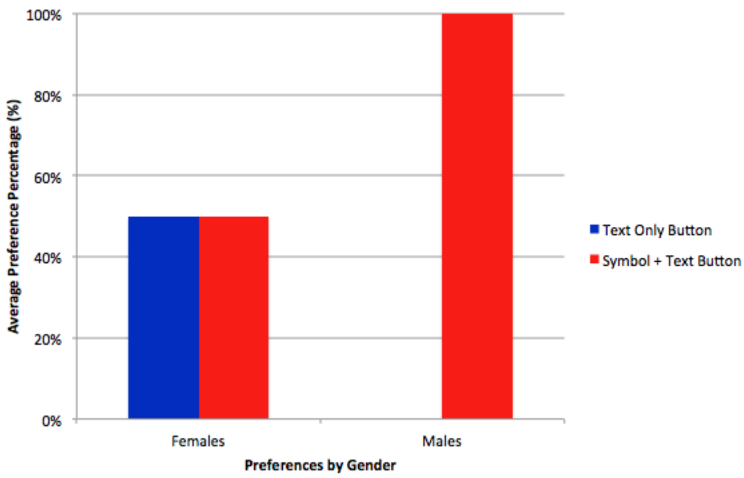


Figure 14: Button Design Preference by Gender for Online Grocery Shopping

5.2.2 Task 2: Booking a Cruise

The average ratings for navigation, satisfaction, and understanding per button type are listed in Table 11, Table 12, and Table 13 below. Similar to the rating results for online grocery shopping, none of the ratings data for booking a cruise was normal. The residuals were ran and normality test was run on this information, yielding normal results for the satisfaction and understanding categories. Again, the normality test on the residuals for navigation failed with a p-value of 0.0355, however this was still an improvement from the original data ($p < 0.0001$) and the Box Cox transformed data ($p < 0.0001$). Therefore, the results for the residuals normality test was deemed as enough validation to run an ANOVA on the navigation data. Table 14 outlines a summary of the normality plots and p-values according to each category.

Table 11: Average Navigation Ratings by Age and Gender for Booking a Cruise

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	4.75	4.75	3	3.5
Symbol + Text Button	4.25	4.75	3.5	3.5

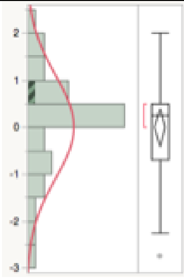
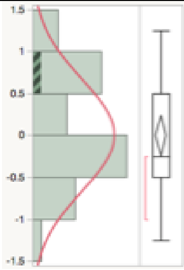
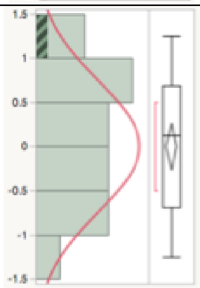
Table 12: Average Satisfaction Ratings by Age and Gender for Booking a Cruise

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	4.75	4.5	4	3.25
Symbol + Text Button	4.25	4.5	4.25	3.75

Table 13: Average Understanding Ratings by Age and Gender for Booking a Cruise

	Females 65 - 74	Females 75 - 84	Males 65 - 74	Males 75 - 84
Text Button	4.75	4.5	4.25	3.75
Symbol + Text Button	4	4.5	4.25	4

Table 14: Normality Test for Ratings for Booking a Cruise

Rating	Normality Plot	p-value
Navigation		0.0355
Satisfaction		0.2339
Understanding		0.0992

A three-way ANOVA was run for each category with the age, gender, and button design effects, which are summarized according to category in Table 15 below.

Table 15: P-values for Booking a Cruise Rating Effects

Effect	**Navigation p-value**	**Satisfaction p-value**	**Understanding p-value**
Age	0.6762	0.2544	0.6782
Gender	0.0068	0.0168	0.2197
Button design	0.8173	0.4623	0.6782
Age*Gender	0.8891	0.2544	0.4091
Age*Button design	0.8891	0.4903	0.4091
Gender*Button design	0.4877	0.2544	0.4091
Age*Gender*Button design	0.8891	0.8173	0.6782

As seen in the table above, there were two significant results:

- Females rated both button designs significantly higher than males in terms of ease of navigation, with a p-value of 0.0068.
- Females rated both button designs significantly higher than males in terms of general satisfaction, with a p-value of 0.0168.

It is also noteworthy that this same trend occurred for overall understanding for both button designs, females rated them both higher than males, however this was not significant. This can be seen visually in Figure 15 below.

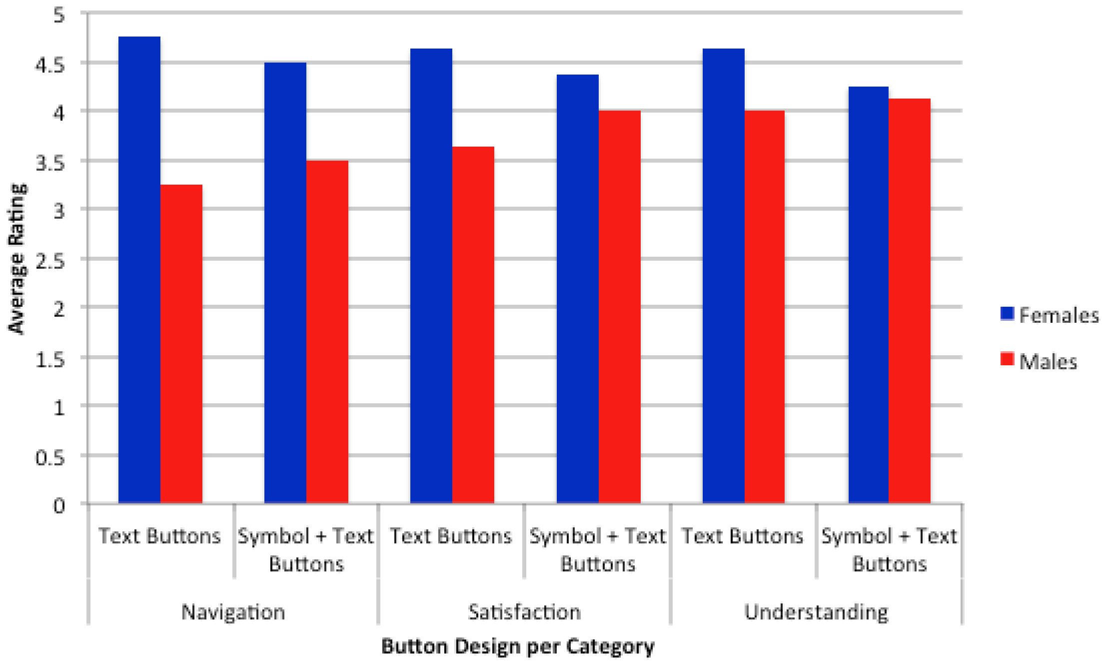


Figure 15: Average Ratings per Category by Gender for Booking a Cruise

When looking into button design preference following this task, 75% of females prefer text only buttons compared to the remaining 25% who prefer symbol and text buttons. Similar to the results from the online grocery shopping task, 12.5% of males prefer text only buttons and the remaining 87.5% prefer symbol and text buttons. When a chi-square test of association was run to test the significance of this data, it was revealed that there was a significant age and gender effect ($p = 0.0024$). It can be concluded that females aged 65 to 74 prefer a mix of text only and symbol and text buttons compared to females aged 75 to 84 who prefer text only buttons, whereas overall males across both age groups prefer symbol and text buttons. The interaction can be seen in Figure 16 below.

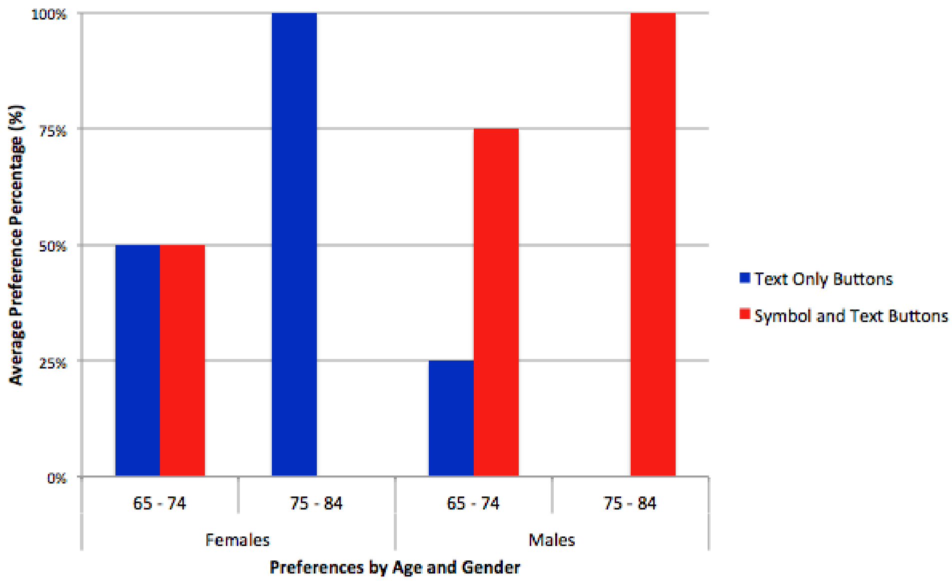


Figure 16: Interaction Effect between Age and Gender Preferences in Button Design

In general, participants performed the second design faster than the first, however the counterbalancing reduced overall differences in learned, as seen with no significant time results. Blocking by participant was used in the analysis in order to identify any potential outliers, however this decreased the significance of the results and was not included in the final results. Furthermore, no analysis was conducted to test potential variances in results by location.

5.3 Observations

Given the age group, procedures, and other boundaries of this study, it was interesting to learn about many of the participants and their current experiences. Many participants wanted to talk after the experiment and questionnaire was completed about their current difficulties with their tablets or smartphones, and some even requested help. From the study however, one of the most interesting things learned from the experiment and questionnaire was the difficulties in understanding the terminology. For example, when told they would be pressing buttons, many participants didn't understand that the button on a touch screen is still a button even though it isn't a physical button, however once explained had an understanding from there on out. This is important when designing instructions or videos on how to use a new technological device, because even if the definition seems obvious to designers and younger generations, older adults did not grow up with this technology, and therefore have a bigger learning curve when using these devices regardless of if they have used them often.

Out of the 32 total participants, the following were pulled from the questionnaire results to identify components of the button designs that they would have liked to have seen differently:

- Three participants did not like the location of the symbol.
- Three participants would have liked colored symbols.
- Three participants thought the buttons could have been bigger.
- Two thought the symbol was distracting or unnecessary for the task at hand.

This here implies the difficulties in designing for all, however proves there is always areas for which future research is needed. In regards to the significant difference in preferences of button designs between females and males, there may be reason to design gender specific interfaces based on these preferences, rather than adopting a design for all approach.

5.4 Summary of Results

Between both tasks and across almost all forms of measurement, including time, ratings for navigation, satisfaction, and understanding, there were no significant results for button design. Therefore, the initial hypothesis suggesting that the redundant interface (the symbol and text button design) would yield faster time to complete the tasks and would obtain higher ratings for navigation, satisfaction, and understanding cannot be confirmed. There were significant results however for the following categories and effects:

- Females rated both button designs significantly higher than males in terms of ease of navigation.
- Females rated both button designs significantly higher than males in terms of general satisfaction.
- Females preferred text only buttons.
- Males preferred symbol and text buttons.

No other ratings for navigation, satisfaction, or understanding were significant.

The largest takeaway from this summary is that button design had no affect on navigation, however it had a significant impact in preference between genders. Reasons to why there might be a significant difference in preferences between genders will be discussed in the Discussion section.

Chapter 6: Discussion

The results from this experiment are powerful due to the incredibly limited research conducted between females and males using touch screen devices. Before discussing potential explanations for gender differences, it is important to reiterate that all reasons described are constrained to the boundaries of this study:

- The older population is constrained to females and males between the ages of 65 and 84
- Redundancy effect is constrained to the fixed symbols used in the two symbol + text button tasks, and explanations cannot be generalized across all symbols.

Furthermore, of this discussion, both qualitative and quantitative metrics will be discussed even though not all results were significant.

Although not significant, there were differences in average times to complete the tasks between females and males, and females and males gave differing average ratings, which poses some questions as to why there is this difference. Furthermore, there was a significant difference in button design preference between females and males, which may or may not relate to the difference in average times per task.

Results showed that as males increased in age, the time to complete the task of online grocery shopping decreased. Results were opposite for the task of booking a cruise; as males increased in age, the time to complete this task increased. Please refer back to Table 2 and Table 3 for more details on this data. This may be due to familiarity of the task at hand. Males in general may be more aware of what it requires to grocery shop compared to booking a cruise, therefore making it easier to complete the task of online grocery shopping. Comparatively, females may be more capable of booking a cruise compared to grocery shopping because this falls into more of a browsing the internet and entertainment category than it does online shopping, which may be more suited to fit the activities females partake in on a daily basis.

With that in mind, the average ratings participants gave each of the two button types in the post-experiment questionnaire appear related to the time to complete the task. Males tended to rate the two button designs with higher average ratings on the task of online grocery shopping, whereas females tended to rate the two button designs with higher average ratings on the task of booking a cruise. Please refer back to the Qualitative Results section for details on the average ratings per task by gender.

Together, the quantitative results show that gender affects time to complete a task, and the qualitative results show that gender affects ease of navigation, general satisfaction, and overall understanding, given the two different tasks. Gender effect was not accounted for in previous research on redundancy effect. All participants in this experiment were screened to assess touch screen use, and majority use a touch screen multiple times a day for at least 6 months, therefore conclusions could not be drawn in relation to Vetere & Howard's [6] study on redundancy effect and technology familiarity. If there were to be a larger sample size however across a higher varying population of touch screen use, it is likely that results would not support Vetere & Howard's results, because there is no relationship between technology familiarity and preference in the current data set.

Because of a similar technology familiarity level across participants in this study, Kalyuga's research that suggests redundant information is essential for novice technology users could not be supported nor rejected [21]. What is interesting about this however is that regardless of experience level, males preferred a redundant interface, whereas females did not. This suggests that redundancy in interface design is more complicated than the cognitive demand required to navigate an interface, instead it is also dependent on perceived ease of use. Even if a user does not show signs of improved performance in a given interface (whether redundant or not), if the user *thinks* one design is better than another then they are more likely to revisit the preferred interface. For one of the participants in Page's study, the participant actually performed better at a touch screen device, however still preferred a physical key-based phone [12]. This is powerful because that person will likely not buy nor is likely to recommend a touch screen device to someone else if they themselves cannot see the perceived benefits of this devices. This therefore shows the impact preference can make on touch screen interface revisits.

When considering why there is a significant difference between females who prefer text only buttons, and males who prefer symbol + text buttons, several explanations come to mind for the considered age brackets. Do females over the age of 65 read more than males, therefore swaying there preferences to that of a more familiar design? Do males learn better with visual examples, therefore preferring symbol and text buttons in design? Psychological analysis as to the reasons behind this difference may be of benefit to the aging population, however, when it comes down to design, it is not of importance as to why this difference exists, but that a difference exists at all. Therefore, the fact that there does exist a difference in preference in design elements between females and males, given the boundaries of this project, suggests that there may be a better approach to designing interfaces for the aging population.

Chapter 7: Conclusions

Through the Literature Review, it is evident that the benefits of interacting with touch screen technology provide ample reasons as to why adults over the age of 65 should adopt such technologies. The difficulties these adults face however, such as not knowing where to go next when navigating a webpage, or how to move to the next page, or even clicking the wrong button, are crucial when it comes to this adoption rate. The overall purpose of the research provided in this report was to address these challenges from a realistic and practical approach. Because of this, redundancy effect was analyzed by looking at how two different button designs, a text only button and a simple, black and white symbol + text button would impact the navigation through a task on a touch screen device for adults between the ages of 65 and 84. The conclusions drawn from this research are limited to the boundaries of this experiment, which limited to age and symbol choice. Conclusions drawn on age are restricted to the ages of 65 and 84, not those below or over the age group. The conclusions drawn on redundancy are limited to the fixed symbols used in the task designs, and cannot be generalized for all symbols. Furthermore, because there were no significant findings from the quantitative results, conclusions for this research are solely based on qualitative findings. Based on these constraints, two major findings from experiment are addressed below.

1. The purpose of this experiment was to test whether or not a redundant interface aided in navigation for adults between the ages of 65 and 84. Research by Gudur, Blackler, Popovic & Mahar stated that redundancy in the interface did not improve speed or accuracy in participants with low technology familiarity (older adults) however did have a positive impact with users of moderate to high technology familiarity (younger adults) [6]. Kalyuga on the other hand conducted a study and found that redundant textual descriptions along with diagrams were essential for novice users, and once the user gained additional expertise this redundant information impeded learning [21]. Results from this experiment contradict both Gudur, Blackler, Popovic & Mahar and Kalyuga's work by concluding that a redundant button design does not help nor hinder navigation in an interface when compared to a text only button design.

2. Another goal of this experiment was to identify any differences in females and males between tasks and button designs. This has not been heavily researched for adults

over the age of 65, therefore the results from this study provide a gateway for exploring the gender differences in interface navigation by revealing that there is indeed significantly different gender preferences. Significant results for gender preferences lead to the recommendation that designers should consider gender specific designs when considering the aging population. When possible, allow for the option to choose one design or the other upon entering a website, or if possible identify gender favored websites and design interfaces with this in mind.

When considering ways to design for opposing genders, designers could design redundant interfaces for aged men and text only interfaces for aged women. Since this is a difficult parameter to withhold, it should be realized that designers should adjust the scale to which gender they are designing for based on the needs and goals of their specific application. Furthermore, because there is such limited research on gender differences, especially for the aged population, more research could help to solidify these findings and further support the need to incorporate gender different designs.

By doing so, the aging population may indeed be able to better see the benefits of using touch screen technology, and better yet they may be able to more easily interact with touch screen devices if they feel that the device is designed with their needs in mind. In conclusion, the aging population is adopting touch screens at the fastest growing rate, and there are ways that interfaces can be designed by taking adults over the age of 65 into account. By considering gender differences in interface use and design and designing based on these specific differences, the gap between the aging population and technology adoption can and therefore should be minimized.

Chapter 8: Future Research

From this study it is evident that there may be gender differences in interface preference, however in order to further validate the significance of this preference from a quantitative standpoint several measures could be taken. This includes:

- Increase the sample size in order to broaden the potential for significance and to account for additional variables. This will bring in participants that represent a larger array of the varying backgrounds of wealth, education, lifestyle, and more that will yield more inclusive results.
- Increase the length and complexity of the task. Increasing the length of the task may provide additional insight into the challenges adults face as they age, such as the mental capacity and memory span required for completing the task. Increasing complexity may yield differences in age and gender due to cognitive demand as a factor of aging. Together these may highlight the differences between age groups and genders even more so than identified in this research.
- Test for other forms of redundancy and its effect on the aging touch screen user population in order to see if there is a better and more effective way to design for all. This has been researched more thoroughly than simply text and symbol + text designs, however has not included adults over the age of 65 or gender. Including gender could determine whether gender differences holds true across modalities.
- Reconfigure the button designs used in this experiment to identify whether symbol location and or the color of symbols has an effect on gender differences in interface design.
- Test for the universal acceptance of the symbols used in this research, and expand the experiment scope to general symbols rather than fixed symbols.
- Explore with psychologists the underlying causes of gender differences in relation to technology interaction.

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APPENDICES

Appendix A: Experiment Introduction

Thank you again for participating in my experiment today! The purpose of this experiment is to better understand interaction with touch screen interfaces and redundancy effect. Todays experiment consists of two designs: a text only design, and a text and symbol design. Before the experiment begins, I will review with you what the design looks like so that you are familiar with the buttons and labels on each page. Once the experiment begins, you will be given a sheet describing the task you are to complete. It is important that you follow the instructions as accurately as possible. There will be two parts for this experiment, which will allow you to experience each of the two designs, followed by a questionnaire, which in total should take around 10 minutes. Your goal should be to complete this experiment with both time and accuracy, however I will be here to help if you get stuck along the way. You may stop the experiment at any time if you decide you do not want to continue. Before we begin, do you have any questions?

Appendix B: Participation Consent Form

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT, "The User-Centered Design of Touch Screens for the Aging Population"

A research project on the ergonomic design of touch screen interfaces for the aging population is being conducted by Sarah Riesenberg, a graduate student in the Department of Industrial Engineering at Cal Poly, San Luis Obispo, under the supervision of Dr. Reza Pouraghabagher. The purpose of the study is to better understand how the use of symbols affect touch screen interface navigation for aged users from an ergonomics perspective. The goal is to be able to recommend interface design requirements for aged touch screen users, with the idea that this research will help shift the definition of the average use, as applied to future modern touch screen devices.

You are being asked to take part in this study by participating in an experiment that consists of two parts, followed by a short questionnaire. Your participation will take approximately 15 minutes. Please be aware that you are not required to participate in this research and you may discontinue your participation at any time without penalty, and you may omit any items you prefer not to answer in the questionnaire at the end.

The possible risks associated with participation in this study include possible frustration due to the unfamiliar design of the interface, however individual results from the experiment will remain confidential. Your responses to the questionnaire will also remain confidential to protect your privacy; your name will not be used in reports of this research. Although there are no direct benefits by participating in this study, potential benefits associated with the study include a greater understanding of the interaction of touch screen devices using redundancy in design for the aged population.

If you have questions regarding this study or would like to be informed of the results when the study is completed, please feel free to contact researcher Sarah Riesenberg at sriesenb@calpoly.edu or 530-219-1313, or Dr. Reza Pouraghabagher at rpouragh@calpoly.edu. If you have concerns regarding the manner in which the study is conducted, you may contact Dr. Michael Black, Chair of the Cal Poly Human Subjects Committee, at (805) 756-2894, mblack@calpoly.edu, or Dr. Dean Wendt, Dean of Research, at (805) 756-1508, dwendt@calpoly.edu.

If you agree to voluntarily participate in this research project as described, please indicate your agreement by signing below. Please keep one copy of this form for your reference, and thank you for your participation in this research.

____________________________________ ______________

Signature of Volunteer Date

____________________________________ ______________

Signature of Researcher Date

Appendix C: Experiment Instructions

Task 1: Online Grocery Shopping

Online Grocery Shopping

Your goal for this task is to online grocery shop based on the requirements below. You will not need to enter any personal information in order to checkout. Have fun!

1. Shop by category
2. In fresh foods, go to produce
3. Find fruit and add blackberries to shopping cart
4. Continue shopping
5. Shop by category and go to fresh foods
6. In the bakery, go to pastries & desserts
7. Add blueberry scones to shopping cart
8. Checkout and continue to the *Thank you for shopping!* page

Task 2: Booking a Cruise

Booking a Cruise

Your goal for this task is to book a cruise to the Caribbean. You will not need to enter any personal information in order to book a cruise. Have fun!

1. Explore onboard activities
2. In indoor activities find games
3. Go to trivia and find which ships have this game on board
4. On Cruise Ship Breeze book a cruise to destination Caribbean
5. Proceed to the Book your cruise now! page

Appendix D: Post-Experiment Questionnaire

Experiment Questionnaire

1. Age: ____________

2. Gender:

0	Female
0	Male
0	Decline to State

3. Have you used a touch screen device before? (Touch screen devices include tablets such as iPads and Kindles and smartphones with touch screens)

0	Yes
0	No

If yes, continue to question 4. If no, continue to question 8.

4. How frequently do you use a touch screen device? Please check only one box.

	Several times overall	Once per month	Once per week	Several times per week	Once per day	Multiple times per day
Touch screen	0	0	0	0	0	0

5. For how many years have you been using a touch screen device? Please check only one box.

	Less than 1 month	Between 1 and 6 months	Between 6 months and 1 year	More than 1 year, but less than 3	More than 3 years
Touch screen	0	0	0	0	0

6. What are you primary activities on your touch screen device? Please check all that apply.

0	Reading
0	Playing Games
0	Internet Use
0	Shopping
0	Other: ____________

7. Does your touch screen require button clicking when using it?

0	Yes
0	No

8. On a scale of 1 to 5, with 1 being the most difficult and 5 being the easiest, please rate your ease of navigation through the two tasks based on the types of buttons used.

	1 Most difficult	2	3	4	5 Least difficult
Text Button	0	0	0	0	0
Symbol + Text Button	0	0	0	0	0

9. On a scale of 1 to 5, with 1 being the lowest satisfaction and 5 being the highest satisfaction, please rate your general satisfaction regarding the types of buttons used.

	1 Lowest satisfaction	2	3	4	5 Highest satisfaction
Text Button	0	0	0	0	0
Symbol + Text Button	0	0	0	0	0

10. On a scale of 1 to 5, with 1 being the least understood and 5 being the most understood, please rate your ease of understanding for the meaning of the buttons based on each of the buttons used.

	1 Least understood	2	3	4	5 Most understood
Text Button	0	0	0	0	0
Symbol + Text Button	0	0	0	0	0

11. Did the symbol on the button increase your confidence in navigating through the task?

0	Female
0	Male
0	Not Sure

12. Regardless of the task, did you prefer button with text only or the buttons with a symbol and text?

0	Text Button
0	Symbol + Text Button

13. Is there anything you did not like about the symbol + text buttons? Please check all that apply.

0	Size of buttons too small
0	Color of symbol
0	Location of symbol
0	Other: ____________
0	None

14. Please check a box to describe your vision.

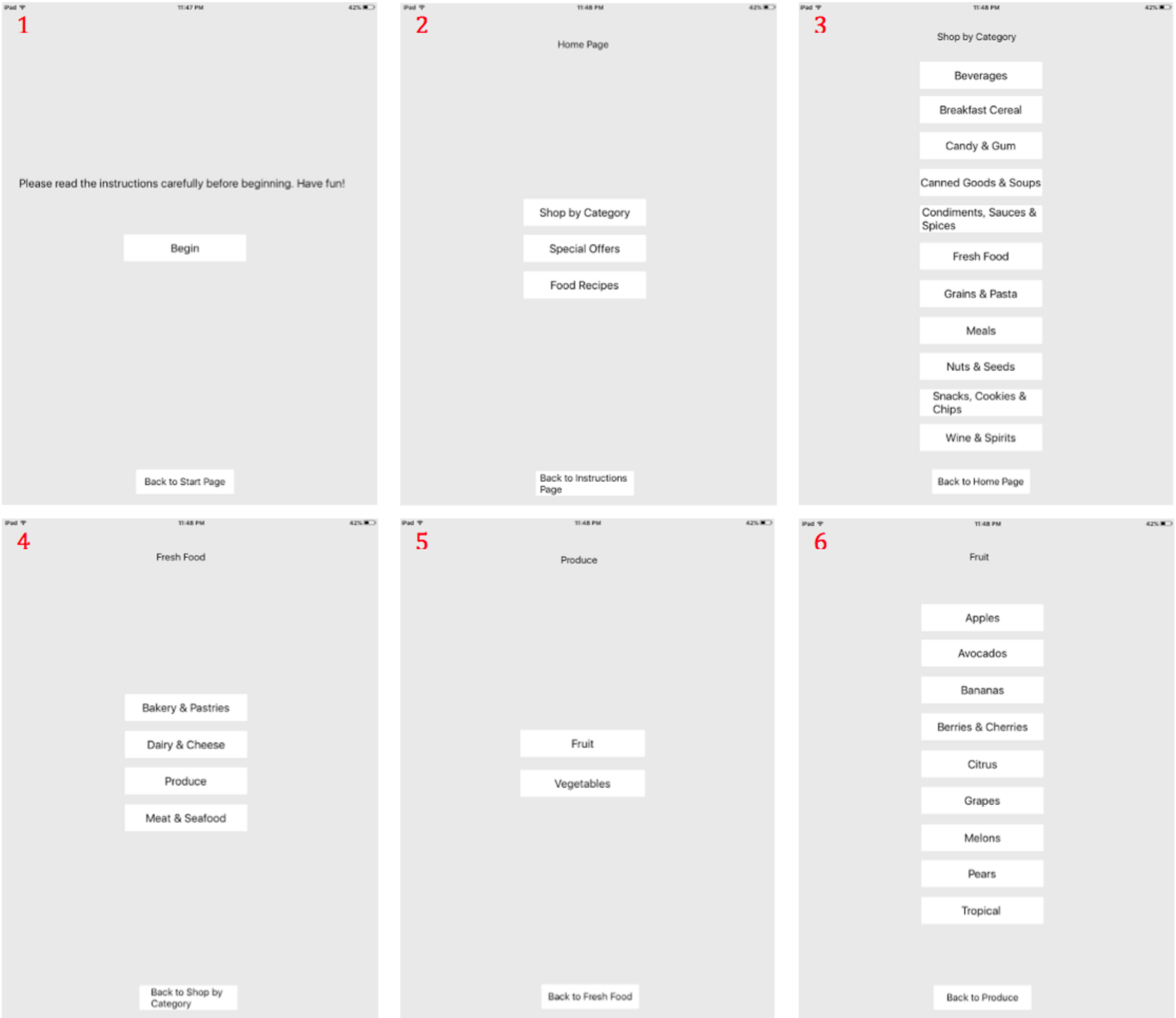
0	Normal (no contacts or glasses required
0	Corrected to normal (you wear contacts or glasses

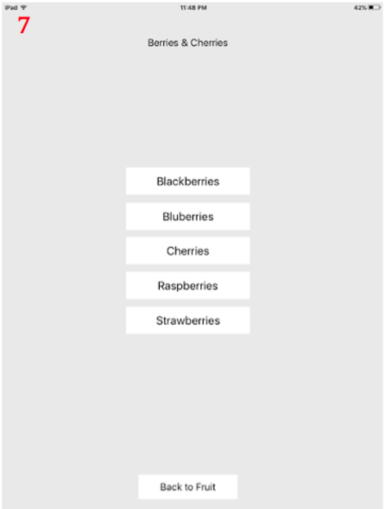
15. Please check a box to describe current health challenges that may affect your interaction with a touch screen device.

	Health Challenge	Mild	Moderate	Severe
0	Arthritis	0	0	0
0	Alzheimers	0	0	0
0	Tremors or Tourettes	0	0	0
0	Visual decline	0	0	0
0	Other: ___________	0	0	0
0	None of the above			
0	Decline to state			

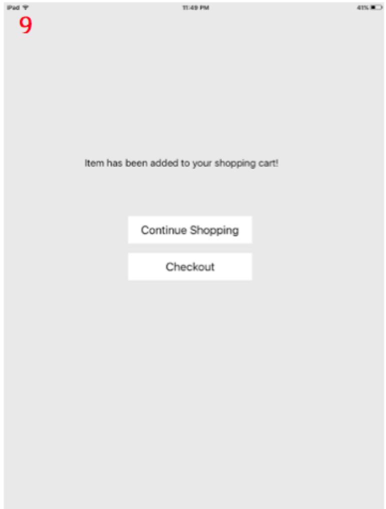
Appendix E: Step by Step Navigation for Each Task & Button Design

1. Online Grocery Shopping - Text Button Interface

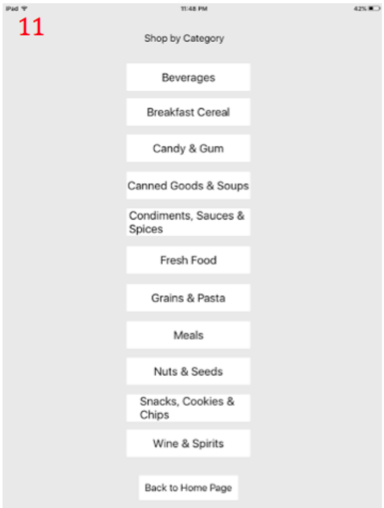



7
Berries & Cherries
Blackberries
Bluberries
Cherries
Raspberries
Strawberries
Back to Fruit


8
Fruit
Add to Cart?
Yes
No
Back to Fruit


9
Item has been added to your shopping cart!
Continue Shopping
Checkout

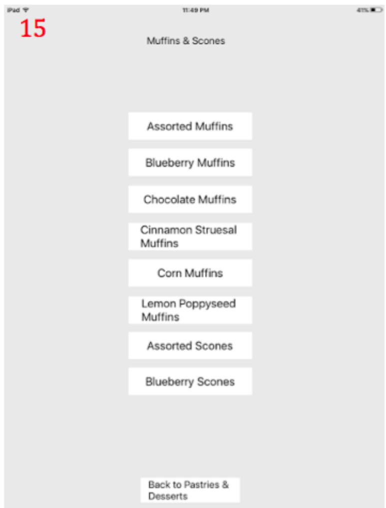

10
Continue Shopping
Back to Shop by Category
Back to Home Page


11
Shop by Category
Beverages
Breakfast Cereal
Candy & Gum
Canned Goods & Soups
Condiments, Sauces & Spices
Fresh Food
Grains & Pasta
Meals
Nuts & Seeds
Snacks, Cookies & Chips
Wine & Spirits
Back to Home Page

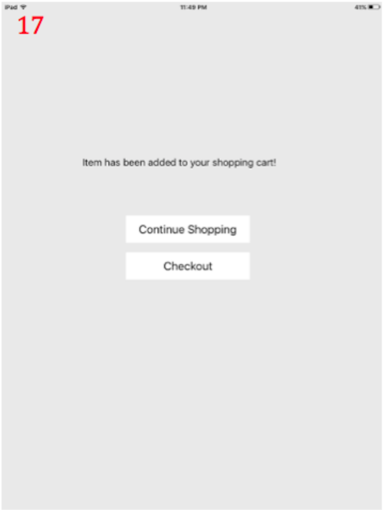

12
Fresh Food
Bakery & Pastries
Dairy & Cheese
Produce
Meat & Seafood
Back to Shop by Category


13
Bakery & Pastries
Bread
Pastries & Desserts
Back to Fresh Food

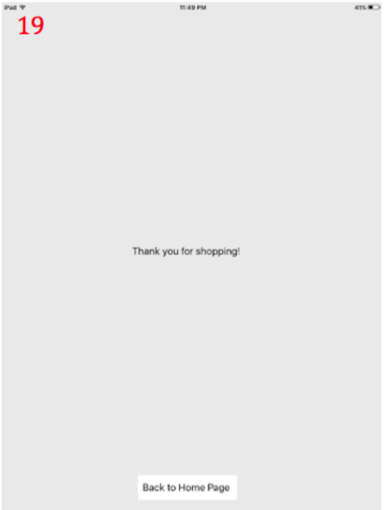

14
Pastries & Desserts
Cakes & Cupcakes
Muffins & Scones
Pies & Tarts
Back to Bakery & Pastries


15
Muffins & Scones
Assorted Muffins
Blueberry Muffins
Chocolate Muffins
Cinnamon Struesal Muffins
Corn Muffins
Lemon Poppyseed Muffins
Assorted Scones
Blueberry Scones
Back to Pastries & Desserts


16
Muffins & Scones
Add to Cart?
Yes
No
Back to Muffins & Scones

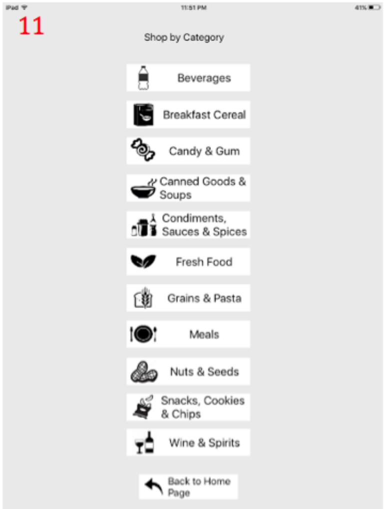

17
Item has been added to your shopping cart!
Continue Shopping
Checkout

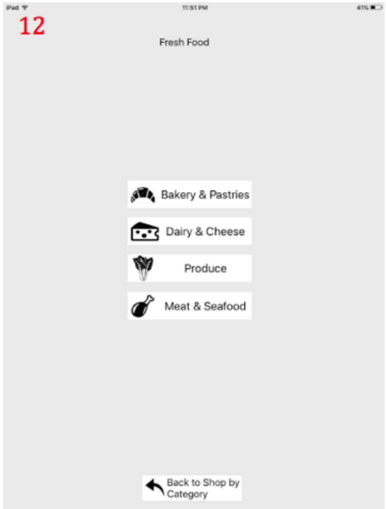

18
Are you sure you want to checkout?
Yes
No

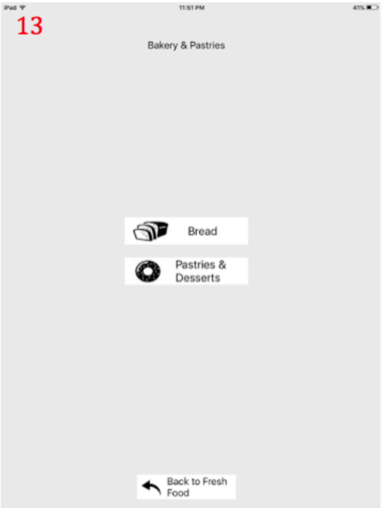

19
Thank you for shopping!
Back to Home Page

2. Online Grocery Shopping - Symbol + Text Button Interface

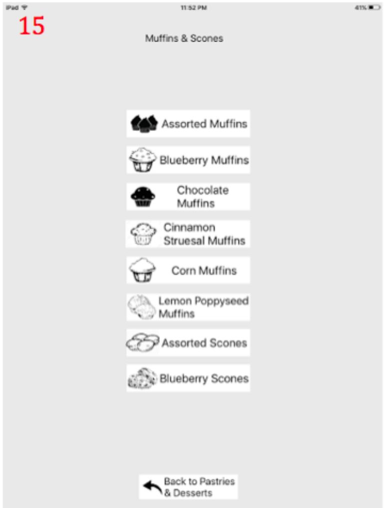

10
Continue Shopping
Back to Shop by Category
Back to Home Page


11
Shop by Category
Beverages
Breakfast Cereal
Candy & Gum
Canned Goods & Soups
Condiments, Sauces & Spices
Fresh Food
Grains & Pasta
Meals
Nuts & Seeds
Snacks, Cookies & Chips
Wine & Spirits
Back to Home Page

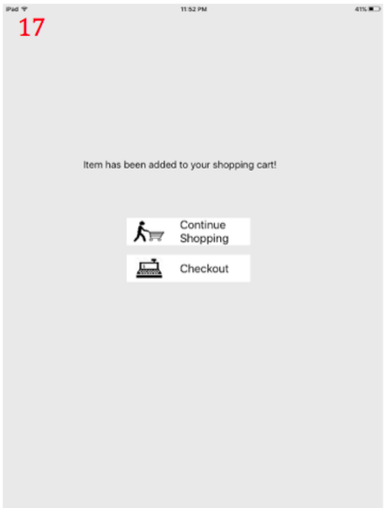

12
Fresh Food
Bakery & Pastries
Dairy & Cheese
Produce
Meat & Seafood
Back to Shop by Category

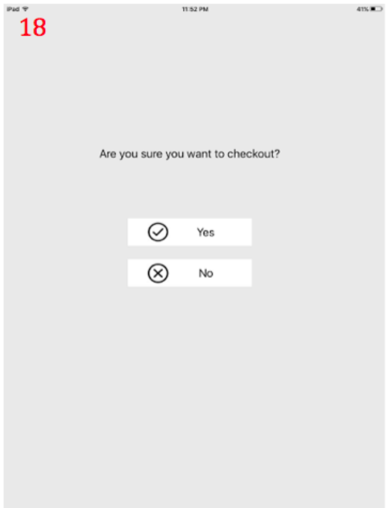

13
Bakery & Pastries
Bread
Pastries & Desserts
Back to Fresh Food

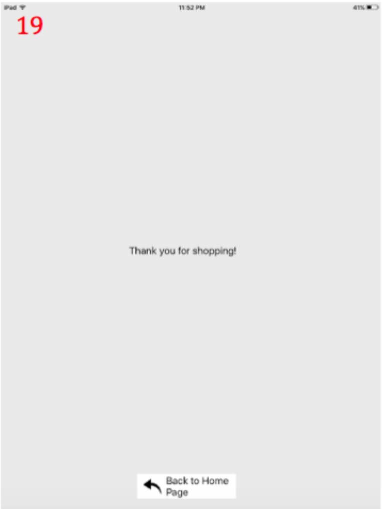

14
Pastries & Desserts
Cakes & Cupcakes
Muffins & Scones
Pies & Tarts
Back to Bakery & Pastries


15
Muffins & Scones
Assorted Muffins
Blueberry Muffins
Chocolate Muffins
Cinnamon Struesal Muffins
Corn Muffins
Lemon Poppyseed Muffins
Assorted Scones
Blueberry Scones
Back to Pastries & Desserts

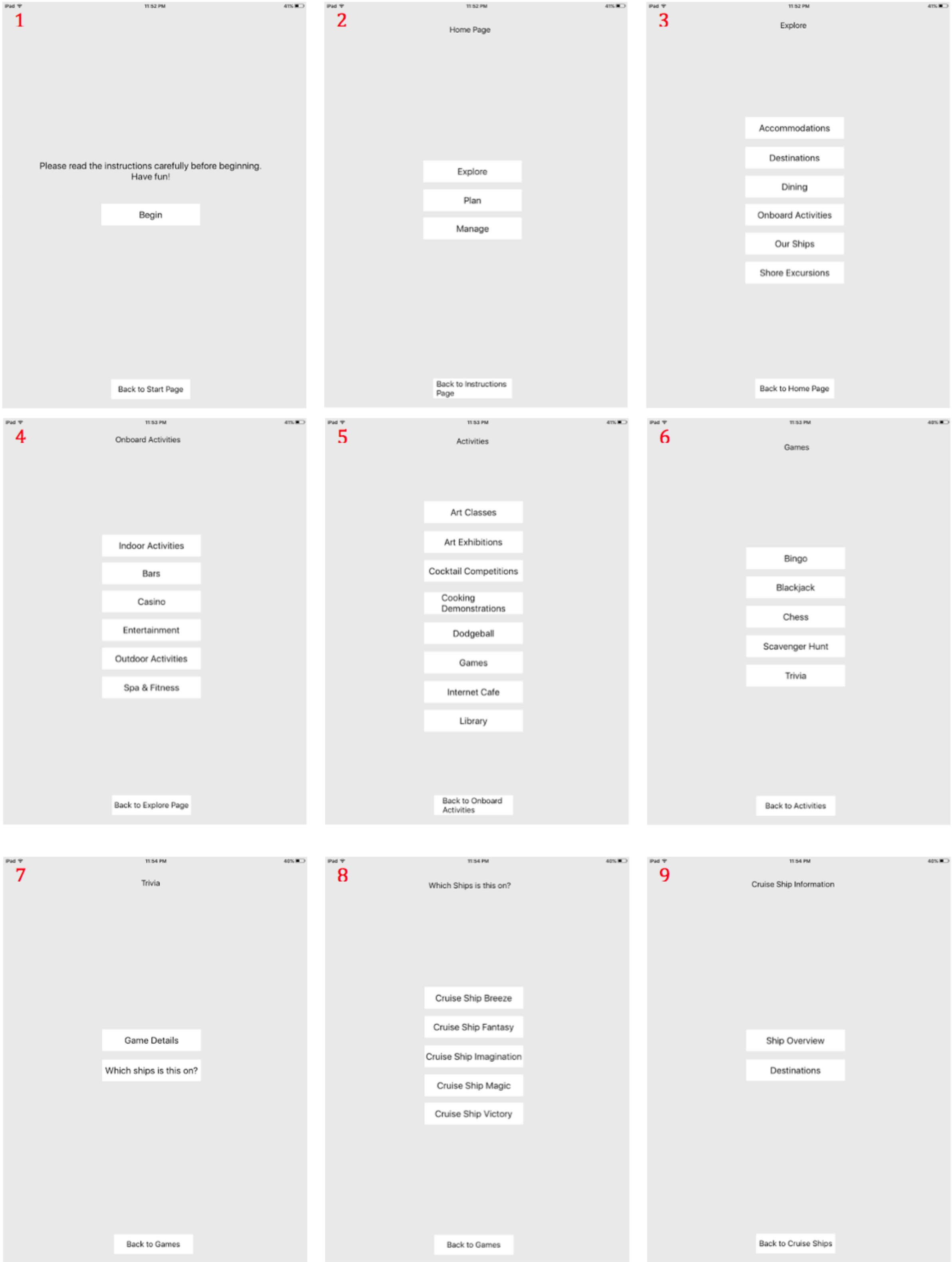

16
Muffins & Scones
Add to Cart?
Yes
No
Back to Muffins & Scones

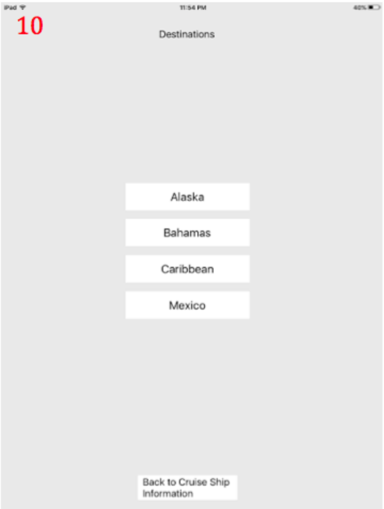

17
Item has been added to your shopping cart!
Continue Shopping
Checkout

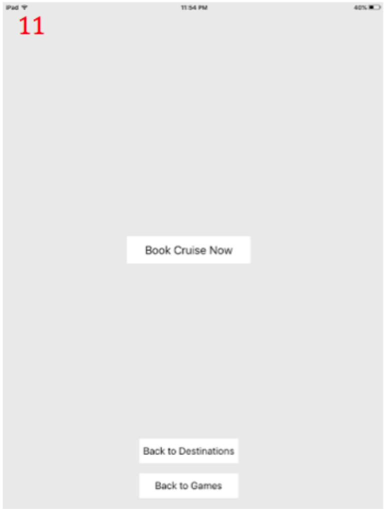

18
Are you sure you want to checkout?
Yes
No

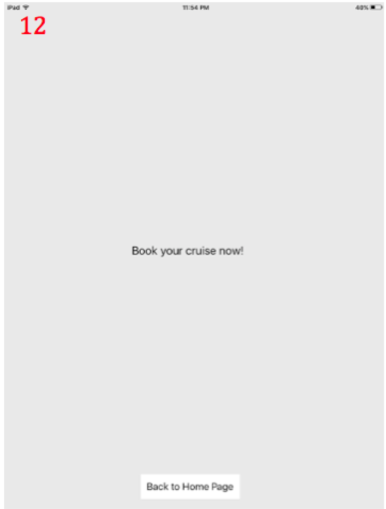

19
Thank you for shopping!
Back to Home Page

3. Booking a Cruise - Text Button Interface




10
Destinations
Alaska
Bahamas
Caribbean
Mexico
Back to Cruise Ship Information


11
Book Cruise Now
Back to Destinations
Back to Games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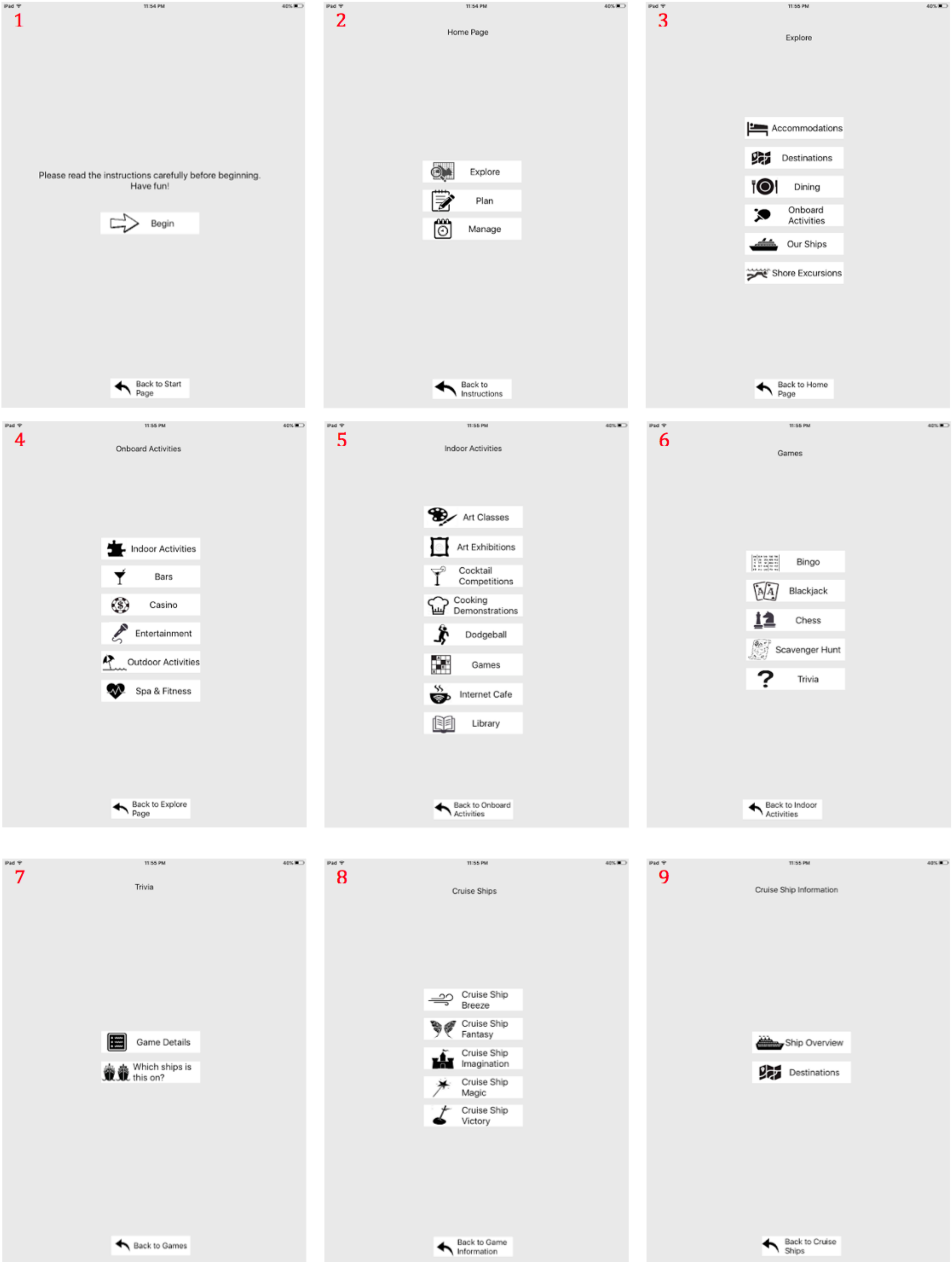
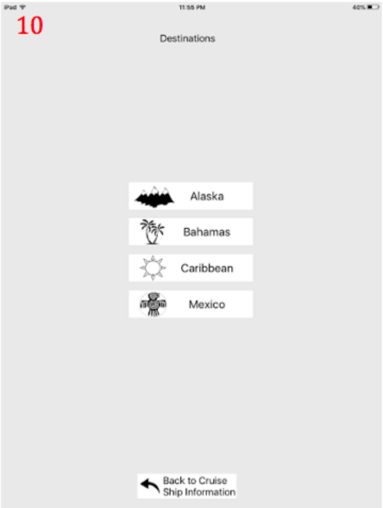
4. Booking a Cruise - Symbol + Text Button Interface

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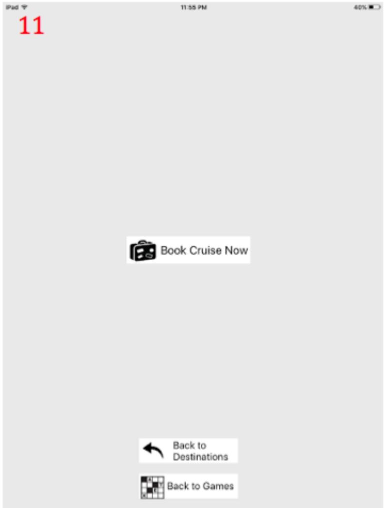
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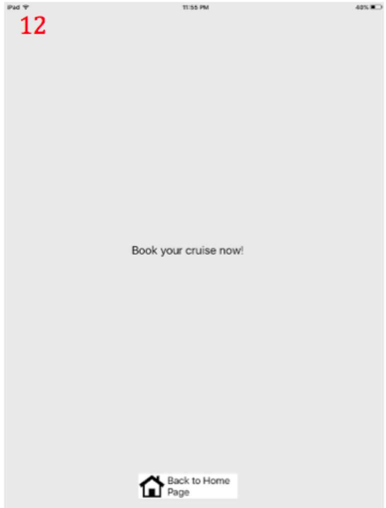
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