ABSTRACT

LIU, HONGYANG. Interaction Design of New Technology for Older Adults from the Ease of Learning Perspective (Under the direction of Dr. Sharon Joines).

In this dissertation research, three studies were conducted to understand older adults’ technology learning processes and evaluate learnability focused features (LFFs) tailored to older adults with different levels of technology experience.

In Study 1, eight focus groups were conducted among 40 older adults (aged 65 and over) with varied levels of technology experience. The focus group data provided insights into older adults’ learning experiences by identifying their learning barriers, learning method preferences, as well as the key aspects that effect older adults’ attitudes toward learning new technology.

In Study 2, six LFFs were evaluated by 17 older adults. During the evaluation, participants were asked to interact with LFFs on two mobile app prototypes. Data collection methods included task performance observations, questionnaires, and structured interviews. Results from the ratings of prototype learnability and older adults’ preferences in the six LFFs were discussed.

In Study 3, a total of 15 user interface and user experience (UI/UX) designers were recruited to evaluate six LFFs by using the cognitive walkthrough (CW) as an evaluation method. Four older adult personas were used as target users for the CW, including a first-time novice user, a first-time proficient user, a returning novice user, and a returning proficient user. LFFs were evaluated from the aspects of accessibility, ease-of-use, and usefulness.

The findings and insights combined from all three studies contribute to the knowledge regarding the effects of technology experience on older adults’ technology learning processes. Furthermore, findings from this dissertation will help inform UI/UX designers on what types of learnability focused features can enhance older adults’ learning experiences.
Interaction Design of New Technology for Older Adults from the Ease of Learning Perspective

by
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DEDICATION

Hi, Mom & Dad
/wave and smile ☺/

Hi, Bohan
/♥ #mary&shan/

Hi, Sharon
/sending → Good Vibes ☀/
BIOGRAPHY

Hongyang Liu is a doctoral candidate in the College of Design at North Carolina State University (NCSU) and works as a research assistant at Research in Ergonomics and Design (RED) Lab. She has experience in user experience research, human factors and ergonomics performance assessment, and interaction design. Before joining NCSU, Hongyang received her Bachelor of Engineering in Industrial Design from Beijing University of Technology in China and her Master of Science in Design from Arizona State University.

Hongyang is a researcher and designer. She has backgrounds in industrial design and cognitive science. Her current research focuses on investigating the relationship between interface design and the learning processes of new technology among older adults. She combines cognitive psychology and user experience research techniques to develop design recommendations for UI/UX designers and design evaluation guidelines for design researchers.
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CHAPTER 1
INTRODUCTION

“First we thought the PC was a calculator. Then we found out how to turn numbers into letters with ASCII — and we thought it was a typewriter. Then we discovered graphics, and we thought it was a television. With the World Wide Web, we've realized it's a brochure.”

— Douglas Adams

Background

In current product design and user interface and user experience (UI/UX) fields, the concept of technology can be generally defined as any electronic device, digital service or digital system that has been designed and developed to serve particular functions. Today, with the development of new technologies, these technologies are prevalent in people’s everyday lives and mediate people’s behaviors, memories, social interactions, and more. The changes in technology, coupled with the changing capabilities of the people using technology, can lead to various interactions and outcomes (Richardson, Zorn, & Weaver, 2002). Those changes have a greater impact on the aging population than others, given the fact that most people in this population have not had the opportunity to learn about and use technologies during their younger years.

Stereotypes often suggest that older adults (i.e., aged 65 and over) have no interest in using or learning to use technology. Indeed, consistent with these stereotypes, older adults do not use certain technologies to the extent that younger adults do (Mitzner et al., 2010). The extent of frustration encountered when dealing with technology is also quite evident. Numerous studies suggested that the decline of physical and cognitive abilities, lack of perceived usefulness and
potential benefit, lack of previous knowledge and experience, anxiety and negative attitudes toward technology, and low self-efficacy can all contribute to the barriers and difficulties of interacting with technology (Cotten, Yost, Berkowsky, Winstead, & Anderson, 2016; Kaye, Yeager, & Reed, 2008; Lee & Coughlin, 2015; Wang, Chen, & Chen, 2017).

However, proper attention to design could eliminate much of this frustration. Older adults could become interested in using and have a desire to learn to use technology if they see the relevance of it to their lives and appropriate learning methods are provided. The world population is aging rapidly. In 2015, the proportion of the aging population reached 8.5% of the total population. This percentage is projected to jump to 17% (1.6 billion individuals) by 2050 (He, Goodkind, & Kowal, 2016, p3). The rapid increase in the number of older adults will be accompanied by a rapid pace of technology change. Therefore, when designing technologies for older adults (or when older adults are included as one of the user groups), it is important to consider the issues and difficulties that older adults could encounter, the methods they can use to overcome the barriers, and the ways to help older adults to keep up with the changing technologies.

**Research Focus and Scope**

Prior to the dissertation research, a pilot study was conducted for the exploration of the research focus. The pilot study took a grounded theory approach to broadly understand older adults’ experiences with technologies and their opinions regarding various technology learning methods. Ten older adults (age range: 65-82), six older adults’ family members (i.e., the younger generation who have experience in teaching the older adult participants with new technologies), and two tech-class tutors were interviewed at a local senior center. Also, two tech-classes were selected for on-site observation. Interviews with older adults explored the problems they had
encountered when they were interacting with technologies and their experiences when they sought help in solving the problems. Interviews with family members and tech-class tutors explored the differences between teaching older adults in a casual environment (i.e., home) and a structured environment (i.e., tech-class). The observations focused on how older adults learned technology-related topics in tech-classes (e.g., how they took notes, what questions they asked).

Findings highlighted that many technologies use barriers actually occurred during *learning*. For example, older adults commented that just when they finally can find everything they needed in the system effortlessly, then all of a sudden, the system updated; and they had to accept the situation and start a new round of learning. Some older adults mentioned that when they interacted with a technology for the first time, they were afraid of breaking the device or messing up the default set-up. Furthermore, older adults reported increased frustration when they asked their family members (usually the younger generation) for help because the family members would become impatient after their repetitive questions and finally give up saying “just Google it!” One of the tech-class tutors, a 74-year old former computer sales representative, mentioned that he spent most of the time explaining each feature of the product before the class members even start to use the product. He commented that to build a good learning experience, he needed to clear up concerns or confusion about what would be expected if the setting of the feature was changed.

Continuously updated apps led to repetitive learning processes; the fear of messing up the settings created a big constraint for older adults limiting their learning opportunity. Adapting to a newer version or changing the setting were barriers due to the effort and mental workload involved. Therefore, many older adult users are unable to take advantage of new features or stick with default settings. Nielsen (1994) discussed that good interface design needs to give users
control and freedom. Technology with higher learnability can do so by minimizing the repetitive learning work or at least making the process easier.

When people are thinking about older adults, the common notion is that they are all alike, and most views are negative: older adults are slow; they are uninterested in new things; and they are technophobic. During the pilot study interview, the 74-year old tech-class tutor’s attitudes and views toward technology were all positive; he enjoyed learning new features, got excited about new products, and was very confident about his technology skills. So clearly, the common notion may be misleading. Older adults can be extremely diverse in many dimensions. In this case, the tutor’s previous technology experiences (i.e., a former computer sales representative) may have played an important role. When considering design for older adults, it is essential to focus on the similarities that allow the optimization of the design. However, individual differences also need to be addressed in order to determine whom the design can and cannot accommodate.

Findings from the pilot study led to two focus areas within this dissertation research: 1) learnability of new technology; and 2) individual differences of older adults’ previous technology experience and level of expertise.

The scope of this dissertation research was limited to 1) today’s older adults with varied levels of technology experience; 2) older adults of ages 65 and over in the United States; 3) older adults with intact intellectual function who live independently; 4) technologies that have simple functions and have interactive interfaces; 5) technologies that are intended to be used for daily living activities; and 6) investigation on learnability focused features (as defined in the ‘Definitions of Key Terms’ section).
The following aspects are beyond the scope of this dissertation research: 1) older adults in other cultures and regions; 2) older adults who are experts with no barriers and difficulties in learning technology; 3) older adults who live in assisted living (e.g., memory care) communities; 4) complex technologies that have many functions and do not have interactive interfaces (e.g., smart speakers with a virtual assistant); 5) technologies heavily reliant on mechanical levers or electronic switches (e.g., a vehicle’s center fascia or dashboard); 6) technologies intended to be used with instructions and not for older adults’ daily activities (e.g., 3D printing); and 7) non-learnability focused features that could influence the learning experience (e.g., font size).

Research Objectives and Research Questions

When studying methods of improving the learnability of new technology, learning experience is an important factor. Every time people adopt or adapt to a new technology either as new users or as returning users, the way they view themselves and the technology shifts a bit. Therefore, the experience also changes. To better understand the learning experience with new technologies among older adults, it is necessary to both learn about how learning processes build during the interaction between users and technologies as well as which learnability focused features will enhance older adults’ learning experiences.

The goal of this dissertation research was to connect cognitive psychology, user experience research techniques, and user-centered design to facilitate UI/UX designers’ understanding of older adults’ user characteristics. Therefore, the target audience of this dissertation research was UI/UX designers. The beneficiary audience was older adults with different technology experiences.

The first objective of this research was to provide insights and to support understanding about older adults’ learning experiences and barriers. The second objective of this research was
to compare the differences in the learning processes of new technologies among older adults with different technology experiences. The third objective of this research was to understand what types of learnability focused features can enhance the learning experience as well as the system’s learnability. The fourth objective of this research was to provide design recommendations for UI/UX designers by highlighting older adults’ learning experiences as well as considering individual differences among older adult users.

Research questions were developed in order to address the research objectives. The primary research questions of this research were as follows:

Research Question 1 [RQ1]: What are the differences in learning new technologies for older adults with different technology experiences?

Research Question 2 [RQ2]: What type(s) of learnability focused features can enhance the learning experience among older adults?

Research Question 3 [RQ3]: What design recommendations should be provided to UI/UX designers for the interaction design of new technologies for older adults?

Definitions of Key Terms

Interaction design: design of interactive products (or systems) in which designers focus on the dynamics between users and products for information input (from user to product) and output (from product to user).

User interface: elements of a product (or system) used to present information about the product’s status and allow users to control the product (or system) by activating the element, which enable users to interact with the product for its intended purpose (International Organization for Standardization [ISO], 2006).
Technology experience: users’ knowledge or skill in using technology that they have gained from direct observation of technology use, or through participation in events or in an activity with the technology.

Learnability: the extent to which a product (or system) can be used in a specified context by users to achieve specified goals of learning to use the product (or system) effectively, efficiently, with freedom from risk, and with satisfaction (ISO, 2011; ISO 2017).

Learnability focused feature: visual elements in a user interface that enable users with limited technology experience to learn to use a product (or system) in a specified context.

**Research Paradigm**

A researcher’s choice of a research design is framed by the researcher’s assumptions about both the nature of reality and how one can understand it (Groat & Wang, 2013, p. 63). Denzin and Lincoln (2011) used the term *research paradigm* to describe such assumptions. Groat and Wang (2013, p. 76) proposed a “three-part continuum” of research paradigms, which includes positivism/postpositivism, intersubjective, and constructivism. This dissertation research can be classified as constructivism\(^1\) in the continuum of research paradigms due to its objectives and the relationship of the researcher to the participants. Within past decades, several other terms, such as *naturalistic, qualitative,* and *interpretive* had been previously used interchangeably to describe this approach to research (Groat & Wang, 2013, p. 78). The knowledge generated under the constructivism paradigm requires the co-created understandings of the system or situation being studied between researcher and participant. This research valued

\(^1\) For the purposes of this dissertation, constructivism is defined as a research paradigm where the researcher would create in-depth insights and interpretations of “a given setting from the perspectives of the individuals who experience that environment” (Groat & Wang, 2013, p. 79). It is not to be confused with the artistic movement Constructivism of the 1910s and 1920s or Deconstructivist theory from architecture and design discourse in the 1990s.)
the interactions between the researcher and the participants, which implies that the researcher played the role of a measurement device. In this dissertation research, the interaction design of new technology is viewed as a dynamic and multi-component system that involves users, activities, and environments. For example, an older adult uses a mobile app to order food at home. In a constructivism paradigm, in order to have a mobile app that supports a better experience, the researcher needs to understand and consider the characteristics of the user (e.g., age), the activity (ordering food online), and the environment (home) by gaining perspectives from participants directly.

**Conceptual Framework**

The interaction between older adults and new technologies is a dynamic system with multiple perspectives and components involved. The following conceptual framework (see Figure 1.1) described multiple perspectives and components during the interaction process.

![Conceptual Framework](image)

*Figure 1.1. Conceptual framework of the dissertation research.*
From the perspective of user characteristics, age-related changes (e.g., working memory, processing speed) and users’ technology experiences (e.g., novice, proficient) may affect older adults’ uptake of new technologies. In contrast, from the perspective of new technology, design elements (e.g., voice command, icons) and external instructions (e.g., training materials, user manuals) can contribute to the learnability of new technology.

As a multi-component system, the interaction between older adults and new technologies involves a learning environment, an activity, and the individual’s motivation. When components are changed, older adults’ learning experiences can change as well. For example, to consider learning to use technology for video-chatting and online-banking, an older adult may use different learning methods and encounter different barriers when learning each technology.

The learning process includes methods that older adults used as well as the barriers they encountered and overcame when they interact with technologies. Learnability can be represented by the features that products (or systems) include to support an effective, efficient, risk-free, and satisfying user experience. By understanding the learning process and evaluating learnability focused features, design recommendations can be developed to improve the interaction design of new technology for older adults. The development of design recommendations was accomplished through multiple studies over several years.

Research Design

Three studies were designed to answer the research questions [RQ1] – [RQ3]. In order to understand older adults’ learning experiences and create shared understandings with the target audience and beneficiary audience, mixed methods were used in this dissertation research.

Study 1 – Exploration. The purpose of Study 1 was to answer [RQ1] while using focus groups as the primary data collection method. Topics in focus group discussion included older
adults’ learning experiences, learning barriers and difficulties, and preferred learning methods. Older adults with different levels of technology experience were recruited in this study.

**Study 2 – Evaluation (by users).** The purpose of Study 2 was to initially address [RQ2]. Informed by the findings from Study 1, prototypes with LFFs (as defined previously) were developed. Older adults evaluated six LFFs in two mock-up mobile apps during the prototypes testing sessions. Data collection methods included task performance observation, post-task questionnaire, and structured interview.

**Study 3 – Evaluation (by subject matter experts).** The purpose of Study 3 was to finish addressing [RQ2]. UI/UX designers inspected six LFFs during cognitive walkthrough sessions. The characteristics of LFFs was presented in the written format in the worksheet. LFFs were evaluated from the aspects of accessibility, ease-of-use, and usefulness.

The findings and insights combined from all three studies were used to answer [RQ3].

**Overview of the Dissertation**

Chapter 2 presents the literature review of related works for this dissertation research, which covers literature on older adults and new technology usage, the complexity of the learning among older adults, and interaction design for older adults. Chapters 3-5 are a compilation of three research articles, and each chapter documents one study as detailed in the previous section. Chapter 3 presents an investigation of the technology learning processes among older adults with four levels of technology experience. The investigation explored older adults’ attitudes toward learning new technology, learning barriers and difficulties, and learning methods. Chapter 4 presents an assessment of a set of interface features. In the assessment, a set of LFFs in different feature categories (i.e., onboarding display, action guidance, customize settings) were applied to the click-through prototypes to test what types of features would impact the learnability of the
technology. Chapter 5 presents an evaluation of the system’s learnability for older adult users using the cognitive walkthrough as the learnability evaluation method. A list of LFFs were reviewed by subject matter experts (UI/UX designers) during the evaluation. The last chapter, Chapter 6, summarizes major findings of the three studies presented in Chapters 3-5 with an emphasis on their connections as well as recommendations for UI/UX design for older adults. Discussions of the theoretical and practical contributions of the research, the limitations of the research, and the suggestions for future studies are also included in Chapter 6.
CHAPTER 2

LITERATURE REVIEW

Older Adults and New Technology

Use of technology among older adults. Use of today’s technologies borders on a need for older adults. Technology usage among older adults is growing faster than any other age group (Cotten et al., 2016). For example, the use of Facebook has grown fastest among older generations (Vogels, 2019). As for smartphone ownership, 68% of Baby Boomers (adults aged 55-73 in 2019) and 40% of members of the Silent Generation (adults aged 74-91 in 2019) owned a smartphone (Vogels, 2019). For tablet ownership, 52% of Baby Boomers and 33% of the Silent Generation reported that they owned tablets (Vogels, 2019). Another study found that 54% of older adults were users of CD players (Selwyn, Gorard, Furlong, & Madden, 2003). Data from a poll found that 22% of older adults owned digital cameras (Gallup, 2007). It also found that 48% of older adults owned DVD players (Gallup, 2007).

Although the use of social media and digital devices among older adults is increasing, the use of technology by older adults is still lower than that of younger age groups to some extent. Older adults were much less likely than young adults to have high-speed Internet connections (Charness, Fox, & Mitchum, 2011). A study indicated that older adults’ technology usage was limited to communication or searching for information about community, health, news, and travel (Olson, O’Brien, Rogers, & Charness, 2011). Interestingly, it also found that the frequency of searching for health information did not differ across age groups (Olson et al., 2011).

Benefits of technology for older adults. The benefits of technology for older adults were being examined as early as 1973, where technology for residents in assisted living communities was tried as a means of “staying connected to the world” (Cotten et al., 2016, p27).
Studies indicated that older adults who had adopted new technologies described their feelings as “keeping pace with the modern world,” and “not being left behind” (Hill, Betts, & Gardner, 2015; Richardson et al., 2002). The range of technologies encountered in the daily lives of older adults is extensive (Czaja, Boot, Charness, & Rogers, 2019). For older adults who live independently, technology can support the majority of their activities, including many home-based tasks, such as cooking, cleaning, and house maintenance (Baltes, Maas, Wilms, Borchelt, & Little, 1999). Survey data suggested that older adults are aware that health technologies can support their living independently in their own homes (Barrett, 2008). They commented that mobile devices and medical alert systems could be lifesaving when in need of immediate help (Barrett, 2008). Technology can also aid older adults in the work domain, especially now that their participation in the workforce is increasing dramatically (Dohm & Shniper, 2007).

**Barriers and difficulties in learning new technology.** Although new technologies are of benefit to older adults with their daily lives, many studies suggested that older adults experience greater difficulty than young adults when learning to use new technologies (Barnard, Bradley, Hodgson, & Lloyd, 2013; Dickinson, Arnott & Prior, 2007; Kelley & Charness, 1995). For example, older adults find learning about computers more difficult than younger people do, as they are more likely to forget and take longer to reach a level of proficiency (Dickinson et al., 2007). Also, a study found that there were significant age differences in computer task performance, as measured by older adults making fewer correct decisions and taking longer to make their decisions than younger adults (Laguna & Babcock, 1997).

The natural decline in older adults’ physical abilities (e.g., vision, hearing ability, motor skills) and cognitive abilities (e.g., reaction time, processing speed, working memory) increase the barriers for older adults’ potential interaction with the electronic devices and interfaces of
digital systems (Czaja, Sharit, Ownby, Roth, & Nair, 2001; Fisk, Rogers, Charness, Czaja, & Sharit, 2009; Gregor & Dickinson, 2007). For example, significant age differences were found in the performance of a complex information search and retrieval task, which indicated the correlation between cognitive abilities and task performance (Czaja et al., 2001).

The difficulties faced by older adults in learning to use new technologies are not confined to physical and cognitive factors (Lee & Coughlin, 2015; Selwyn, 2004). Other factors have also been recognized in many studies, including 1) familiarity with new technology (Lawhon, Ennis, & Lawhon, 1996; Turner, Turner, & Van de Walle, 2007; Wilkinson, Langdon, & Clarkson, 2010); 2) attitude toward technology (Kelley & Charness, 1995; Broady, Chan, & Caputi, 2010); 3) anxiety in learning new technology (Birdi, Pennington, & Zapf, 1997); 4) self-efficacy in learning new technology (Igbaria & Iivari, 1995; Middlemass, Vos, & Siriwardena, 2017; Tsai, Shillair, Cotten, Winstead, & Yost, 2015); and 5) usability of technology (Chun & Patterson, 2012; Hawthorn, 2000; Leung, McGrenere, & Graf, 2011; Page, 2014; Wilkinson, Langdon, & Clarkson, 2011). For example, distinct differences between older adults and young adults were observed in problem-solving and task completion, with the older adults making fewer attempts toward task completion, taking longer in overall task completion, but recording a lower rate of error in the process. Some of these differences may be attributable to older adults’ lack of familiarity with new technology (Wilkinson et al., 2010).

There are mixed findings regarding older adults’ attitudes toward new technology. Studies reported that older adults have more negative attitudes toward new technology than young adults (Ryan, Szechtmn, & Bodkin, 1992; Kelley & Charness, 1995). However, a study found that despite experiencing more difficulties in using computers, there were no age-related differences in overall attitudes towards computers (Czaja & Sharit, 1998). Similarly, Broady et
al. (2010) found that the factors influencing older adults regarding their use and attitudes towards technology are quite similar to those influencing young adults.

**Older Adults as Technology Users – User Characteristics**

**Physical abilities.** There are many changes in physical abilities that occur with aging that are relevant to the interaction between older adults and new technology. With increased age, there are declines in visual acuity, accommodation, contrast sensitivity, visual search skills, and the ability to detect targets against a background (Czaja & Sharit, 2016; Hutchison, Eastman, & Tirrito, 1997). For example, declines in accommodation take older adults longer for their eyes to adjust to shifts in viewing distances (e.g., the information presented on a TV screen vs. the information presented on a smartphone screen) (Piper, Brewer, & Cornejo, 2017). Hearing ability also declined with age (Czaja & Sharit, 2016). Digital systems that include a speech component can be problematic for older adults if the rate of speech is too rapid or is distorted (Sharit, Czaja, Nair, & Lee, 2003). Moreover, with the changes in motor skills that occurs with aging, mouse control movements such as cursor movement, double-clicking, fine positioning, and dragging were difficult for older adults (Czaja & Sharit, 2016).

**Cognitive abilities.** Many cognitive abilities are also associated with learning and using new technologies. For example, crystallized and fluid intelligences had a significant impact on the use of new technologies (Czaja et al., 2006). Crystallized intelligence is the ability to retain and apply previous knowledge gained through past experiences (Ackerman, 1996). Fluid intelligence is the ability to solve novel problems (Ackerman, 1996). Crystallized intelligence remains throughout typical subjects’ lifespan, but fluid intelligence declines with age. Reaction time, processing speed, and working memory also declined with the natural process of aging. They were found to be closely associated with users’ task performances with interfaces,
including information searching behavior and web navigation performance (Blackler, Popovic, & Mahar, 2010; Gudur, Blackler, Popovic, & Mahar, 2009; Laberge & Scialfa, 2005; Sharit, Hernández, Czaja, & Pirolli, 2008).

**Technology experience.** According to Dreyfus’s (2004) five-stage model of adult skill acquisition, learners’ level of experience can be categorized into five stages (from a low level of experience to a high level of experience): novice, advanced beginner, competent, proficient, and expert (Dreyfus, 2004). The skill model is summarized in the table below (see Table 2.1).

<table>
<thead>
<tr>
<th>Skill Level</th>
<th>Components</th>
<th>Perspective</th>
<th>Decision</th>
<th>Commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>Context-free</td>
<td>None</td>
<td>Analytic</td>
<td>Detached</td>
</tr>
<tr>
<td>Advanced beginner</td>
<td>Context-free and situational</td>
<td>None</td>
<td>Analytic</td>
<td>Detached</td>
</tr>
<tr>
<td>Competent</td>
<td>Context-free and situational</td>
<td>Chosen</td>
<td>Analytic</td>
<td>Detached understanding and deciding; involved outcome</td>
</tr>
<tr>
<td>Proficient</td>
<td>Context-free and situational</td>
<td>Experienced</td>
<td>Analytic</td>
<td>Involved understanding; detached deciding</td>
</tr>
<tr>
<td>Expert</td>
<td>Context-free and situational</td>
<td>Experienced</td>
<td>Intuitive</td>
<td>Involved</td>
</tr>
</tbody>
</table>

*Note.* Adapted from Dreyfus (2004).

In Table 2.1, **Components** refers to the elements of the situation that the learner is able to perceive (Dreyfus, 2004). As the learner’s experience is accumulating, the components that the learner can perceive may become overwhelming. To cope with this overload, the learner must choose which components to focus on. Hence, the learner gains a **Perspective**. The learner achieves a perspective when he or she achieves the skill level of Competent. **Decision** refers to a learner’s process or behavior in the situation he or she is in. Only an expert will act intuitively in
decision making. *Commitment* refers to the degree to which the learner is immersed in the learning situation regarding understanding, deciding, and action pairing (Dreyfus, 2004).

In this model, the expert represents the learner with the highest level of experience among the five stages. Experts have acquired knowledge that is organized in a way that reflects a deep understanding of their subject matter and can be retrieved fluently (National Research Council, 1999, p. 31-32). In terms of interacting with new technology, experts could be users who are very experienced in technology in general or in a specific domain. Technology experience can effect users’ task performances. A study found that experience in using digital cameras that were similar to the digital cameras used in the experiment helped participants to complete the tasks more quickly, more intuitively, and with fewer errors (Blackler et al., 2010).

Technology experience is also an important factor that effects people’s attitudes and feelings toward new technology (Holzinger, Searle, & Wernbacher, 2011; Renaud & Van Biljon, 2008; van der Wardt, Bandelow, & Hogervorst, 2010; Venkatesh, Morris, Davis, & Davis, 2003). Additionally, these studies indicated that attitudes (e.g., technology acceptance), anxiety, and self-efficacy (e.g., level of confidence) are to some extent all interconnected with each other.

**Attitudes.** Older adults with more knowledge of and expertise with the relevant technologies are more likely to accept a new technology and have more positive attitudes toward technology (Jay & Willis, 1992; Holzinger et al., 2011; Ziefle, 2002). Technology experience has a significant impact on users’ attitudes toward Internet-based activities (Eastman & Iyer, 2004). Novices are less likely than experienced computer users to use opt-in electronic signatures and are more concerned that they would have less protection with electronic contracts (Eastman & Iyer, 2004).
The Technology Acceptance Model (TAM) proposed several factors that are essential in determining user attitude towards accepting a new technology (Davis, 1989). Studies suggested that users’ technology experience effects two factors of technology acceptance: 1) the perceived ease of use (Ziefle, 2002), and 2) the perceived usefulness (Taylor & Tedd, 1995).

**Anxiety.** Studies found that technology experience is negatively associated with anxiety where higher computer experience is related to lower computer anxiety (Igbaria & Chakrabarti, 1990; Necessary & Parish; 1996). Moreover, many studies suggested that people with increased anxiety towards computers are more likely to have negative attitudes (e.g., lack of perceived ease of use) towards using computers (Hackbarth, Grover, & Yi, 2003; Igbaria & Chakrabarti, 1990; Necessary & Parish; 1996). This finding indicated that anxiety and attitude are negatively associated with each other.

Studies suggested that, under certain conditions, technology-related anxieties increase with age (Laguna & Babcock, 1997) and decrease with technology experience (Charness, Kelley, Bosman, & Mottram, 2001). For example, older novices were observed taking longer to learn the task and making more errors than young novices during the test, which also brought out more anxieties among older novices (Charness et al., 2001). However, no age effect was observed among experienced users (Charness et al., 2001).

**Self-efficacy.** Technological self-efficacy is the belief in one’s own ability to use or learn to use new technologies (Kinzie, Delcourt, & Powers, 1994). Self-efficacy was reported to be an important barrier for older adults’ technology adoption (Charness & Boot, 2009; Lam & Lee, 2006; Vroman, Arthanat, & Lysack, 2015). Technology experience is positively associated with self-efficacy (Igbaria & Iivari, 1995; Middlemass et al., 2017; Tsai et al., 2015). Many studies
reported a positive relationship between computer training and computer self-efficacy (Igbaria & Iivari, 1995; Potosky, 2002; Wagner, Hassanein, & Head, 2010).

In addition, a study suggested that self-efficacy in the use of telemonitoring equipment in the healthcare environment is linked to users’ positive attitudes toward digital devices (Middlemass, 2017). Self-efficacy was also found to be positively associated with perceived ease of use, which indicated that higher self-efficacy was related to higher technology acceptance (Chung, Park, Wang, Fulk, & McLaughlin, 2010; Hong, Thong, Wong, & Tam, 2001).

The Complexity of Learning: From Learning Theories to Learning Methods

Stages of learning. Learning is not expected to be instantaneous. When people attempt to gain knowledge or acquire a skill, the learning process is relatively complex or time-consuming and it has often been characterized as progressing through several stages (Czaja & Sharit, 2016). During the initial stage, learners are processing new information and are being challenged by the need to differentiate among various facts, rules, and concepts. Older novices may need more training and instructions than young adults and experienced older adults when learning a new technology. To compensate for the lack of technology experience, instructors for the tech-class should consider providing overviews and context for the more specific task-related information at the beginning of the training (Cotten et al., 2016). However, Czaja and Sharit (2016) mentioned that with older learners, too much preliminary information could backfire as it may not be retained by older adults as easily. Also, it could lead to confusion and cause anxiety. Thus, it is probably best to keep such overviews brief and straightforward (Czaja & Sharit, 2016).

Additional insights into learning stages came from studies on the difference between novice and expert (Lazonder, Biemans, & Wopereis, 2000; National Research Council, 1999; Ziefle & Bay, 2004). For example, an expert will observe features and identify meaningful
patterns that the novice will not (National Research Council, 1999). However, being an expert does not necessarily mean that he or she is always an out-performer. A study found that experts scored higher than novices on the tasks of locating websites but not on the tasks of locating information (Lazonder et al., 2000). The study also showed that participants (i.e., novice users) who received brief on-site training before the test performed better than participants in the control group (i.e., non-users) who had no hands-on experience regarding the subject matter (Lazonder et al., 2000). This finding indicated that even a minimum hands-on experience could benefit people when developing skills.

**Learning theories: behaviorism vs. constructivism.** Two learning theories can be applied to the context of the learning: behaviorism learning theory and constructivism learning theory. Behaviorism learning theory is based on Skinner’s Stimulus-Response (S-R) theory, which states that “learning is a change in a behavioral disposition that can be shaped by selective reinforcement” (Jonassen, 1993). The premise of behaviorism is that an effective way for a student to learn is to transmit knowledge from the expert to the learner (Leidner & Jarvenpaa, 1995).

In contrast, constructivism learning theory is a view of learning based on the belief that knowledge isn’t a thing that can be simply given by the instructor. Constructivism draws on the developmental work of Piaget (1977). Under this view, learning is a dynamic, constructive process. The learner is an information constructor. Learners actively construct or create their subjective representations of objective reality.

Nevertheless, studies found that when learners are in a constructivist classroom, learning can be very effective among learners of all ages (Brooks, 1990; Chu & Tsai, 2009; Spigner-Littles & Anderson, 1999; Yager, 1991; Yager, 2000). In a constructivist classroom
environment, learners are encouraged to be actively involved in their process of learning (Leidner & Jarvenpaa, 1995). Piaget (1977) asserted that learning occurs by active construction of meaning (i.e., learning-based approach), rather than by passive acceptance (i.e., teaching-based approach). Constructivism alters the roles between instructors and learners in the learning process. It allows learners have more control over the learning process (Yager, 1991).

Concurring with the premise of constructivism, findings from studies showed that learning is most effectively accomplished when new information is connected to and built upon a student's prior knowledge and real-life experiences (Chu & Tsai, 2009; Spigner-Littles & Anderson, 1999). The findings indicated that learners would have good experiences (e.g., learning effectively) when information is relevant to them and when they understand why and how to use the new information.

However, there is a limitation in constructivism2. A study indicated that the learning-based approach would be more practical when it is applied to an environment where learners have a higher level of educational background or with a higher level of expertise regarding the subject matter (O’Loughlin, 1992). The point is that learners need to embrace what they don’t know and to come up with questions about the subject matter in order to engage with the learning process (Thomas & Brown, 2011). Hence, the learning-based approach may not be suitable for novices, considering the Components (as detailed in a previous section) have yet to be perceived by novice learners to some extent (Dreyfus, 2004).

**Learning methods.** There are a wide variety of methods for older adults to learn to use new technologies: 1) learning alone; 2) learning from domain experts; 3) learning from family/friends; and 4) learning from unspecified others (Mitzner et al., 2008; Kurniawan, 2006;

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2 This constructivism is not to be confused with the constructivism – one of the “three-part continuum” of research paradigms – which was mentioned in the ‘Research Paradigm’ section in Chapter 1.
Martínez-Alcalá et al., 2019). The learning alone methods include trial and error, Internet searching, using Help features, and reading instruction manuals (e.g., printed user manuals). The learning from domain experts methods include asking for IT support (e.g., computer support specialists) and taking training classes. Learning from family/friends methods include learning from family/friends from the same generation (e.g., sister, spouse) and family/friends from younger generation (e.g., child, grandchild). Learning from unspecified others methods include, but are not limited to, asking neighbors, co-workers, and digital device salespeople (who are not counted among domain experts). A study showed that older adults have a strong preference for self-training by reading manuals and other printed instructions as well as for hands-on learning through trial and error (Mitzner et al., 2008).

Interaction Design for Older Adults

Interaction design principles. Design principles are prescriptive rules that describe which design elements are required for designing in a certain context (e.g., display design for older adults). In general, design principles are abstract, context-based, and hard to transform into concrete design elements. One of the goals of creating design principles is to facilitate heuristic evaluation (Inostroza & Rusu, 2014; Pinelle, Wong, & Stach, 2008).

Heuristic evaluation can be used during the usability inspection process to find usability problems in a specific UI/UX design area. Nielsen’s (1994) *Usability Heuristics for User Interface Design* is a well-known usability heuristic which contains 10 general principles for interaction design (see Table 2.2).
Table 2.2
Usability Heuristics for User Interface Design

<table>
<thead>
<tr>
<th>10 Usability Heuristics for User Interface Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1: Visibility of system status               #2: Match between system and the real world</td>
</tr>
<tr>
<td>#3: User control and freedom                  #4: Consistency and standards</td>
</tr>
<tr>
<td>#5: Error prevention                          #6: Recognition rather than recall</td>
</tr>
<tr>
<td>#7: Flexibility and efficiency of use         #8: Aesthetic and minimalist design</td>
</tr>
<tr>
<td>#9: Error recognition, diagnosis, and recovery #10: Help and documentation</td>
</tr>
</tbody>
</table>

Note. Adapted from Nielsen (1994).

There are few studies regarding how design principles inform the design process and benefit final design deliverables (Terblanche, 2014). For those highly abstract design principles, it is hard for designers to apply them to their design concepts development. However, studies found that the application of design principles always went along with the application of design guidelines (Farage, Miller, Ajayi, & Hutchins, 2012; Holzinger, Searle, & Nischelwitzer, 2007; Terblanche, 2014).

Interaction design guidelines. Compare with design principles, design guidelines are more specific. They can provide the perspective of “how-to” for designers. But design guidelines are also context-based (Zaphiris, Kurniawan, & Ghiawadwala, 2007). Since the mid-1980s, interaction design guidelines for software user interfaces and Human-Computer Interaction (HCI) have increased in importance. Benefits resulting from the use of interaction design guidelines include: 1) increasing designers’ (or engineers’) productivity; 2) reducing project training expenses; and 3) improving overall product quality and usability (Reed et al., 1999).

In Designing for older adults, Czaja et al. (2019) came up with a series of design guidelines to facilitate UI/UX designers in designing for older adults. The guidelines are summarized in Table 2.3.
**Table 2.3**  
*Designing for Older Adults: UI/UX Guidelines*

<table>
<thead>
<tr>
<th>Focus area</th>
<th>Design guideline and recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Navigation</strong></td>
<td>• Minimize scrolling operations, particularly horizontal scrolling on large screen devices;</td>
</tr>
<tr>
<td></td>
<td>• Organize menus and websites with reasonable hierarchy;</td>
</tr>
<tr>
<td></td>
<td>• Provide organizational tools for search.</td>
</tr>
<tr>
<td><strong>Working memory</strong></td>
<td>• Put information into the display rather than forcing users to keep it in mind;</td>
</tr>
<tr>
<td></td>
<td>• Ensure that design elements appear in consistent locations.</td>
</tr>
<tr>
<td><strong>Error</strong></td>
<td>• Minimize the number of steps in a procedure;</td>
</tr>
<tr>
<td></td>
<td>• Make damaging errors difficult to carry out by providing multiple warnings;</td>
</tr>
<tr>
<td></td>
<td>• Provide clear feedback to help the user identify omission errors;</td>
</tr>
<tr>
<td></td>
<td>• Allow users to backtrack from error states with “undo” options.</td>
</tr>
<tr>
<td><strong>UX</strong></td>
<td>• Use large fonts, high contrast displays;</td>
</tr>
<tr>
<td></td>
<td>• Provide alternatives for difficult to perform gestures;</td>
</tr>
<tr>
<td></td>
<td>• Provide instructional materials that have been tested for usability;</td>
</tr>
<tr>
<td></td>
<td>• Inform the user about confidentiality and privacy conditions in lay language.</td>
</tr>
</tbody>
</table>

*Note.* Adapted from Czaja et al. (2019, p123-124).

Although, design guidelines can be valuable and useful when they can lead to the development of actionable recommendations. Many questions were still raised regarding the application and utility of design guidelines. Survey results showed that in practice, only a minority of designers consult design guidelines (Mosier & Smith, 1986). In the survey, only 58% of the target users of the design guidelines attained success in finding the information they needed. This may be a result of the following: 1) designers have trouble accessing relevant information; 2) designers have difficulty determining what should be prioritized among conflicting guidelines; 3) guidelines are too abstract; and 4) guidelines are not necessarily up-to-date with emerging technologies (Mosier & Smith, 1986).

A study implied that design guidelines are likely to have more impact when they are being introduced in the workshops. In this way, designers can integrate guidelines with their expertise and experience (De Souza & Bevan, 1990). Also, a study showed that the design
guidelines should be arranged based on the design elements as well as user actions (Kim, 2010). Designers can easily conduct the keyword-search when the guidelines are arranged based on the design elements (e.g., navigation, link, icon). Furthermore, designers can use the guidelines to facilitate the user journey mapping if the guidelines also covered the perspective of user actions (e.g., scan, find, act) (Kim, 2010).

**Learnability of technologies.** There is a wide range of design principles associated with the learnability (defined in Chapter 1). The ones that are most applicable to UI/UX are: 1) predictability; 2) consistency; 3) familiarity; 4) generalizability; and 5) simplicity (Dix, Finlay, Abowd, & Beale, 2004; Green & Eklundh, 2003; Weiss et al., 2011). Technology with higher learnability can provide users with higher levels of self-efficacy, more positive attitudes, and reduced anxiety (Leung, McGrenere, & Graf, 2009).

Many design strategies have been applied to improve the learnability of technology, including: 1) internal visual structures (e.g., navigation aid); 2) internal instructional features (e.g., input prompt); and 3) external instructional materials (e.g., user manual) (Gerjets, Scheiter, Catrambone, 2004; Green & Eklundh, 2003; Hickman, Rogers, & Fisk, 2007; Van Merriënboer, Kirschner, & Kester, 2003; Ziefle & Bay, 2006). For example, a well-designed user manual would minimize working memory demands by providing fewer steps of instruction as well as including relevant pictures (Van Horen, Jansen, Maes, & Noordma, 2001). Also, studies reported that older adults’ learning experiences would be enhanced if appropriated supporting information or extra training materials were provided during the learning process (Loorbach, Karreman, & Steehouder, 2007; Morrell, Park, Mayhorn, & Kelley, 2000; Hickman et al., 2007; Segrist, 2004).
However, some design strategies have different effects on older adults and young adults (Wilkinson et al., 2011) while some design strategies have different effects on the different stages of learning (Leung, Findlater, McGrenere, Graf, & Yang, 2010; Green & Eklundh, 2003) as well as different skill levels (Melguizo & Van Oostendorp, 2012).

For design strategies for interface elements (i.e., internal visual structures and internal instructional features), findings from a study showed that designing for learnability is more essential for first-time users than returning users (Green & Eklundh, 2003). And design features such as relevant and immediate feedbacks are crucial for enabling successful performance (Green & Eklundh, 2003). Furthermore, a study found that reduced-functionality interfaces provided greater benefit for older adults than for young adults in terms of task completion time during initial learning, perceived complexity, and preference (Leung et al., 2010). However, interacting with the reduced-functionality interface would not improve older adults’ performance in learning the advanced task set on the full-functionality interface (Leung et al., 2010). Similarly, it was found that expandable menus are more beneficial than sequential menus among participants with low spatial skills, while participants with high skills do not seem to be affected by task difficulty or menu type (Melguizo & Van Oostendorp, 2012).

For design strategies for external instructional materials, a study suggested that technology instruction for older adults should be separated by expertise and experience (Mayhorn, Stronge, McLaughlin, & Rogers, 2004). Moreover, instruction materials for novices should be presented in a step-by-step procedural format (Mayhorn et al., 2004). Furthermore, a study implied that when step-by-step instructions were provided, participants who received guided action training performed faster (for older adults) and more accurately (for both older adults and young adults) than participants who received guided attention training (Hickman et
al., 2007). However, when instructions were no longer available, there was a benefit for those who had initially received guided attention training (Hickman et al., 2007).

In addition, a study indicated that older adults would benefit more from simple instructions than expanded instructions (Morrell et al., 2000). Similarly, a study suggested that the user manual for older adults needs to minimize the usage of jargon or technical terms (Loorbach et al., 2007). If jargon is inevitable, then the product should provide explanations in a separate glossary so that older adults can track questions and refresh their memory (Loorbach et al., 2007).

Regarding the medium of the external instructional materials, a study showed that both older adults and young adults preferred video instructions over text manuals (Gramß & Struve, 2009). Another study reported that the majority of older adult participants preferred paper-based manuals over digital materials if given the options (Tsai, Rogers, & Lee, 2012).

**Summary of Literature Review**

Most of the studies in the literature review focused on understanding the age-related differences (e.g., physical and cognitive abilities) in learning technologies. Also, given that new technologies are commonly perceived as products for younger people, many studies conducted cross-sectional experiments to see how age-related differences effect task performances.

Some studies in the literature review indicated that older adults could experience difficulties during the learning process due to the lack of technology experience. However, there is a gap in studying the differences in learning new technology among users with varied levels of technology experience. Although many studies focused on the differences between novice and expert in learning new technology, most of them only included young adults (or teenagers) as participants. Thus, the studies conducted in this dissertation focused on addressing this gap.
Moreover, many studied indicated that by providing appropriate strategies (e.g., learning materials, learning methods), some of the frustration or barriers during the learning processes could be reduced. Based on the literature review, many strategies have been used to facilitate users’ learning process of new technology. And some of them are design strategies that focus on providing the self-paced learning environment to users (e.g., simplified menu, input prompt, user manual). These design strategies can improve the learnability of new technology, guide users through the initial learning process, and minimize users’ time and effort in learning new technology. Furthermore, some of them can be designed by UI/UX designers and applied as design elements to the interaction design of new technology.

A framework regarding design strategies, UI/UX design elements, and the users’ time and effort in learning new technology was proposed by the researcher. The relationships between the three aspects, as well as a set of potential UI/UX design elements (i.e., learnability focused features), were generalized in Figure 2.1.

![Figure 2.1. Design strategies, UI/UX design elements, and the users’ learning process.](image)

In this figure, different strategies are positioned in relation to users’ learning with the decreasing time and effort from left to right. For example, users will spend more time in taking a tech-class or in searching and watching a video tutorial than go through a guided process (e.g., input prompt). However, this does not mean that the technology can only be learned by taking a
tech-class has low learnability. The reason for choosing a strategy highly depends upon the complexity of the technology, the procedure of the task, the availability of the instructional resources, and the user’s preference.

Additionally, in terms of investigating users’ learning experience, expert users seem to be appropriate and reliable participants considering they know lots of new technologies. But studies found that experiences do not guarantee that experts are able to explain their learning process and learning experience well. Hence, experts may not be suitable as participants for a qualitative research study (e.g., focus group) regarding the discussion of the learning experience.
CHAPTER 3

OLDER ADULTS’ EXPERIENCE WITH LEARNING NEW TECHNOLOGY

Chapter 3 is formatted as a manuscript for the submission in category of Student papers to the journal Gerontechnology. Appendixes mentioned in this chapter are supporting materials for the explanatory purpose of the dissertation. They may not be included in the final submission for the journal.

Title: Older Adults’ Experience with and Barriers to Learning New Technology: A Focus Group Study

Authors: Hongyang Liu and Sharon Joines (College of Design, North Carolina State University, Raleigh, NC)

Abstract: Technology as a concept can generally be defined as any electronic device, digital service or digital system. Although these technologies can benefit older adults through their everyday activities, older adults have more difficulty than younger individuals in using and learning to use new technology. Moreover, people with different levels of technology experience may have different learning experiences. Experienced users are expected to have better understandings of new technologies and more efficient ways of learning. Therefore, when designing technologies for older adults, it is important to consider the barriers that older adults could encounter, the methods they can use to overcome the barriers, as well as the different needs among older adults with varied technology experiences. In this study, eight focus groups were conducted among 40 older adults with four levels of technology experience. The focus group data provided insights into older adults’ learning experiences by identifying key aspects in technology that effect older adults’ attitudes toward learning new technology, learning barriers, learning method preferences, and their initial learning processes.
Introduction

Background. The concept of technology can be generally defined as any electronic device (e.g., smartphone), digital service (e.g., social media) or digital system (e.g., voice command). Technology is prevalent in people’s everyday life, especially among older adults (i.e., aged 65 and over). The range of technologies encountered in the daily lives of older adults is extensive (Czaja, Boot, Charness, & Rogers, 2019). Studies indicated that older adults who had adopted new technologies described their feelings as “keeping pace with the modern world,” and not “being left behind” (Hill, Betts, & Gardner, 2015; Richardson, Zorn, & Weaver, 2002). However, the extent of frustration that older adults encountered when dealing with technology is also quite evident (Barnard, Bradley, Hodgson, & Lloyd, 2013).

Related work. Many studies suggest that older adults experience greater difficulty than young adults when learning to use new technologies (Barnard et al., 2013; Dickinson, Arnott & Prior, 2007; Kelley & Charness, 1995). The decline of physical and cognitive abilities can contribute to the barriers to and difficulties in interacting with technology (Kaye, Yeager, & Reed, 2008; Lee & Coughlin, 2015; Wang, Chen, & Chen, 2017). Other factors have also been recognized including: 1) familiarity with new technology (Turner, Turner, & Van de Walle, 2007; Wilkinson, Langdon, & Clarkson, 2010); 2) attitudes toward technology (Kelley & Charness, 1995; Broady, Chan, & Caputi, 2010); 3) anxiety in learning new technology (Birdi, Pennington, & Zapf, 1997); 4) self-efficacy in learning new technology (Igbaria & Iivari, 1995; Tsai, Shillair, Cotten, Winstead, & Yost, 2015); and 5) product usability (Chun & Patterson, 2012; Leung, McGrenere, & Graf, 2011; Page, 2014).

However, by providing appropriate learning methods, some of the frustration could be eliminated (Mitzner et al., 2008; Kurniawan, 2006; Martínez-Alcalá et al., 2019). For example,
older adults have a strong preference for self-training by reading manuals and other printed instructions as well as for hands-on learning through trial and error (Mitzner et al., 2008).

Additional insights into the difficulties in learning to use new technology came from studies on the difference between novice and expert in the learning process (Lazonder, Biemans, & Wopereis, 2000; Ziefle & Bay, 2004). For example, older adults with less technology experience may spend more time in training and need more instructions than experienced older adults. To compensate for the lack of technology experience, researchers suggested that instructors for the tech-class should consider providing overviews and context for the more specific task-related information at the beginning of the training (Cotton et al., 2016).

Nevertheless, Czaja and Sharit (2016) mentioned that with older learners, too much preliminary information could backfire as it may not be retained by older adults as easily. Also, it could lead to confusion and cause anxiety. For example, it is hard for a novice user to fully understand the concept of each feature and the reasoning behind each action when the novice is being introduced to various features and steps in a system all at once. Therefore, due to the lack of understanding, the novice user had to follow the rules (e.g., first, click the red button in the middle; then, check the box at the end of the page). However, merely following rules may lead to poor performance in the real world. If the system updated, the novice will not be able to adapt to the changes and alter their actions accordingly.

It is well known that technology experiences play an important role in the human-computer interaction area. Technology experience effect users’ task performances. A study found that experience using digital cameras similar to the digital cameras used in the experiment helped participants complete the tasks more quickly, more intuitively, and with fewer errors (Blackler, Popovic, & Mahar 2010).
Study overview. To better understand the experience with and barriers to learning new technologies among older adults, this study aimed to explore the technology learning processes among older adults with different levels of technology experience. The study was approved by the NC State Institutional Review Board (IRB) (see Appendix A). Data included in this article were gathered from a focus group study conducted in Raleigh, NC, Cary, NC, and Chapel Hill, NC, which included a total of 40 older adults. Each focus group contained five participants. Topics such as older adults’ attitudes toward learning new technology, learning barriers and difficulties, learning methods, and their opinions about different learning methods were discussed during the focus group sessions.

Method

Screening test. A Technology Experience Profile (TEP) was used as a screening test to categorize individuals into different technology experience groups. TEP assessed individual’s use and familiarity with various technologies (Barg-Walkow, Mitzner, & Rogers, 2014). To ensure the technology experiences differences among the participants groups, individuals within the following TEP score ranges were eligible to be recruited and participate in the focus group: 1) novice group (score range 36-54); 2) advanced beginner group (score range 72-90); 3) competent group (score range 108-126); and 4) proficient group (score range 144-162). These criteria did not apply to the pilot tests (as detailed in the next section). After the score sorting from 104 TEP responses, a total of 40 older adults (23 females and 17 males) aged 65-87 years ($M = 71.13, SD = 5.43$) were recruited for this study (see Appendix B). Each technology experience group contained 10 participants.

Pilot tests. Prior to the focus group sessions, two pilot sessions were conducted to test the structure of the focus group, as well as to ensure the understanding and comprehension of the
discussion topics among the participants. The first pilot group consisted of five older adults with a similar level of technology experience (TEP score ranged from 91-126). The second pilot group consisted of five older adults in the opposite TEP scores range (two participants scored below 72, and three participants scored above 162). Based on the pilot results, the first pilot group came up with more topic-related discussions. In contrast, fewer topic-related discussions were generated from the second pilot group. Thus, in the focus groups, participants in each session were purposefully chosen and arranged to ensure that they were not on the opposite end of the TEP score ranges. For instance, participants in the novice group and participants in the advanced beginner group were scheduled in the same focus group session.

**Focus groups.** A total of eight focus groups, with five participants in each session, were conducted in this study. At the beginning of each session, participants were asked to review the informed consent while the researcher summarized the general goals of the study and explained the rules for the discussion (e.g., speak one at a time, contribute own experiences). After collecting all the signed informed consent, the researcher started the audio-recording, and the session began.

During the focus group session, three main topics were discussed, including attitudes toward learning new technology, barriers/difficulties in learning processes, and learning methods (see Appendix C for the focus group discussion guideline). In addition to the audio recording, the researcher also took written notes during the discussion.

Each focus group session lasted 90-100 minutes. At the end of each session, the participant received a $15 gift card as a compensation for participation.

**Data analysis.** Audio files recorded during the focus group sessions were transcribed verbatim into Microsoft Word documents by professional transcriptionists. Transcripts were
proofread and segmented into categories/subcategories, and then coded using MAXQDA 2018 (a qualitative data analysis software package) by the researcher. Five categories were identified among all segments: 1) attitudes, 2) learning barriers, 3) learning methods, 4) starting points, and 5) user needs. After the thematic coding process, the frequency of occurrence of the codes under each theme (and subtheme) was calculated (see Appendix D for segment and coding scheme). All frequency counts for each code were sorted by the technology experience groups (see Appendix E for a full breakdown of all the frequencies). The overview of all categories/subcategories and themes/subthemes in this study can be found in Appendix F.

Results

Attitudes. Two subcategories were coded under the attitudes toward learning new technology: positive attitudes and negative attitudes. There were, overall, a greater reported number of positive attitudes toward learning new technology (total = 186) than negative attitudes toward learning new technology (total = 139).

Table 3.1 showed the frequencies of codes regarding positive attitudes and negative attitudes among the four groups of participants. For positive attitudes toward learning new technology, the novice group had the lowest frequency counts, while the proficient group had the highest frequency counts. A trend was identified as the frequency counts of codes regarding positive attitudes increased with the level of technology experience. For negative attitudes toward learning new technology, the novice group had the highest frequency counts, while the proficient group had the lowest frequency counts. A trend was identified as the frequency counts of codes regarding negative attitudes decreased with the level of technology experience.
Table 3.1

*Frequency Counts of Positive Attitudes and Negative Attitudes among Four Groups*

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Novice (n = 10)</th>
<th>Advanced beginner (n = 10)</th>
<th>Competent (n = 10)</th>
<th>Proficient (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive attitudes</td>
<td>37</td>
<td>41</td>
<td>49</td>
<td>62</td>
</tr>
<tr>
<td>Negative attitudes</td>
<td>54</td>
<td>39</td>
<td>26</td>
<td>20</td>
</tr>
</tbody>
</table>

A total of eight themes were identified under the two subcategories (see Figure 3.1). Seven out of eight themes were the different activities that technologies can support, including *communication, education/research, entertainment, finance, health, shopping,* and *transportation.* For participants’ attitudes that didn't direct to any specific activity, they were coded under the theme *unspecified.*

*Figure 3.1. Distribution of frequency counts of the themes in subcategories “positive attitudes” and “negative attitudes.”*

Among all the themes under the positive attitudes, *entertainment* had the highest frequency counts, while *transportation* had the lowest frequency counts. Among all the themes
under the negative attitudes, technologies related to entertainment had the highest frequency counts, while finance had the lowest frequency counts.

Furthermore, themes related to the different activities that technologies can support were coded with three subthemes, including effort, memory, and time. The coding scheme was based on the reason that participants mentioned when they were discussing their attitudes toward learning a specific type of new technology. For example, the following quote would be sorted in to “the Category attitudes> Subcategory negative attitudes>Theme entertainment>Subtheme time”: “I can’t (referring to learn to use the four remote controls he or she had at home), I don’t have time to do all that….I want it now and I can’t get it now. I hated those remotes”.

Among the three subthemes under the subcategory positive attitudes, the subtheme effort had the highest frequency counts, while the subtheme memory had the lowest frequency counts. The same results also showed in the frequencies counts of the codes regarding three subthemes under the subcategory negative attitudes (see Figure 3.2).

![Distribution of Frequency Counts of the Subthemes in Subcategories “Positive Attitudes” and “Negative Attitudes”](image)

**Figure 3.2.** Distribution of frequency counts of the subthemes in subcategories “positive attitudes” and “negative attitudes.”

Among four technology experience groups, differences were identified in the distribution of frequency counts for the three subthemes under both subcategories (see Figure 3.3 and Figure
3.4). For positive attitudes, the frequency counts of codes in subtheme *effort* increased with the level of technology experience. Moreover, the frequency counts of codes in subtheme *time* decreased with the level of technology experience. For negative attitudes, the frequency counts of the codes in all three subthemes decreased with the level of technology experience in all three subthemes.

![Figure 3.3](image1.png)

*Figure 3.3. Distribution of frequency counts for the subthemes “effort,” “memory,” and “time” under the positive attitudes in four technology experience groups.*

![Figure 3.4](image2.png)

*Figure 3.4. Distribution of frequency counts for the subthemes “effort,” “memory,” and “time” under the negative attitudes in four technology experience groups.*
Learning barriers. Three themes and seven subthemes were identified under the category of learning barriers: 1) abilities (subthemes: motor control, vision, working memory); 2) product characteristics (subthemes: complexity, familiarity, generalization, reliability); and 3) instructions. Among all three themes, product characteristics had the highest frequency counts (frequency count = 86), while instructions had the lowest frequency counts (frequency count = 13).

The four groups had similar frequencies counts for the codes regarding theme abilities. Three subthemes were identified, including 1) motor control (e.g., “Some of it is so tiny and -- I've got big fingers”), 2) vision (e.g., “my vision is not good enough to notice oops it's not at the right place”), and 3) working memory (e.g., “…because I'll watch it, and I'll think, "I got it,” because I get it in my iPad and then I'm doing it on the computer, and then I have to go back three times”).

The distributions of four subthemes under the theme product characteristic were different among the four groups. Participants in the novice group had the most learning barriers regarding subthemes complexity, familiarity, and reliability among the four groups. As a total of 31 codes regarding the theme product characteristic were identified among participants in the novice group, 13 were coded under the subtheme complexity (e.g., “the instruction said that ‘click over here, and click here, and click here’ and the next sentence is, ‘if you don’t like clicking, you can do this with the keyboard’. There were too many alternatives”). In contrast, a total of 4 codes regarding complexity were identified among participants in the competent group and proficient group (both groups only had 2 frequency counts). A trend was identified as the frequency counts of codes complexity decreased with the level of technology experience.
The opposite trends were identified as the frequency counts of codes regarding subthemes familiarity (e.g., “Sending an attachment is not something that I feel familiar with at all”) and reliability (e.g., “every time I tried that, it crashed.”) decreased with the level of technology experience. But the differences among the four groups under these two themes were not distinct.

Under the theme instructions, the novice group had the lowest number of frequency counts (frequency count = 2), while the competent group had the highest number of frequency counts (frequency counts = 5). Some of the participants in the competent group and proficient group commented that they often encountered difficulties as the instructions or Help features were not clear enough as they were trying to do some troubleshooting by themselves.

![Figure 3.5. Distribution of frequency counts for the subthemes “abilities,” “product characteristics,” and “instruction” in four technology experience groups](image)

**Learning methods.** Three themes were identified under the learning methods category: learning alone, learning from domain experts, and learning from family/friends. Among all three themes, learning alone had the highest frequency counts (frequency count = 102), while learning from family/friends had the lowest frequency counts (frequency count = 24).
Under the theme *learning alone*, a trend was identified as the frequency counts of codes in subthemes *read instruction manuals, trial and error, and watch YouTube videos* increased with the level of technology experience (see Figure 3.6).

*Figure 3.6. Distribution of frequency counts for the subtheme “learning alone” in four technology experience groups.*

Under the theme *learning from domain experts*, two subthemes were identified, including *ask IT support* and *take class* (see Figure 3.7). The novice group had the highest frequency counts of the codes *ask IT support* (frequency counts = 9). In contrast, *ask IT support* was coded 1 time in the competent group and 2 times in the proficient group. Moreover, the competent group had the lowest frequency count of the code *take class* (frequency counts = 3). This subtheme was coded 5 times in the novice group and 6 times in the proficient group.

Under the theme *learning from family/friends*, two subthemes were identified, including *ask family/friends from same generation* and *ask the family/friends from younger generation* (see Figure 3.7). The advanced beginner group had the highest frequency counts of the codes regarding *ask the same generation* (frequency counts = 4). This subtheme was coded 2 times in the novice group and the competent group, and 1 time in the proficient group. Moreover, the novice group and advanced beginner group both had a higher frequency counts of the codes
Regarding *ask the younger generation* (frequency counts 6 and 5, respectively). This subtheme was coded 2 times in the competent group and the proficient group.

**Figure 3.7.** Distribution of frequency counts for the subthemes “learning from domain experts” and “learning from family/friends” in four technology experience groups.

**Starting points.** A starting point refers to the factor that leads the participants to perform their first task (or act) when they started their new technology learning process. Four themes were identified under the category of starting points, including *a wanted task* (e.g., “I normally just did that one thing that I want to do”), *basic functions* (e.g., “I just started from some basic functions”), *others’ recommendations* (e.g., “someone said to me ‘have you tried this?’, then I will try”), and *systems’ default* (e.g., “I go to the ‘Settings’ first. And if there is anything I want to change or anything that I am not familiar with, then...”). Among all four themes, *others’ recommendations* had the highest frequency counts (frequency count = 19), while *systems’ default* had the lowest frequency counts (frequency count = 7).

Differences were identified between technology experience groups (see Figure 3.8). For theme *a wanted task*, the frequency counts decreased with the level of technology experience. The opposite trend was identified in theme *systems’ default*, where the frequencies of codes decreased with the level of technology experience. The competent group and proficient group
both had a higher frequency counts of the codes regarding *basic functions* (frequency counts 4 and 3, respectively), while the novice group and the advanced beginner group both had a lower frequency counts (frequency counts 1 and 2, respectively). Four technology experience groups had a similar frequency counts of the codes regarding *others’ recommendations*.

![The Distribution of Frequency Counts for the Theme "Starting Tasks" in Four Technology Experience Groups](image)

*Figure 3.8.* Distribution of frequency counts for the theme “starting points” in four technology experience groups.

**User needs.** During the discussions, some of the participants commented that they would like to have a jargon “glossary,” so that “*the functionality would be a little more clear.*” Moreover, some of the participants mentioned that they want to have an “*undo (button)*” for everything so that they can “*go back to the beginning (before everything got messed up).*” Only participants in the competent group and the proficient group made comments in this category.

**Discussion**

This focus group study investigated the differences in learning new technologies for older adults with different levels of technology experience. A clear conclusion drawn from this study was that the technology experience effected many aspects of learning experience and learning process. This finding was consistent with some of the conclusions in the literature mentioned
earlier (Lazonder et al., 2000; Ziefle & Bay, 2004). Figure 3.9 presented a synthesized older adults’ learning process based on the findings from the focus group discussions.

Figure 3.9. A synthesized older adults’ learning processes based on the findings from the focus group discussions. (N: participants in the novice group; A: participants in the advanced beginner group; C: participants in the competent group; P: participants in the proficient group.)

Five categories regarding older adults’ new technology learning processes were included in the figure. They were (from left to right) positive and negative attitudes toward learning new technology, the initial point for the learning process, barriers to learning, learning method preferences, and user needs. For attitudes, initial points, learning barriers, and learning method, items listed in the figure were the ones had the most frequency counts. User needs that discussed during the focus groups were listed as additional insights.

For attitudes toward learning new technology, older adults with a lower level of technology experience had fewer positive attitudes toward learning new technology than older adults with a higher level of technology experience, especially for the aspect of effort. For example, some of the experienced participants commented that they considered learning a new technology to be a smooth and relatively easy process as it doesn’t require much effort.
Furthermore, older adults with a lower level of technology experience had more negative attitudes toward learning new technology than older adults with a higher level of technology experience. For example, due to the lack of technology experience, many participants in the novice group commented that learning new technology was exhausting and time-consuming, as well as increasing their anxiety. They also said that many technologies were providing too much information (or too many functions) to remember.

For barriers to learning new technology, the lower level of technology experience groups reported more barriers than the higher level of technology experience groups regarding product complexity. Participants in novice and advanced beginner groups frequently mentioned that a system has “too many buttons,” and they got confused very easily. The opposite trends were discovered regarding the product generalization, where the higher level of technology experience groups reported more barriers that the lower level of technology experience groups. This may be due to product generalization usually associated with the similarity (or difference) across different technologies. Only older adults who had experiences in using many different technologies could make comments on this aspect.

Furthermore, learning barriers reported by experienced older adults can be associated with their learning method preferences. For example, problems with instructions were mostly reported by experienced older adults. Individuals were more likely to learn by themselves when they were at a relatively higher level of technology experience. As user manuals or quick starters are common tools to use for people who want to learn and explore the technology by themselves, problems regarding the instructions could be pointed out by them more often.

Differences in the starting points of the learning process were identified among four technology experience groups. Many novices commented that they did not try to start to learn
technology just because there were functions or features provided to them. However, proficient older adults preferred to see what the product can provide and what’s the similarity between the new technology and the technology they have already learned. At the beginning of the learning process, some of the participants commented that they usually started from the things listed on systems’ default to see all the settings in order to be familiar with the product.

In addition, the novice older adults commented that they preferred to start with a task that they had in mind at the beginning of their learning process. This finding can be linked to the learning method preferences where the novices least preferred in reading manuals and using Help features. In contrast, they preferred learning from domain experts and learning from family/friends. Studies suggested that instructional materials for novices should be presented in a step-by-step procedural format (Mayhorn, Stronge, McLaughlin, & Rogers, 2004; Gerjets, Scheiter, Catrambone, 2004). Combining the findings from the focus group; therefore, when designing for a better learning experience, it is important to consider the user characteristics of novice older adults. For instance, a task-oriented, jargon-free interactive tutorial might facilitate novice users’ initial learning process.

Some of the comments made during the focus groups were not segmented. Participants in the novice group mentioned that they had financial concerns related to learning new technology. For example, they were commenting that IT supports they paid was “very expensive.” Security concerns were also mentioned frequently by participants across all groups. Concerns about security included malware/virus, the safety of password management software, and the privacy of health information via online portals. These concerns were not part of the learning process. Instead, they were more toward the aspects regarding anxiety and technology acceptance. These aspects can be considered as potential directions for future studies.
Future studies can also address the user needs that were discussed during the focus groups. Those concepts can be applied to the development of user interface features that may enhance older adults’ learning experiences by minimizing those repetitive learning works or at least making the process easier.

Future directions in this research area could also examine why older adults decide not to engage with new technology with the focuses on product characteristics. This would provide further insight into the relationship between product design and perceptions of technology from non-users.

Acknowledgment

I would like to acknowledge the assistance from Osher Lifelong Learning Institute (OLLI) at NC State University, Cary Senior Center, Woodland Terrace senior community, and Seymour Center, in helping with participant recruitment and providing locations for the focus groups. I would also like to show my gratitude to all the participants for sharing their experiences with me.
References


CHAPTER 4

INTERFACE FEATURES, PRODUCT LEARNABILITY, AND OLDER ADULTS

Chapter 4 is formatted as a manuscript for the submission to Proceedings of the Human Factors and Ergonomics Society Annual Meeting (2020). Appendixes mentioned in this chapter are supporting materials for the explanatory purpose of the dissertation. They may not be included in the final submission.

Title: Designing for Older Adults: User Experience Evaluation of Learnability Focused Features of Mobile Apps Interfaces

Authors: Hongyang Liu and Sharon Joines (College of Design, North Carolina State University, Raleigh, NC)

Abstract: Numerous studies showed that older adults encounter many difficulties in using and learning to use new technology. To eliminated older adults learning barriers, it is important to investigate what design elements can enhance older adults’ learning experiences as well as can ensure technology learnability.

In this study, six learnability focused features (LFFs) were evaluated by 17 older adults. Participants were asked to interact with LFFs on the mobile app prototypes. Data collection methods included task performance observations, questionnaires, and structured interviews. Older adults’ ratings regarding prototypes learnability were collected from effectiveness, efficiency, complexity, and overall satisfaction. In addition, older adults’ preferences in the six LFFs were also collected. The effects that each LFF had on older adults’ learning experiences are discussed in the study.
Introduction

**Background.** Today, technologies are prevalent in people’s everyday life. Technologies mediate people’s behaviors, memories, social interactions, and more. The changes in technology, coupled with the changing capabilities of the people using technology, can lead to various interactions and outcomes. Those changes have a greater impact on the aging population than others (Cotten, Yost, Berkowsky, Winstead, & Anderson, 2016; Kaye, Yeager, & Reed, 2008; Lee & Coughlin, 2015; Richardson, Zorn, & Weaver, 2002).

**Older adults’ learning experiences.** Older adults (i.e., aged 65 and over) encountered many difficulties in using and learning to use new technology (Barnard, Bradley, Hodgson, & Lloyd, 2013; Dickinson, Arnott & Prior, 2007; Kelley & Charness, 1995). Findings from one of our pilot studies indicated that some of the difficulties in using technology were not necessarily associated with product usability. Older adult users often encounter difficulties while learning to use a technology. For example, older adults commented on the high demands of effort and time in repetitive learning processes, which were due to software automatically updating on a regular basis. For some, the processes of adapting to a newer version or changing a default setting were not opportunities but barriers. Therefore, many older adult users are unable to take advantage of new features or stuck with default settings. Good interface design needs to give users control and freedom (Nielsen, 1994); this aspect of interface design can be guided by the concept of product learnability. In the software updating case, the product with higher learnability can enhance older adults’ learning experiences by minimizing those repetitive learning processes or at least making the process easier.

**Designing for learnability.** There is a wide range of concepts associated with learnability, including: 1) predictability; 2) consistency; 3) familiarity; 4) generalizability; and 5)
simplicity (Dix, Finlay, Abowd, & Beale, 2004; Green & Eklundh, 2003; Weiss, Bernhaupt, & Tscheligi, 2011). Technology with higher learnability can provide users with higher levels of self-efficacy, more positive attitudes, and reduced anxiety (Leung, McGrenere, & Graf, 2009).

Many design strategies have been applied to improve the learnability of product (or system), including: 1) internal visual structures (e.g., navigation aid); 2) internal instructional features (e.g., input prompt); and 3) external instructional materials (e.g., user manual) (Gerjets, Scheiter, Catrambone, 2004; Green & Eklundh, 2003; Hickman, Rogers, & Fisk, 2007; Van Merriënboer, Kirschner, & Kester, 2003; Ziefle & Bay, 2006).

Designing for learnability is more essential for first-time users than returning users (Green & Eklundh, 2003). Design features such as relevant and immediate feedbacks are crucial for enabling successful performance (Green & Eklundh, 2003). Furthermore, reduced-functionality interface provides greater benefit for older adults than for young adults in terms of task completion time during initial learning, perceived complexity, and preference (Leung, Findlater, McGrenere, Graf, & Yang, 2010). However, interacting with the reduced-functionality interface would not improve older adults’ performance in learning the advanced task set on the full-functionality interface (Leung et al., 2010). Similarly, expandable menus are more beneficial than sequential menus among participants with low spatial skills, while participants with high skills do not seem to be affected by task difficulty or menu type (Melguizo & Van Oostendorp, 2012).

**Study Overview**

There have been and will continue to be enormous evolvements and changes in technology. To eliminated older adults learning barriers, it is important to investigate which design elements can ensure product learnability as well as enhance older adults’ learning
In this study, the term *learnability* was defined as the extent to which a product (or system) can be used in a specified context by users to achieve specified goals of learning to use the product (or system) effectively, efficiently, with freedom from risk, and with satisfaction (ISO, 2011; ISO 2017). Furthermore, the term *learnability focused features (LFFs)* was defined as visual elements in a user interface that enable users with limited technology experience to learn to use a product (or system) in a specified context.

In this study, six LFFs were evaluated by 17 older adults. LFFs were applied to two click-through prototypes. One was an online food-ordering system. And another was a Bluetooth device pairing system. During the evaluation sessions, participants were asked to go through multiple tasks in the systems to try out all the LFFs separately. Prototypes were displayed on a touch-based digital device. Data collection methods included task performance observations, questionnaires, and structured interviews. Results about the ratings of prototypes learnability and participants’ preference in the six LFFs were discussed. This study was approved by the University’s Institutional Review Board (IRB) (see Appendix G).

**Method**

**Participants.** Participants were selected from a pool of 54 individuals from the researcher’s previous research study (Study 1 in Chapter 3). Participants for that study were recruited from Osher Lifelong Learning Institute (OLLI) at NC State University and the surrounding senior centers.

The Short Portable Mental Status Questionnaire (SPMSQ) (Pfeiffer, 1975) was used as a screening test to ensure participants had intact intellectual functioning. Individuals making 0-2 errors on the SPMSQ were classified as having Intact Intellectual Functioning. A total of 17
older adults (7 females and 10 males) aged 65-78 ($M = 70.29$; $SD = 4.12$) with a broad range of technology experiences participated in this study (see Tables 4.1 and 4.2).

Table 4.1

**Participant Demographics and Technology Experience Profile (TEP) Scores**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Age (Years) Mean (Std Dev)</th>
<th>Education Mean (Std Dev)</th>
<th>Health Mean (Std Dev)</th>
<th>TEP Total Mean (Std Dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>17</td>
<td>70.29 (4.12)</td>
<td>6.29 (.68)</td>
<td>3.71 (.77)</td>
<td>108.71 (27.02)</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
<td>68.43 (2.94)</td>
<td>6.00 (.57)</td>
<td>3.71 (.76)</td>
<td>99 (29.70)</td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
<td>71.60 (4.45)</td>
<td>6.50 (.70)</td>
<td>3.70 (.82)</td>
<td>29.7 (24.19)</td>
</tr>
</tbody>
</table>

*Note. Explanation of scoring for Education level:*

- Score 4: Vocational training;
- Score 5: Some college/Associate’s degree;
- Score 6: Bachelor’s degree (BA, BS);
- Score 7: Master’s degree (or other post-graduate trainings);
- Score 8: Doctoral degree (PhD, MD, EdD, DDS, JD, etc.).

*Explanation of scoring for Health status (in general):*

- Score 1: Poor; Score 2: Fair; Score 3: Good; Score 4: Very good; Score 5: Excellent.

TEPs were collected from the screening survey in Study 1 (Chapter 3). There was a total of 104 completed survey responses in the previous study. By signing the consent form on the first page of the screening survey, respondents were agreed to be contacted about future research opportunities, regardless of their participation in Study 1. However, all participants in this study did not participate in Study 1 (Chapter 3).

Table 4.2

**Digit-Symbol Substitution Test (DSST) Scores, Recall Test Scores, Short form of the Mobile Device Proficiency Questionnaire (MDPQ-16) Scores, and Technological Self-Efficacy Scores**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>DSST Mean (Std Dev)</th>
<th>Recall Mean (Std Dev)</th>
<th>MDPQ-16 Mean (Std Dev)</th>
<th>Technological Self-Efficacy Mean (Std Dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>17</td>
<td>67.00 (8.55)</td>
<td>5.00 (1.58)</td>
<td>72.82 (5.98)</td>
<td>13.00 (3.10)</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
<td>69.00 (7.53)</td>
<td>4.71 (1.25)</td>
<td>72.00 (5.72)</td>
<td>12.86 (2.79)</td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
<td>65.60 (9.32)</td>
<td>5.20 (1.81)</td>
<td>73.40 (6.40)</td>
<td>13.10 (3.45)</td>
</tr>
</tbody>
</table>

*Note. Explanation of scoring for DSST: the number of correct “number-symbol” matches achieved in 90 seconds (with maximized score in 100). Explanation of scoring for recall in DSST: the number of correct “number-symbol” matches recalled in 90 seconds (with maximized score in 9).*
**Materials.** Four data collection tools were used to examine older adults’ experiences with different LFFs as well as their preferences. Two tools were used as self-report materials for participants (post-task questionnaire and post-test questionnaire) and two were used by the researcher (observation sheet and post-test structured interview script). The technological self-efficacy questionnaire and the post-task questionnaire listed in this section were designed for the context of this study only. To ensure reliability, Cronbach’s alpha was used to measure the internal consistency of two questionnaires (see Appendix H).

*Ability tests.* Prior to participation, participants took 2 ability tests: 1) the Digit Symbol Substitution Test (DSST) (Wechsler, 1981); and 2) recall of digit-symbol keys in DSST. The DSST was used to measure processing speed. The recall test was used to measure memory. The scores were taken into account when analyzing participants’ performance (i.e., the questions they asked made during the testing session).

*Pre-test questionnaires.* Prior to the prototype testing sessions, participants completed three questionnaires (see Appendix I and Appendix J): 1) a Demographics Questionnaire (modified from Czaja et al., 2006); 2) a technological self-efficacy questionnaire; and 3) a short form of the Mobile Device Proficiency Questionnaire (MDPQ-16) (Roque & Boot, 2018).

*Post-task questionnaire.* Post-task questionnaires were given to participants after their completion of each task. The questionnaires were used to assess LFFs by asking participants to rate the effectiveness, efficiency, complexity, and overall satisfaction of their interaction with the prototypes (see Appendix K). The questions in the post-task questionnaire were inspired by Davis’s Technology Acceptance Model (TAM) (Davis, 1989). Questions were rated on a 6-point Likert scale ranging from 1-Strongly Disagree to 6-Strongly Agree (with no “Neutral” opinions).
**LFFs.** Six LFFs were applied to the prototypes and were evaluated by participants, including: 1) self-select onboarding display (OA); 2) QuickStart onboarding display (OB); 3) warning message (AA); 4) pop-up text (AB); 5) customize icon (CA); and 6) customize shortcut (CB) (see Figure 4.1). The detailed design of the six LFFs was presented in Appendix L.

Figure 4.1. An overview of the concepts of the six LFFs. (From left to right: 1) self-select onboarding display (OA); 2) QuickStart onboarding display (OB); 3) warning message (AA); 4) pop-up text (AB); 5) customize icon (CA); and 6) customize shortcut (CB).)

Table 4.3 described the design concepts of the six LFFs. The six LFFs can be sorted into three categories based on their different characteristics, including: 1) the onboarding display; 2) the action guidance; and 3) the customize settings.

<table>
<thead>
<tr>
<th>Feature name</th>
<th>Code</th>
<th>Feature description</th>
<th>Feature category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-select onboarding</td>
<td>OA</td>
<td>A task-oriented onboarding display; Users will be asked by the system about what they would want to do when they are opening the launching screen of the system; This is an interactive display.</td>
<td>Onboarding display</td>
</tr>
<tr>
<td>QuickStart onboarding</td>
<td>OB</td>
<td>A function-oriented onboarding display; Users will be introduced about what they could do in the system when they are opening the launching screen of the system; This is not an interactive display; It only presents Info.</td>
<td>Onboarding display</td>
</tr>
<tr>
<td>Warning message</td>
<td>AA</td>
<td>A text-based action guide; Users will be remaindered by the system once wrong action or error is detected; It provides the feedback of the users’ actions.</td>
<td>Action guidance</td>
</tr>
</tbody>
</table>
### Table 4.3 (continued)

<table>
<thead>
<tr>
<th>Pop-up text</th>
<th>AB</th>
<th>A text-based action guide; Users will be remaindered by the system before they act; The guide texts will pop up on the screen.</th>
<th>Action guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customize icon</td>
<td>CA</td>
<td>A signifier-driven customization setup; Users will be able to change the appearances of the icon and then select a function from the pre-prepared list in the system to assign to the icon.</td>
<td>Customize settings</td>
</tr>
<tr>
<td>Customize shortcuts</td>
<td>CB</td>
<td>A procedure-driven customization setup; Users will be able to create a set of procedures and assigned them as one shortcut function to simplify the procedures.</td>
<td>Customize settings</td>
</tr>
</tbody>
</table>

**Prototypes.** An iPad mini (7.9-inch Retina display) was used as the device for two click-through prototypes (see Appendix M for an overview of the two prototypes). Prototype #1 was a mobile app for online food-ordering (PF). Prototype #2 was a mobile app for the Bluetooth device pairing (PB). Adobe XD was used to create two mock-up mobile apps (see Figure 4.2).

*Figure 4.2. Screenshots of the user interfaces in the two prototypes. (From left to right: 1) account information interface of the mock-up online food ordering system; 2) interface of applying pop-up text (AB) to the mock-up online food ordering system; 3) devices searching results in the mock-up device pairing system; and 4) interface of applying QuickStart onboarding display (OB) to the mock-up device pairing system.)*
Six LFFs (mentioned above) were applied separately to Prototype #1 and Prototype #2. Participants evaluated each LFF two times, but each time they were interacting with the LFF under different prototypes.

Observation sheet. During the prototype evaluation process, the researcher took written notes to document any learnability related questions participants asked during each evaluating session. In addition, any comments made by participants regarding the LFF were also documented.

Preference questionnaire (post-test questionnaire). The preference questionnaire was used to evaluate participants’ overall preferences in the six LFFs. At the end of the session, participants ranked six LFFs from 1 to 6 (with 1 being the most preferred, 6 being the least preferred).

Structured interview script. Follow-up interviews were conducted to allow participants to elaborate on their ratings for each post-task questionnaire and their ranking on the preference questionnaire. Also, the researcher asked participants which LFF they would recommend to their family/friends (see Appendix N).

Procedures. The procedures of the user experience study are summarized in Figure 4.3. The whole process took approximately 1.5 hours. At the end of the follow-up interviews, participants received a $10 gift card as compensation and appreciation.
Figure 4.3. User experience evaluation procedures.

Data analysis. Friedman’s Chi-Square tests were used to test for the differences of participants’ ratings in the post-task questionnaire among the six LFFs. Kruskal-Wallis test was used to test the differences of preference ranking among the six LFFs. Bonferroni corrections were applied with an adjusted $p$-value at $0.05/15 = 0.003$.

Results

Learnability ratings within the prototype. Tables 4.4 and 4.5 presented the rating results from post-test questionnaires. Four aspects assessed in the post-test questionnaire, including effectiveness, efficiency, complexity, and overall satisfaction were analyzed separately. The scores of the rating of complexity were calculated from the original data. The higher the score is, the LFF in the prototype was perceived as more complex. For pairwise comparison among the six LFFs, only the comparisons with significant differences were reported in this section.
## Table 4.4
Results from Post-Test Questionnaires in Prototype 1 (PF)

<table>
<thead>
<tr>
<th></th>
<th>Mean (Std Dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OA</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>(1.17)</td>
</tr>
<tr>
<td>Efficiency</td>
<td>4.53</td>
</tr>
<tr>
<td></td>
<td>(1.55)</td>
</tr>
<tr>
<td>Complexity</td>
<td>2.12</td>
</tr>
<tr>
<td></td>
<td>(0.93)</td>
</tr>
<tr>
<td>Overall satisfaction</td>
<td>5.29</td>
</tr>
<tr>
<td></td>
<td>(1.10)</td>
</tr>
</tbody>
</table>

*Note.* Questions were rated on a 6-point Likert scale ranging from 1-Strongly Disagree to 6-Strongly Agree (with no “Neutral” opinions).

There were statistically significant differences among the six LFFs in the ratings of effectiveness, efficiency, complexity, and overall satisfaction in both prototypes, PF and PB.

For PF, there were statistically significant differences between CA and OA ($p < .0001$), CA and OB ($p < .0001$), CA and AA ($p < .0001$), CA and AB ($p < .0001$), CA and CB ($p < .0001$) in the rating of effectiveness.

There was a statistically significant difference between AA and OA ($p < .008$), AA and OB ($p < .0001$), AA and AB ($p < .0001$), AA and CA ($p < .001$), AA and CB ($p < .001$) in the rating of efficiency.

There were statistically significant differences between OA and CA ($p < .0005$), OA and CB ($p < .0018$), OB and CA ($p < .0001$), OB and CB ($p < .0001$) in the rating of complexity.

There were statistically significant differences between OA and CA ($p < .0001$), OB and CA ($p < .0001$) in the rating of overall satisfaction. Also, there were statistically significant differences between OA and CB ($p < .003$), OB and CB ($p < .003$) in the rating of overall satisfaction.
Table 4.5

Results from Post-Test Questionnaires in Prototype 2 (PB)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OA</td>
<td>OB</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>4.47</td>
<td>4.41</td>
</tr>
<tr>
<td></td>
<td>(1.18)</td>
<td>(0.94)</td>
</tr>
<tr>
<td>Efficiency</td>
<td>5.06</td>
<td>4.94</td>
</tr>
<tr>
<td></td>
<td>(1.48)</td>
<td>(1.30)</td>
</tr>
<tr>
<td>Complexity</td>
<td>1.65</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td>(0.61)</td>
</tr>
<tr>
<td>Overall satisfaction</td>
<td>5.24</td>
<td>5.41</td>
</tr>
<tr>
<td></td>
<td>(1.15)</td>
<td>(0.71)</td>
</tr>
</tbody>
</table>

Note. Questions were rated on a 6-point Likert scale ranging from 1-Strongly Disagree to 6-Strongly Agree (with no “Neutral” opinions).

For PB, there were statistically significant differences between AA and OA ($p < .0001$), AA and OB ($p < .0001$), AA and AB ($p < .0005$), AA and CB ($p < .008$) in the rating of effectiveness. Also, there were statistically significant differences between CA and OA ($p < .0001$), CA and OB ($p < .0001$), CA and AB ($p < .0001$), CA and CB ($p < .0001$) in the rating of effectiveness.

There were statistically significant differences between AA and OA ($p < .0001$), AA and OB ($p < .0001$), AA and AB ($p < .0001$), AA and CA ($p < .0001$), CA and CB ($p < .0001$) in the rating of efficiency.

There were statistically significant differences between CA and OA ($p < .001$), CA and OB ($p < .001$), CA and AA ($p < .001$), CA and CB ($p < .001$) in the rating of complexity. Also, there were statistically significant differences between CB and OA ($p < .001$), CB and OB ($p < .001$), CB and AA ($p < .001$), CB and CB ($p < .001$) in the rating of complexity.

There were statistically significant differences between AA and OA ($p < .0001$), AA and OB ($p < .0001$), AA and AB ($p < .0005$), AA and CB ($p < .0005$) in the rating of overall
satisfaction. Also, there were statistically significant differences between CA and OA ($p < .0001$), CA and OB ($p < .0001$), CA and AB ($p < .0001$), CA and CB ($p < .0005$) in the rating of overall satisfaction.

Figures 4.4 and 4.5 presented overviews of the rating results from post-test questionnaires of the two prototypes.

![Figure 4.4](image)

**Figure 4.4.** An overview of the rating results in prototype 1 (PF). Note: Different lowercase letters in each result (i.e., a, b, c) indicated statistically significant differences.

![Figure 4.5](image)

**Figure 4.5.** An overview of the rating results in prototype 2 (PB). Note: Different lowercase letters in each result (i.e., a, b, c) indicated statistically significant differences.
After reversing the weights in the rating of complexity (higher score = less complexity),
the average of the four aspects was also calculated (see Figure 4.6) for each prototype.

For PF, there were statistically significant differences between CA and OA ($p < .0001$),
CA and OB ($p < .0001$), CA and AB ($p < .0005$) in the average of the total of four aspects.

For PB, there were statistically significant differences between AA and OA ($p < .0001$),
AA and OB ($p < .0001$), AA and AB ($p < .0001$) in the average of the four aspects in PB. Also,
there were statistically significant differences between CA and OA ($p < .0001$), CA and OB ($p < .0001$),
CA and AB ($p < .0001$) in the average of the four aspects. Moreover, there were
statistically significant differences between CB and OA ($p < .0008$), CB and OB ($p < .003$), CB
and AB ($p < .0008$) in the average of the four aspects.

Figure 4.6. An overview of the average of the total of four rating scores in two prototypes. Note:
Different lowercase letters in each result (i.e., a, b, c) indicated statistically significant
differences.

**Learnability ratings between two prototypes.** After comparing the rating results in
each evaluating aspect across two prototypes (see Appendix O), there were statistically
significant differences in feature AA ($p < .001$) between PF and PB in the rating of effectiveness.

There were statistically significant differences in feature AA ($p < .0001$) and AB ($p < .008$)
between PF and PB in the rating of complexity. There were no statistically significant differences among six LFFs between PF and PB ($p < .001$) in the ratings of efficiency and overall satisfaction.

**Preferences.** After reversing the weights in the preference questionnaire (higher score = more preferred), the average of the preference rankings was calculated. Table 4.6 listed participants’ preferences in the six LFFs. There were no statistically significant differences among the six LFFs in the preference ranking.

Table 4.6  
*Preference Rankings of the Six LFFs*

<table>
<thead>
<tr>
<th>Preference</th>
<th>OA</th>
<th>OB</th>
<th>AA</th>
<th>AB</th>
<th>CA</th>
<th>CB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.59</td>
<td>3.82</td>
<td>4.12</td>
<td>3.59</td>
<td>2.82</td>
<td>3.24</td>
</tr>
<tr>
<td>Mean (Std Dev)</td>
<td>(1.94)</td>
<td>(2.01)</td>
<td>(1.27)</td>
<td>(1.00)</td>
<td>(1.78)</td>
<td>(1.89)</td>
</tr>
</tbody>
</table>

*Note.* The weights were reversed from the original data. The most preferred = 6; The least preferred = 1. There were no statistically significant differences among the six LFFs.

Table 4.7 listed the counts of the “most preferred” and the “least preferred” among the Six LFFs. For “most preferred,” 6 out of 17 participants ranked OB as their most preferred LFF, followed by OA, AA, and CB, with each LFF had 3 counts for “most preferred.” For “least preferred,” 6 out of 17 participants ranked CB as their least preferred LFF, followed by CA and OA (with 5 and 4 participants ranked it as their least preferred LFF, respectively).

Table 4.7  
*Counts of the “Most Preferred” and the “Least Preferred”*

<table>
<thead>
<tr>
<th>Count</th>
<th>OA</th>
<th>OB</th>
<th>AA</th>
<th>AB</th>
<th>CA</th>
<th>CB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most preferred</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Least preferred</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Follow-up interviews (recommending the LFF to others). When asking participants which LFF they would recommend to their family/friends, 6 out of 17 participants said they would recommend CA to their family/friends as they thought CA could help them eliminate any confusion regarding different buttons (e.g., remote control, video recorder). Four participants mentioned that they would recommend AB (see Table 4.8). Some of the participants thought that AB could guide their family/friends to go through the procedures quickly without having to ask for help. Reasons for recommending OA, OB, and AA to others included "no more open-box fear (referring to a non-user)” (OA), “very informative” (OB), and “reduce anxiety” (AA). Only one participant recommended CB as the participant commented that “…doesn’t need to fill out all the personal information to create a new account.”

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>OA</td>
<td>2</td>
</tr>
<tr>
<td>OB</td>
<td>2</td>
</tr>
<tr>
<td>AA</td>
<td>2</td>
</tr>
<tr>
<td>AB</td>
<td>4</td>
</tr>
<tr>
<td>CA</td>
<td>6</td>
</tr>
<tr>
<td>CB</td>
<td>1</td>
</tr>
</tbody>
</table>

Discussion

Results demonstrate that some of the LFFs had different effects on many aspects of older adults’ user experience regardless of the prototypes. The evaluation results showed that the customize icon (CA) had the lowest score in the rating of effectiveness among the six LFFs. The warning message (AA) had the lowest score in the rating of efficiency. As for the perceived complexity, the customize icon (CA) and the customize shortcut (CB) received the highest rating (i.e., high complexity) in both prototypes as they were "making the process unnecessarily complicated.”

In addition, there was an interesting trend in the rating of complexity, where the ratings of the six LFFs fit into three clusters (see Figures 4.4 and 4.5). The higher rating score
represented the LFF was perceived with higher complexity. The top two ratings were the features under the category of customize settings (CA and CB). The two features under the category of action guidance (AA and AB) were in the middle. And the lowest two ratings, the least complexity, were the features under the category of onboarding display (OA and OB).

The opposite trend was also identified in the rating of the participants’ overall satisfaction with the LFFs in both PF and PB. In this case, the top two ratings were the features under the category of onboarding display (OA and OB). The lowest two ratings were the features under the category of customize settings (CA and CB). The two features under the category of action guidance (AA and AB) were again in the middle.

These findings indicated that older adults’ overall satisfaction with the feature was potentially associated with the complexity of the feature instead of effectiveness or efficiency. In this study, the customize icon (CA) and the customize shortcut (CB) were designed under the concept of providing users with more options and opportunities and inviting them to be part of the interface design process. However, more functions required more steps for set-up, more opportunity for errors, and more confusion. Some of the participants made comments like “what am I supposed to do” or “so I set up the icon, and…now what?” during the testing sessions for CA and CB. The takeaway from these results was that when the LFF required more steps to accomplish its function, it would negatively impact on older adults’ overall satisfaction with the feature.

Some of the LFFs had different impacts on older adults’ user experience between two prototypes. The warning message (AA) got a higher average score in the rating of effectiveness in PF than in PB. Moreover, warning message (AA) and pop-up text (AB) were both perceived as more complex when they were applied to PF than when they were applied to PB.
In this study, warning message (AA) was designed under the concept of providing feedback and identifying incorrect action, to avoid any unwanted results or destructive consequences. Yet, the paring device task in the Bluetooth device pairing system has a structured procedure where users have a limited chance to go to another route or take a detour. In contrast, food ordering can be an iterative process where users can go back to do more browsing or add more items to the cart. The iterative process will lead to more chances of making a mistake. Hence, AA would be a more useful LFF when the tasks contain more unpredictable steps.

For the rating of complexity, the higher rating scores of warning message (AA) and pop-up text (AB) in PF could be explained by the limitation in the prototype design. In this study, to make sure that participants can understand the function that each LFF provides, each LFF was applied to two or more interfaces in the prototype. However, this may lead to feature overuse. This limitation was mentioned by some of the participants during the follow-up interviews as they thought the overlays design in AA and the pop-up icon in AB made them very “anxious.” One of them commented that “I saw this window popped up and I thought ‘No! I did something wrong!’ And it turned out it just wants to confirm the information with me.”

Even though there were no significant differences among the six LFFs for the overall preference ranking, some of the conclusions can still be drawn based on the ranking score average and the frequencies counts of the “most preferred” and the “least preferred.” However, findings from the overall preference contradicted with the rating results in user experience. For example, even though AA had lower scores (compared with the average) in the average of the four aspects in user experience, it was the most preferred LFF (based on the ranking score average) among all the six LFFs. The reason behind this inconsistency can be partially explained by the participant characteristics. For six participants who ranked AA as their most preferred
(score 6) or second preferred (score 5) LFF, four of them rated AA at a relatively low level for the prototypes efficiency aspect (either 2 or 3 on a 6-point Likert scale). During the follow-up interview, two participants mentioned that their ratings were based on their own experience with prototypes. However, they were ranking the LFFs preferences by considering other scenarios as if trying to justify the negative experience they had when they were interacting with AA. One of them commented that “(AA) can be really helpful. Because I’d like to have a preview or have some sort of messages to tell me that I posted the same photos twice on Facebook.” Moreover, one participant commented that since she didn’t have a preference in the six LFFs, so she ranked the LFFs under the consideration of which LFF would be the most helpful to the participant's family or friends.

Additionally, during the follow-up interview, when asking participants which LFF they would recommend to their family/friends, six participants said they would recommend customize icon (CA) to their family/friends. To be noticed, five participants ranked CA as their least preferred LFF. And only two participants ranked CA as their most preferred LFF. This inconsistency may be explained by the fact that participants who recommended CA all had a relatively high score in Technology Experience Profile (a screening test they took entering the participant pool) as well as in MDPQ-16. As they were recommending CA to other people, they were thinking of those who were not experienced in using or learning technology. However, this explanation could not be applied to the inconsistency in the results of the counts of recommending QuickStart onboarding (OB) (frequency counts = 2) and the counts of ranking OB as “the most preferred” LFF (frequency counts = 6).

One of the limitations of this study was the design execution of the prototypes and LFFs. The lo-fi prototypes and simplified LFFs with only a few interactive steps were not able to
represent the real-world situation. Although the design concept of each LFF was explained to the participants during the evaluation, there was still a chance that participants’ ratings and rankings results were effected by the features’ visual components (e.g., color scheme, icon size, animation and transition style).

Another limitation was the measurement of the user experience and learnability. Besides the four aspects of perceived learnability that were measured in this study, other aspects can also be considered. For example, future studies could test the retention of task procedures or system functions. This could test whether the LFFs would help the user in memorizing how to use the technology.

A side note for the limitation as well as for the opportunity for the future study comes from participant characteristics. It is expected that participants’ previous experience in participating in user experience related research may impact their performance or preference. For future studies, previous experience in participating in usability related research could be considered as part of the participant characteristics. A simple screening question, such as “have you participated in any user experience or usability related research study in the past year?” might be sufficient.

Acknowledgment

I want to acknowledge the assistance from Tricia Inlow-Hatcher (the director of Osher Lifelong Learning Institute (OLLI) at NC State) and Teresa Sawyer (the director at Woodland Terrance) in providing locations for this study. Also, I thank the participants for their time and effort in reflecting their thoughts and sharing their opinions with me.
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CHAPTER 5
DESIGN PROFESSIONALS’ ASSESSMENT OF LEARNABILITY FOCUSED FEATURES

Chapter 5 is formatted as a manuscript for the submission to Advances in Human-Computer Interaction. Appendixes mentioned in this chapter are supporting materials for the explanatory purpose of the dissertation. They may not be included in the final submission for the journal.

Title: Design Professionals’ Assessment of Learnability Focused Features Use by Older Adults: Cognitive Walkthrough as A Rough Simulation Method

Authors: Hongyang Liu and Sharon Joines (College of Design, North Carolina State University, Raleigh, NC)

Abstract: In this study, cognitive walkthrough (CW) was used as the method to evaluate a set of learnability focused features (LFFs). LFFs was defined as visual elements in a user interface that enable users with limited technology experience to learn to use a system in a specified context. A total of 15 design professionals were recruited as evaluators. During each session, four personas were used as target users for the CW, including first-time novice user, first-time proficient user, returning novice user, and returning proficient user. Each LFF was evaluated from the aspects of accessibility, ease-of-use, and usefulness. Findings and insights gained from this study can be used to inform user interface and user experience (UI/UX) designers on how to design features for interfaces to improve older adults’ learning experiences by considering older adults’ user characteristics.
Background

In current interaction design and user interface and user experience (UI/UX) fields, the concept of technology can be generally defined as any electronic device (e.g., smartphone, TV, wireless headphone), digital service (e.g., banking app, podcast, online shopping) or digital system (e.g., thermostat, navigation, voice command). Technology is prevalent in people’s everyday life. Technology usage among older adults is growing faster than any other age group. For example, the use of Facebook has grown fastest among older generations. Since 2015, Baby Boomers (adults aged 55-73 in 2019) have increased their Facebook use from 50% to 60%; and Silent Generation (adults aged 74-91 in 2019) have increased their Facebook use from 22% to 37% (Vogels, 2019). However, studies showed that older adults (i.e., aged 65 and over) encountered many difficulties in using and learning to use new technology (Barnard, Bradley, Hodgson, & Lloyd, 2013; Dickinson, Arnott & Prior, 2007). The extent of frustration encountered when dealing with technology is also quite evident.

User Characteristics

There are many changes in physical abilities that occurred with aging that are relevant to the interaction between older adults’ and new technology. With increased age, there are declines in visual acuity, accommodation, contrast sensitivity, visual search skills, and the ability to detect targets against a background (Czaja & Sharit, 2016; Hutchison, Eastman, & Tirrito, 1997).

Many cognitive abilities are also associated with learning and using new technologies. Fluid intelligence, reaction time, processing speed, and working memory decline as a part of the process of aging. They were found to be closely associated with users’ task performances with interfaces, including information searching behavior and web navigation performance (Gudur,
Technology experience is also identified as an important factor that affects older adults’ attitudes and feelings toward new technology (Holzinger, Searle, & Wernbacher, 2011; van der Wardt, Bandelow, & Hogervorst, 2010). Additionally, these studies indicated that attitudes (e.g., technology acceptance), anxiety, and self-efficacy (e.g., level of confidence) are to some extent interconnected.

**Design for Older Adults**

Proper attention to design could eliminate much of the barriers older adults encounter during their new technology learning process. In *Designing for older adults*, Czaja et al. (2019) provides a series of design guidelines that can facilitate UI/UX designers in designing for older adults. Some of the guidelines and recommendations include: 1) organize menus and websites with reasonable hierarchy; 2) provide organizational tools for search; 3) minimize the number of steps in a procedure; 4) provide alternatives for difficult to perform gestures; and 5) provide instructional materials that have been tested for usability (Czaja et al., 2019, p123-124).

Many studies indicated that based on different design guidelines, design strategies that applied to the interaction design have different effects on older adults and young adults (Wilkinson, Langdon, & Clarkson, 2011). For example, a study found that reduced-functionality interfaces provided greater benefit for older adults than for young adults in terms of task completion time during initial learning, perceived complexity, and preference (Leung et al., 2010). Furthermore, some design strategies have different effects on the different stages of learning (Leung, Findlater, McGrenere, Graf, & Yang, 2010; Green & Eklundh, 2003) as well as different skill levels (Melguizo & Van Oostendorp, 2012). For example, findings from a study
showed that designing for learnability regarding the user interface elements is more essential for first-time users than returning users (Green & Eklundh, 2003).

**Cognitive Walkthrough**

Cognitive walkthrough (CW) is a user interface and user experience (UI/UX) evaluation method that helps designers (or other domain experts) to think like their target users through a structured process (Wharton, Rieman, Lewis, & Polson, 1994). CW has usually been used to help design teams test the learnability of system interfaces, features, or procedures (Farrell & Moffat, 2014; Shekhar & Marsden, 2018; Spencer, 2000).

During a CW session, evaluators (i.e., designers) need to think from the users’ perspective. For example, they need to think about whether any first-time user will be comfortable understanding and using the interface without any formal training or background knowledge. The process can be done by first thinking about the user and defining the system, and then taking a step-by-step approach to examining the design (e.g., features, interfaces).

**Learnability focused features (LFFs).** The purpose of this study was to evaluate a set of learnability focused features (LFFs), which could potentially be used as user interface design strategies under the concept of designing for older adults. CW was used as the evaluation method. This study was approved as exempt by the University’s Institutional Review Board (IRB) (see Appendix P).

In this study, *user* interface (UI) was defined as elements of a system used to present information about the system’s status and allow users to control the system by activating the element, which enable users to interact with the system for its intended purpose (International Organization for Standardization [ISO], 2006). The term *learnability* was defined as the extent to which a system can be used in a specified context by users to achieve specified goals of learning.
to use the system effectively, efficiently, with freedom from risk, and with satisfaction (ISO, 2011; ISO 2017). Furthermore, LFFs were defined as visual elements in a user interface that enable users with limited technology experience to learn to use a system in a specified context.

**Participants.** A total of 15 design professionals were recruited by the researcher through personal networks to participate as evaluators. Participants were young professional UI or UX designers — most were familiar with design principles/guidelines for older adults:

- Age range: 25-36 years ($M = 28.33, SD = 3.81$);
- Gender: 8 females and 7 males;
- Occupation (sorted by job titles): 4 junior UI designers, 6 senior UI designers, and 5 senior UX designers;
- Participants’ familiarity with the design principles/guidelines about designing for older adults (self-reported):
  - Not familiar: 2;
  - Somewhat familiar: 7; and

All participants reported that they were familiar with both scenarios used in this study (online food-ordering system and Bluetooth device pairing system). Furthermore, all participants have experience in using CW as a UI/UX evaluation method.

**Materials.** Instead of presenting the LFFs in the interfaces of the prototype systems, in this study, the six LFFs were presented to the evaluators in a written format (see Table 5.1). Even though UI/UX designers rarely work with text-based contents, but this arrangement was designed purposefully based on the results from the researcher’s pilot tests. During the pilot tests, LFFs were visually presented in the format of user interfaces to the pilot test participants. However, there were not many system learnability related comments. Instead, participants in the pilot tests made many comments on the design execution of the LFF. Moreover, the pilot
sessions took longer than expected due to the critique of the visual components in the LFFs. Therefore, to eliminate the distraction created by the visual components in the LFFs (e.g., color scheme, icon size, animation and transition style), the evaluators in this study were asked to mentally apply the concept of each LFF in the evaluation process.

Table 5.1
*Concept Description of the Six LFFs in CW Worksheet*

<table>
<thead>
<tr>
<th>Feature category</th>
<th>Feature name</th>
<th>Feature description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onboarding display</td>
<td>Self-select onboarding</td>
<td>A task-oriented onboarding display; Users will be asked by the system about what they would want to do when they are opening the launching screen of the system; This is an interactive display.</td>
</tr>
<tr>
<td></td>
<td>QuickStart onboarding</td>
<td>A function-oriented onboarding display; Users will be introduced about what they could do in the system when they are opening the launching screen of the system; This is not an interactive display; It only presents Info.</td>
</tr>
<tr>
<td>Action guidance</td>
<td>Warning message</td>
<td>A text-based action guide; Users will be remaindered by the system once wrong action or error is detected; It provides the feedback of the users’ actions.</td>
</tr>
<tr>
<td></td>
<td>Pop-up text</td>
<td>A text-based action guide; Users will be remaindered by the system before they act; The guide texts will pop up on the screen.</td>
</tr>
<tr>
<td>Customize settings</td>
<td>Customize icon</td>
<td>A signifier-driven customization setup; Users will be able to change the appearances of the icon and then select a function from the pre-prepared list in the system to assign to the icon.</td>
</tr>
<tr>
<td></td>
<td>Customize shortcut</td>
<td>A procedure-driven customization setup; Users will be able to create a set of procedures and assigned them as one shortcut function to simplify the procedures.</td>
</tr>
</tbody>
</table>

Two systems were prototyped to support the application of the concept of the LFFs: 1) a mobile app for online food-ordering and 2) a mobile app for the Bluetooth device pairing (see Figure 5.1). Adobe XD was used to create the two mock-up mobile apps. Screenshots of the user interfaces in the two prototyped systems were presented to the evaluators in the CW worksheets. The actual screen size for each screenshot was 7.9 inches with 768 x 1024 screen resolution.
Figure 5.1. Screenshots of the user interfaces in two prototyped systems. (From left to right: 1) screenshot of log in in the mobile app for online food-ordering; 2) screenshot of item browsing in the mobile app for online food-ordering; 3) screenshot of device searching in the mobile app for the Bluetooth device pairing; and 4) screenshot of device set up in the mobile app for the Bluetooth device pairing.)

**Procedures.** All CW sessions took place in a one-on-one setting (either online or in-person depending on the participants’ physical location and their preference). Thus, 15 CW sessions were conducted for this study. At the beginning of the evaluation session, the participants were asked to review and sign informed consent as well as review the CW worksheet provided by the researcher. Worksheets were sent to online participants prior to CW sessions. For in-person sessions, paper-based worksheets were provided. Content in the worksheet included the background and goal of the CW session, older adults’ characteristics, description of the six LFFs, user interfaces of the two prototyped systems, personas and scenarios, as well as the evaluation criteria. After discussing the worksheet content with the researcher, the CW evaluation began.

During the CW, the researcher led the participant to evaluate each LFF in a written format. The goal of the study was to evaluate LFFs by envisioning the learning experiences of older adults when the LFFs were applied to the system. The functional aspects of the LFFs were
evaluated, including usefulness, ease-of-use, and accessibility. The visual components (e.g., color scheme, icon size, animation and transition style) were not considered during the evaluation.

To evaluate the six LFFs, the researcher presented participants with 2 scenarios, including: ordering food online (S1) and pairing a headphone via Bluetooth (S2). Both scenarios consisted of five steps (see Figure 5.2). Two systems were prototyped to support the scenarios: 1) a mobile app for online food-ordering and 2) a mobile app for the Bluetooth device pairing. During the evaluation, the participant was asked to envision an older adult persona (as detailed in the following section) in the scenario where LFFs were applied to the systems’ interfaces.

![Figure 5.2. Steps in the scenarios of ordering food online (S1) and pairing a headphone (S2).](image)

Participants evaluated the six LFFs after each of the five steps. For each step, participants were asked to evaluate the LFFs considering accessibility, ease-of-use, as well as usefulness:

- Will the user notice the LFF is available? (accessibility)
  - Will the user notice the LFF is available as the LFF is provided to the user by default?
  - Will the user notice the LFF is available even if the LFF isn’t provided to the user by default?
• Will the user consider the LFF is easy to use as the LFF only requires minimum time and effort from the user to interact with it? (ease-of-use)

• Will the user consider the LFF is useful as the LFF can facilitate the user to achieve each goal? (usefulness)

The participant was asked to skip the LFF when it was not able to apply to the system prototypes in the step (e.g., Self-select onboarding was not applicable for Step 3 in S1). The user mentioned on the list above was replaced by the following older adult (65 years old) personas: 1) first-time novice user, 2) first-time proficient user, 3) returning novice user, and 4) returning proficient user. The four personas were presented in a random order for each scenario and for each participant to avoid order effects. Participants ran through the first scenario 4 times evaluating the six LFFs. Then the participants ran through the second scenario. The two scenarios and two prototyped systems were also provided in a counterbalanced order among all participants (e.g., the participant in one session evaluated S1 first and then S2; the participant in the next session evaluated S2 first and then S1). During the evaluation session, the researcher took written notes on the participant’s comments. Each CW session took approximately 60 minutes.

Data Synthesis

Participants’ comments and evaluation results from 15 CW sessions were synthesized using user journey maps to document the scenario for each older adult persona interacting with the LFFs in each scenario. Figure 5.3 depicted a user journey map for a 65 years old first-time novice user’s learning experience in pairing a headphone. Pain points, summarized at the bottom of the user journey maps, were identified during the participants’ CW. The feeling faces (e.g., smiley faces) for representing the emotional aspect in user experience were created based on the
frequency counts of pain points under each step. Criteria for assigning the feeling faces to each step were as following:

- For each persona in each scenario, after calculating the frequency counts of pain points under each step, assigning “smiley face” to the steps where the frequency counts of pain points were in the first quartile (the lowest 25% of the frequency counts);
- assigning “neutral face” to the steps where the frequency counts of pain points were in the second quartile (between 25.1% and 50%) up to the median of the frequency counts and third quartile (51% to 75%) above the median of the frequency counts; and
- assigning “sad face” to the steps where the frequency counts of pain points were in the fourth quartile (the highest 25% of the frequency counts).

![User Journey Map](image)

**Figure 5.3.** A user journey map for a 65 years old first-time novice user’s learning experience in pairing a headphone. Note: The frequency counts of pain points under each step were: 4, 1, 6, 9, and 10.
During the CW sessions, the concept of user interface (UI) elements emerged from the participants’ comments. This concept was also reflected in the user journey map. Figure 5.3 summarized “what would the user see” and “what would the user act” under each step in the scenario. For example, to finish Step 1 in S2: searching for the device, the user needs to click the Bluetooth icon (act) as well as waits (see) until the device showed up on the screen. Combining with the definition of the user interface (as defined in the section “Learnability focused features”), the UI elements in this study were sorted into two categories: elements for information presentation and elements for activity control. Figure 5.4 illustrated two examples of the UI elements in two prototyped systems.

(See Figure 5.4. Examples of the UI elements in two prototyped systems. (UI elements for information presentation were labeled by the “eye” symbols; UI elements for activity control were labeled by the “tap gesture” symbols.)

In this study, the UI elements for information presentation referred to the visual elements either 1) presented before users’ action (e.g., before Step 4 in S1: the information regarding order summary); or 2) presented after users’ actions (e.g., after Step 4 in S1: the progress bar shows the
transaction processing). The UI elements for activity control referred to the visual elements where either 1) users’ actions were required in order to proceed to the next step (e.g., Step 4 in S1: “Place your order” button); or 2) users’ actions were not required, but they could still choose to act to start a new task (e.g., Step 2 in S2: the “remind me later” button on the user interface of updating device).

However, the second situation in the information presentation category and the second situation in the activity control category were not under consideration for the evaluation of the LFFs in this study. During the CW sessions, participants were asked to go through five steps in each scenario. All the screenshots of the user interfaces in the two prototypes were designed and prepared in advance. Therefore, the information presented after each action would not have an impact on the next step. Furthermore, in order to proceed to the next step, users’ actions were required in every step. Hence, participants were not asked to apply any LFF on the interfaces regarding these two situations.

Based on different UI elements, the evaluation results of LFFs in each step were sorted into the two categories to gain generalized insights. Among the ten steps in the two scenarios, screenshots of the user interfaces in 8 steps contained both UI elements (i.e., information presentation and activity control). Screenshots of the user interfaces in Steps 1 and 5 in S1, as well as Step 3 in S2 only contained UI elements for activity control. Screenshots of the user interfaces in Step 2 in S1 only contained UI elements for information presentation. The main results from the evaluation sessions with UI/UX designers are summarized in Figure 5.5.
The results for each LFF were listed based on the different evaluation aspects (i.e., usefulness, ease-of-use, and accessibility). In this study, when 80% of the evaluators (i.e., 12 out of 15 participants) agreed that the LFF could fulfill the criterion, the LFF was considered as “meet the criterion.” The four personas mentioned in the previous section were depicted separately in the figure to visualize the extent to which each LFF was evaluated as useful, easy to use, or accessible.

**Findings and Insights**

The following sections discussed the participants’ comments on each LFF based on its feature category as well as the general insights gathered from the CW sessions.

**Feature category 1: onboarding display.** Due to the nature of onboarding screens, the two features under the category of onboarding display (i.e., self-select onboarding and...
QuickStart onboarding) aimed to help the user get started. Most evaluators considered that these two onboarding displays would not be noticed to returning users regardless of their technology experience, but they would be helpful to first-time users.

As for facilitating returning users, instead of considering the task-oriented onboarding display (i.e., self-select onboarding) or the function-oriented onboarding display (i.e., QuickStart onboarding) to the user interfaces, some of the evaluators mentioned that a progressive onboarding display could be more helpful. They were commenting that a progressive onboarding display can be applied to the user interfaces where all four personas could benefit from it. For example, some of the evaluators commented that as the returning users come back and move on to the next task, a progressive onboarding display can be unlocked to feed the users the relevant information as they progressed. This insight can be used as a new concept for the development of the LFFs.

Due to the limitation of the two scenarios in this study, QuickStart onboarding was not very useful to the users as many functions were too obvious. Four evaluators commented that if the mobile app had a complex workflow (e.g., a finance app) or the scenario had a series of complex steps (e.g., signing-up for a food delivery subscription), then onboarding displays proposed in this study would have been more helpful (i.e., fulfill the usefulness). At the same time, their ease-of-use would remain the same.

Moreover, some of the evaluators commented that first-time novice users could be overwhelmed by the information provided in the QuickStart onboarding, as they were receiving the information all-at-once at the beginning of their learning process. Hence, instead of only being activated during first-time (i.e., onboarding) use, the QuickStart should be available all the time to support information retrieval.
Furthermore, 6 out of 15 evaluators commented that the onboarding displays should be activated before the user logs in to the app. All six comments were made under the returning novice user persona in S1 (Step 1).

**Feature category 2: action guidance.** Among the four personas, the warning message feature was not considered easy to use by the first-time novice users for the activity control purpose. Evaluators expressed concern that first-time novice users wouldn’t fully understand the warning messages. Some of them pointed out that first-time novice users cannot takeaway information from warning messages. On the contrary, warning messages would only increase anxiety.

For all four personas, evaluators considered the pop-up text feature could be useful, easy to use, and accessible under both information presentation as well as activity control purposes.

Furthermore, many evaluators noted that there were some ground rules that need to be applied to the features under the category of action guidance (i.e., warning message and pop-up text). For example, a few evaluators suggested triggers (e.g., button click, finger hovering) could be applied to any action guidance feature to ensure that users are able to control the feature. Evaluators also expressed concern that uninvited action guidance may surprise users and result in a quick or an accidental dismissal of the pop-up text (or warning message) regardless of their using stage and technology experience.

**Feature category 3: customize settings.** Considering that the two features under the category of customize settings (i.e., customize icon and customize shortcut) required users to get to know the functions the system can provide to ensure the effective and efficient customization, they were evaluated as not accessible to nor easy to use by first-time users. Also, evaluators
expressed concern that the process of creating the customizations might be hard for returning novice users.

Even though the customize icon was considered easy to use by returning proficient users, the evaluators noted that experienced users may not consider this feature helpful. Many evaluators pointed out that the goal for the customizing icon was to assign a meaning to an icon so that it could be understood without reading a label. Moreover, some of the evaluators were concerned that too many customize icons might lead to confusion. They noted that it is essential to ensure that a master list of “functions and icons” is available to users all the time so that they can keep track of the icon and its meaning.

**General insights.** Based on the step by step evaluation and comments made during discussions by the evaluators, the results from this study are summarized in a 4-quadrant chart based on the 4 older adult personas (see Figure 5.6). It presents which type of LFFs would facilitate the learning process among older adults based on technology experience level (novice user vs. proficient user) as well as stage of use (first-time user vs. returning user).

![Figure 5.6. LFFs facilitate learning for four personas.](image)

Due to the lack of knowledge and skills, LFFs regarding customize settings (i.e., customize icon and customize shortcut) were considered to be beyond the capability of first-time
novice users. However, from the researcher’s previous study, novice older adults encountered most of their learning barriers when they were recognizing icons/buttons or remembering operating procedures of the technology. Therefore, the timings of introducing the concept of customize icon or shortcut may effect novice older adults’ learning experiences. Considering these LFFs could benefit first-time users, these concepts could be introduced during the technology onboarding stage.

Additional findings were generated based on evaluators comments regarding the design execution of the “opt-in/opt-out” (accessibility). One of the concerns was that first-time users would not be able to notice the option for “opt-in” and “opt-out” is available to them, especially for the two features under the category of customize settings (i.e., customize icon and customize shortcut). The takeaway from this comment was that “opt-in/opt-out” should be addressed as a separate LFF. The information regarding the accessibility of “opt-in/opt-out” could be combined with QuickStarter onboarding or pop-up text for providing information to the users proactively.

**Limitations and Future Studies**

The two scenarios (i.e., food-ordering and device pairing) used in this study may not be the most representative platforms in applying the LFFs. Future studies could be conducted to evaluate LFFs in the technology platform that supported other activities (e.g., health, finance).

Moreover, many LFFs in this study contained text-based contents (e.g., OB, AA, AB). These contents can effect the usefulness and ease-of-use of the LFFs. Future studies could be conducted by adding the text as one of the factors to see how a content perspective (e.g., technical jargon, negative words) would effect the learning experience. For instance, to what extent does the quantity and the quality of the text contents in LFFs ensure a more intuitive and efficient learning experience.
References


CHAPTER 6
CONCLUSIONS

Summary of Findings across Three Studies

The three studies reported in this dissertation were interconnected. Each explored different aspects of older adults’ learning experiences with new technology and answered different research questions proposed at the beginning of this dissertation. Study 1 investigated the new technologies learning process among older adults with varied technology experience. Some of the users’ needs discussed in Study 1 were applied to the ideation and prototyping process for learnability focused features (LFFs), which may enhance older adults’ learning experiences. Then, in the next two studies, six LFFs were evaluated by older adult users and the UI/UX designers, respectively.

Table 6.1 lists the mixed findings from the three studies regarding the pro and cons of each LFFs. Even though the LFFs were not evaluated in the focus group study, design concepts of the six LFFs were generated based on the discussions in Study 1. In the Table, symbol “+” or “−” was used to identify the results as positive or negative effect each LFF had on the UI/UX design. Results listed under Study 3 were generalized insights from the study (after taking into account the three evaluation aspects).

Table 6.1
A Matrix Chart between LFFs and Results from the Three Studies

<table>
<thead>
<tr>
<th>LFF</th>
<th>Study 1</th>
<th>Study 2</th>
<th>Study 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onboarding display: self-select onboarding</td>
<td>(+ addressed to the novice group’s initial learning point as they preferred to start from a task they had in mind)</td>
<td>+ high average scores in the rating of overall satisfaction</td>
<td>+ useful to novice users – lack of usefulness for proficient users</td>
</tr>
</tbody>
</table>
| Onboarding display: QuickStart onboarding | (+ met the user needs: reported by the users in higher technology experience groups)  
(− led to negative attitudes: reported by the users in higher technology experience groups) | + high average scores in the rating of efficiency  
+ low average scores in the rating of complexity  
+ high average scores in the rating of overall satisfaction  
+ have the most counts of the “Most Preferred”  
+ useful to first-time users  
− led to negative attitudes: first-time novice users  
− lack of usefulness for returning users |  |
| Action guidance: warning message | (+ met the user needs: reported by the users in higher technology experience groups) | − low average scores in the rating of effectiveness  
− low average scores in the rating of efficiency  
+ the most preferred (based on the ranking score average)  
+ useful to users with varied technology experience level and stage of use |  |
| Action guidance: pop-up text | (+ inspired by the advanced beginner group’s learning method as they preferred to follow the track of a set of procedures/steps)  
(+ led to positive attitudes: users in higher technology experience groups) | + high average scores in the rating of effectiveness  
+ high average scores in the rating of efficiency  
+ useful to users with varied technology experience level and stage of use |  |
| Customize settings: customize icon | (+ meet the user needs: reported by the users in higher technology experience groups)  
(+ led to positive attitudes: reported by the users in novice group) | − the lowest average score in the rating of effectiveness  
− high average score in the rating of complexity  
− low average scores in the rating of overall satisfaction  
− the least preferred (based on the ranking score average)  
− not easy to use by first-time novice users  
+ useful to returning novice users and proficient users |  |
Table 6.1 (continued)

| Customize settings: customize shortcut | (+ led to positive attitudes: reported by the users in novice group) (+ inspired by the advanced beginner group’s learning method as they preferred to follow the track of a set of procedures/steps) | + high average scores in the rating of efficiency – high average score in the rating of complexity – low average scores in the rating of overall satisfaction – have the most counts of the “Least Preferred” | – not easy to use by novice users + useful to proficient users |

Note. The six LFFs were listed by their feature categories and feature names. Depending on what effect the LFF had on the UI/UX (e.g., preference, effectiveness, meeting user needs), symbol “+” or “−” was used to identify the results as positive and negative effect, respectively. Results listed under Study 3 were generalized insights after taking into account the three evaluation aspects (i.e., accessibility, ease-of-use, and usefulness).

For some of the LFFs, there were overlapping results among the three studies. For example, there were consistent positive opinions toward pop-up text feature among older adults (in Study 1), users (in Study 2), and designers (in Study 3). However, some of the LFFs were controversial owing to inconsistent responses across studies. For example, the customize icon feature was mentioned during the focus group studies where experienced participants commented that customized icons could help them recognize the buttons easily. Also, participants in the novice group pointed out that instead of remembering all the different functions, they preferred to learn when to use the appropriate buttons by assigning colors to the buttons. Nevertheless, the results in Study 2 didn’t favor this LFF. This was consistent with the results in Study 3, where the customize icon feature was perceived as not easy to use by first-time novice users. Moreover, some of the participants pointed out that the customize icon feature may not be noticeable to users. But for proficient users and returning novice users, the customize icon feature could be helpful once they went through the initial setting stage.
The limitations of the three studies, which were discussed in the previous chapters (Chapter 3-5), may have resulted in some of the inconsistencies in Table 6.1. For example, one of the limitations was the design execution of the prototypes and LFFs. The simplified prototypes and LFFs could have limited the users’ perception of the LFFs.

**Recommendations on Designing Interface Features for Older Adults**

One of the goals for UI/UX design is to think about how the experience makes users feel and how easy it is for users to accomplish their desired tasks. Designing for older adults from the ease of learning perspective is not about reducing and simplifying the technology’s functions. It focuses on making the learning methods more accessible and creating experiences that are preferred by older adults without compromising the functionality of the technology.

Designing for learnability is essential for creating positive experiences for novice older adult users. Considering their user characteristics, a task-oriented learning process is recommended. It can provide an easy start to the learning process. However, returning users and proficient users may also encounter learning barriers. As they were becoming experienced, most of their learning barriers occurred in the later stages of the learning process. Hence, an experience-oriented learning process is recommended.

Based on the findings from the three studies, recommendations for designing UI features tailored to older adult users’ technology experience levels are as follows:

- For novice users, initiate task-oriented features that are:
  - conversational — provide a casual/informal environment to reduce “open-box” anxiety and negative attitudes;
  - noticeable — let users be aware of the most important information they need to know during the technology onboarding process;
• persistent — ensure users get the most important information by preventing accidental dismissal due to the mistakes and/or slips; however, the opt-in/opt-out needs to be accessible to users; and

• proactive — predict users’ actions in advance and provide an option regarding their next step; however, it is not recommended to offer multiple options for the same task.

• For proficient users, promote experience-oriented features that:
  
  • encourage self-paced learning — let users be progressively informed and involved in the technology’s function customization; and
  
  • are transferable — let users transfer their experiences (i.e., knowledge and skills) from one part of a technology’s UI to another, and from one technology to another technology.

**Theoretical Contributions and Practical Contributions**

Findings from this dissertation contributed to the knowledge regarding the effects of technology experiences on older adults’ new technology learning processes. More specifically, it improves design researchers’ and designers’ understanding of to the extent to which product learnability and user characteristics come into play in older adults’ learning experiences in new technology.

Furthermore, findings from this dissertation will help inform UI/UX designers regarding what types of learnability focused features can enhance older adults’ learning experiences as well as the product (or system) learnability. It provides guidance on how to design features for interfaces to highlight older adults’ learning experiences by taking into account older adults’ learning barriers, learning method preferences, initial learning steps, and user characteristics.
Research Limitations and Future Studies

The limitations of this dissertation research were as follows:

First, most of the older adults participating in this dissertation research (Study 1 and Study 2) attained a bachelor’s degrees or higher, which was higher than the general older adult population. It is expected that participants with lower education levels might yield different results in the learning process and learning experiences, as well as preferences.

Second, older adult participants in Study 1 and Study 2 were all residents of the United States. It is expected that culture could have an impact on users’ attitudes toward learning new technology and preferences.

Third, scenarios (online food-ordering and Bluetooth device pairing) used in Study 2 and Study 3 may not be the most representative platforms in applying the learnability focused features. Evaluating the features in the technology platform that support other activities (e.g., health, finances, communications) may lead to different results in learning experiences.

Finally, Studies 2 and 3 only evaluated LFFs with a few interactive steps. Although the design concept of each LFF was explained to the participants during the evaluations, participants may have misunderstood the function of the LFFs.

The limitations of this research highlight topics to be addressed in the future. Additional studies, including various types of interfaces and devices as well as a broad range of older adult participants, would obtain more general results. Future studies could test the retention of task procedures or system functions. This could evaluate whether the learnability focused features would help the user memorize how to use the product (or system). Moreover, instead of on-site observation, learnability could also be assessed after one day, one week, or extended periods. It would provide empirical results in returning users’ experiences in re-learning the technology.
REFERENCES


Richardson, M., Zorn, T. E., & Weaver, C. K. (2002). *Senior's Perspectives on the Barriers, Benefits and Negatives Consequences of Learning and Using Computers*. Department of Management Communication, University of Waikato.


Appendix A

Institutional Review Board (IRB) Approval Letter for Study 1 (Chapter 3)

Date: 29Mar2019

Study Title: Interaction Design of New Technologies for Older Adults: From the Ease of Learning Perspective (Focus Group)

NC State eIRB #: 9323

Funding Source: N/A

Dear Honyang Liu,

The project listed above has been reviewed and approved by the NC State Institutional Review Board for the Use of Human Subjects in Research. This project received approval via expedited procedures as outlined in 4 CFR 46.110 under category 7.

This protocol was approved for a one year period on: 21Nov2016

NOTE:

1. This board complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU the Assurance Number is: FWA00003429.

2. Your approval for this study lasted for one year from the Approval date.

Sincerely,

Jennie Ofstein
IRB Director
Institutional Review Board (IRB)
irb-director@ncsu.edu
919.515.8754
North Carolina State University
Appendix B

Participant Characteristics in Study 1 (Chapter 3)

Figure 1. The number of responses in each technology experience profile (TEP) score range (n = 104).

Table 1

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Age (Years)</th>
<th>TEP Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (Std Dev)</td>
<td>Mean (Std Dev)</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>71.13 (5.43)</td>
<td>101.85 (41.39)</td>
</tr>
<tr>
<td>Female</td>
<td>23</td>
<td>70.51 (5.26)</td>
<td>92.87 (41.08)</td>
</tr>
<tr>
<td>Male</td>
<td>17</td>
<td>71.94 (5.71)</td>
<td>114.00 (39.79)</td>
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<td>48.00 (4.85)</td>
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<td>Proficient Male</td>
<td>4</td>
<td>71.00 (4.55)</td>
<td>121.75 (3.95)</td>
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</table>

Note. Only individuals who participated in the focus groups were included in this table.
Appendix C

Focus Group Discussion Guideline for Study 1 (Chapter 3)

Session #: __________________ Date/Time/Location: __________________
Participant (# - TEP): 1______________ 2______________ 3______________ 4______________ 5______________

Procedures:
1. Information consent form
2. Participants review form, they can get a copy if they want to keep one
   a. This study aims to explore the factors in interaction design that can influence the learning process among seniors. This focus group will be used to investigate the learning method preferences, learning processes, interactions with new technologies, and learning tools among seniors with different levels of new technology experiences.
   b. Discussions will be audio recorded
   c. Feel free to ask if there is a question
   d. After the discussion, get $15 gift card on site
   e. Rule #1: sharing your ideas and experiences
   f. Rule #2: don’t hesitate to add anything new
3. Is there any question? Sign the form
4. Start audio recording
5. Introduction
   a. The electronic/digital product
   b. Service
6. Think for a moment about your daily life,
   a. What are the barriers or difficulties that you have experienced when you use the new technology/during the learning process?
      i. Device
      ii. Interface (display)
      iii. Activities (tasks; operational procedures)
      iv. Visual and auditory processing
      v. Working memory
      vi. Schema and mental model
   b. How did you get over those difficulties? (any learning method used? The approach you took?)
      i. Motivation
      ii. How to get rid of anxiety?
iii. Pick up what you’ve learned before (learning curve)
c. If you haven’t yet, in your opinion, how to get over those difficulties
d. How did you make sure that you can manage the new technology?
e. The learning method preference
   i. Learning alone
      • Trial and error/ exploring
      • Internet searching
      • Using Help feature
      • Reading the instruction manual
   ii. Learning from domain experts
      • Asking for IT support
      • Taking training classes
   iii. Learning with others
      • Learning with partner/spouse, children, family/friends from the same generation
      • Learning with family/friends from the younger generation
      • Learning with work colleagues
   f. Their opinion about different learning methods/ why do you use that leaning method?

7. New technology under a different context
   a. Communication
   b. Learning/education/self-help activities
   c. Entertainment activities
   d. Shopping activities
   e. Healthcare-related activities
   f. Security issue/ scamming

8. What might make it easier to use technological devices (interventions)
   a. When you want the learning process or training process to be introduced during the time you are using new technology?
   b. Do you think the learnability of new technology is an important factor that product designers need to consider during the designing process? (how easily and quickly novice users can learn a new technology) Why?
   c. Which improvement would you like to see come to market?

9. Our purpose today was to discuss any needs you have and the challenges you face now and in the future regarding learning to use new technology. Is there anything you want to add?
Appendix D

Segment and Coding Scheme in Study 1 (Chapter 3)

Table 1
Description of Segments Scheme for Focus Group Transcripts

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only segment quote from participants</td>
<td>Before Moderator: How did you guys get over those difficulties?</td>
</tr>
<tr>
<td></td>
<td>After Do not segment this. Instead, put a memo to mark that this is</td>
</tr>
<tr>
<td></td>
<td>where the learning methods/tools started</td>
</tr>
<tr>
<td>Segment the quotes with participant # and</td>
<td>Before Female participant #2:</td>
</tr>
<tr>
<td>technology experience group</td>
<td>After [111-3]:</td>
</tr>
<tr>
<td>Only segment quotes about the participant’s</td>
<td>Before male participant #1: My wife always read that (referring to the</td>
</tr>
<tr>
<td>own experience and opinions</td>
<td>after the product quick starter)…</td>
</tr>
<tr>
<td></td>
<td>After Do not segment this</td>
</tr>
<tr>
<td>A segment must include no more than one</td>
<td>Before “I use both. YouTube is a very good resource… And sometimes I</td>
</tr>
<tr>
<td>scenario.</td>
<td>just clicked that Help button on the upper corner. But the information</td>
</tr>
<tr>
<td></td>
<td>they provided was not very helpful.”</td>
</tr>
<tr>
<td></td>
<td>After “I use both. [YouTube is a very good resource… ] [And sometimes</td>
</tr>
<tr>
<td></td>
<td>I just clicked that Help button on the upper corner. But the information</td>
</tr>
<tr>
<td></td>
<td>they provided was not very helpful.”</td>
</tr>
</tbody>
</table>

Note. The example shows the comparison between Before vs. After. Before shows the transcripts showed in the original transcript. After shows that what the transcripts would look like after it is being segmented by the researcher by using the criterion listed in the first column.
Moderator: So how did you learn to use those Apps or software, I mean, in the first place?

170-4: As an educator, different people have different learning styles because we're different. It depends on some of the technologies. For myself, if I pull out an audio system, I'm going to sit down with the manual and the manual will help me out. But on another issue over the last year, I started using some software for digital photography, it's called Lightroom it's like mini Photoshop. So the first time up it's like, "I see there's a lot of stuff here", then I looked at some YouTube videos, they help you get through tutorials, they help get to just the things you want and then you can start exploring some of the things, but at least you can get going. You are not sitting there with frozen with some pictures you want to.

In that case, video tutorials work better. It depends on the learning style, but then I'm sitting here thinking with different technologies, I would use a different mode of tutorial.

135-3: YouTube can be really helpful.

164-3: One of the things I used find frustrating, okay, you've got YouTube, you've got your application up over here and you're trying to figure out how to do that, "I've got to go to YouTube." You've got to minimize that and bring up YouTube and go back and forth. What I ended up doing is getting a second monitor. Tremendous help when you don't have to close one and open and go back and forth. You have your application here.

135-3: I use an iPad or iPhone too.

174-3: Yes, the short term memory, because I'll watch it, and I'll think, "I got it," because I get it in my iPad and then I'm doing it on the computer, and then I have to go back three times.

148-4: That's why I'm constantly taking notes. That's how I learn stuff, is writing it down.

164-3: I have to do that too, sometimes.

148-4: Then try to read your writing.

These two quotes were segmented, but they were not categorized under the [learning methods]. They were categorized under [learning barriers].

Figure 1. Example of segment scheme for focus group transcripts.
<table>
<thead>
<tr>
<th>Category</th>
<th>Segment example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attitudes</strong></td>
<td>(Moderator: When you think about learning a new technology, what is your attitude toward learning processes? Tell me the very first thing that pop-up in your mind.)</td>
</tr>
<tr>
<td></td>
<td>[164-3: Exciting. An opportunity to learn.]</td>
</tr>
<tr>
<td></td>
<td>[174-2: Scared.]</td>
</tr>
<tr>
<td><strong>Learning barriers</strong></td>
<td>(Moderator: Think for a moment about your daily life, what other barriers or difficulties that you have experienced during the time when you learned?)</td>
</tr>
<tr>
<td></td>
<td>[140-1: What I know is, sometimes they'll say, &quot;Okay, hit this button to get to this.&quot; Well, my laptop doesn't call it that button, so I don't know what they're talking about. Which button?]</td>
</tr>
<tr>
<td></td>
<td>[126-4: For me, it's learning and remembering the new terminologies, the vocabularies that's associated with new stuff.]</td>
</tr>
<tr>
<td><strong>Learning methods</strong></td>
<td>(Moderator: Is there any particular learning method that you used to try to get over all difficulties or barriers?)</td>
</tr>
<tr>
<td></td>
<td>[128-1: I paid for tech support, I call a lot.]</td>
</tr>
<tr>
<td></td>
<td>[126-4: … if it's a Google device I have a Google tablet I can go to their help pages, they understand how to do that.]</td>
</tr>
<tr>
<td><strong>Starting points</strong></td>
<td>(Moderator: When you just got a new product, what was the first step that you tried to do in terms of the learning process? And what made you try it?)</td>
</tr>
<tr>
<td></td>
<td>[152-4: Actually, I start off just using it to whatever the basic function I bought it for. I use it that way first.]</td>
</tr>
<tr>
<td></td>
<td>[152-4: If I'm talking to somebody and they say, &quot;Have you tried this or that?&quot; Then, I'll go and experiment with that.]</td>
</tr>
<tr>
<td><strong>User needs</strong></td>
<td>(Moderator: Among all the learning methods, tools, and learning materials we just discussed, what improvement would you like to see that come with the product?)</td>
</tr>
<tr>
<td></td>
<td>[127-4: If there was a glossary, it would help, because then I'd know, &quot;Well, this word means that.&quot; And the functionality would be a little more clear, but, yes.]</td>
</tr>
<tr>
<td></td>
<td>[170-4: I'm thinking in terms of software and to me one of the most important things is the undo key. When I get somewhere I didn’t want to be, can I go back.]</td>
</tr>
</tbody>
</table>
# Appendix E

## Distribution of Codes in Study 1 (Chapter 3)

**Table 1**

*Complete Frequency of Codes for Positive Attitudes (subcategory)*

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<tr>
<th>Theme</th>
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<th>Novice</th>
<th>Advanced beginner</th>
<th>Competent</th>
<th>Proficient</th>
<th>(Total)</th>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Communication</strong></td>
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<td></td>
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<tr>
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*(continued)*

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*Note.* The list of themes is sorted alphabetically.
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<td>0</td>
<td>0</td>
<td></td>
<td>(0)</td>
</tr>
<tr>
<td><strong>Total (Finance)</strong></td>
<td><strong>2</strong></td>
<td><strong>1</strong></td>
<td><strong>3</strong></td>
<td><strong>1</strong></td>
<td></td>
<td><strong>(7)</strong></td>
</tr>
<tr>
<td>Health:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
<td>(10)</td>
</tr>
<tr>
<td>Memory</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td></td>
<td>(8)</td>
</tr>
<tr>
<td>Time</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
<td>(10)</td>
</tr>
<tr>
<td><strong>Total (Health)</strong></td>
<td><strong>6</strong></td>
<td><strong>9</strong></td>
<td><strong>7</strong></td>
<td><strong>6</strong></td>
<td></td>
<td><strong>(28)</strong></td>
</tr>
<tr>
<td>Transportation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td></td>
<td>(8)</td>
</tr>
<tr>
<td>Memory</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>(0)</td>
</tr>
<tr>
<td>Time</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>(0)</td>
</tr>
<tr>
<td><strong>Total (Transportation)</strong></td>
<td><strong>1</strong></td>
<td><strong>3</strong></td>
<td><strong>2</strong></td>
<td><strong>2</strong></td>
<td></td>
<td><strong>(8)</strong></td>
</tr>
<tr>
<td>Shopping:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
<td>(12)</td>
</tr>
<tr>
<td>Memory</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Time</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
<td>(5)</td>
</tr>
</tbody>
</table>
Table 2
(continued)

<table>
<thead>
<tr>
<th>Total (Shopping)</th>
<th>9</th>
<th>6</th>
<th>2</th>
<th>1</th>
<th>(18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (Negative attitudes)</td>
<td>54</td>
<td>39</td>
<td>26</td>
<td>20</td>
<td>(139)</td>
</tr>
</tbody>
</table>

*Note.* The list of themes is sorted alphabetically.

Table 3
*Complete Frequency of Codes for Learning Barriers*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Frequency count</th>
<th>Novice</th>
<th>Advanced beginner</th>
<th>Competent</th>
<th>Proficient</th>
<th>(Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning barriers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor control</td>
<td></td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>(15)</td>
</tr>
<tr>
<td>Vision</td>
<td></td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>(13)</td>
</tr>
<tr>
<td>Working memory</td>
<td></td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>(20)</td>
</tr>
<tr>
<td><strong>Total (Abilities)</strong>*</td>
<td></td>
<td>13</td>
<td>9</td>
<td>12</td>
<td>14</td>
<td>(48)</td>
</tr>
<tr>
<td>Product characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complexity</td>
<td></td>
<td>13</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>(24)</td>
</tr>
<tr>
<td>Familiarity</td>
<td></td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>(25)</td>
</tr>
<tr>
<td>Generalization</td>
<td></td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>(16)</td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>(21)</td>
</tr>
<tr>
<td><strong>Total (Product characteristics)</strong></td>
<td></td>
<td>31</td>
<td>20</td>
<td>17</td>
<td>18</td>
<td>(86)</td>
</tr>
<tr>
<td>Instructions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (Instructions)</strong></td>
<td></td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>(13)</td>
</tr>
<tr>
<td><strong>Total (Learning barriers)</strong></td>
<td></td>
<td>46</td>
<td>32</td>
<td>34</td>
<td>35</td>
<td>(147)</td>
</tr>
</tbody>
</table>

*Note.* The list of themes is sorted alphabetically.
Table 4
*Complete Frequency of Codes for Learning Methods*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Novice</th>
<th>Advanced beginner</th>
<th>Competent</th>
<th>Proficient</th>
<th>(Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning methods</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Learning alone</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read instruction manuals</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>(14)</td>
</tr>
<tr>
<td>Read notes</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>(14)</td>
</tr>
<tr>
<td>Trial and error</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>10</td>
<td>(28)</td>
</tr>
<tr>
<td>Use a second device as guidance</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>(10)</td>
</tr>
<tr>
<td>Use Help features</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>(8)</td>
</tr>
<tr>
<td>Watch YouTube videos</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>(28)</td>
</tr>
<tr>
<td><strong>Total (Learning alone)</strong></td>
<td>11</td>
<td>24</td>
<td>31</td>
<td>36</td>
<td>(102)</td>
</tr>
<tr>
<td><strong>Learning from domain experts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask IT support</td>
<td>8</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>(16)</td>
</tr>
<tr>
<td>Take class</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>(18)</td>
</tr>
<tr>
<td><strong>Total (Learning from domain experts)</strong></td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>8</td>
<td>(34)</td>
</tr>
<tr>
<td><strong>Learning from family/friends</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask the same generation</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>(9)</td>
</tr>
<tr>
<td>Ask the younger generation</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>(15)</td>
</tr>
<tr>
<td><strong>Total (Learning from family/friends)</strong></td>
<td>8</td>
<td>9</td>
<td>4</td>
<td>3</td>
<td>(24)</td>
</tr>
<tr>
<td><strong>Total (Learning methods)</strong></td>
<td>32</td>
<td>42</td>
<td>39</td>
<td>47</td>
<td>(160)</td>
</tr>
</tbody>
</table>

*Note.* The list of themes is sorted alphabetically. Subtheme read notes (under the theme learning alone) refers to the notes that individuals took from their previous learning processes. The format of the notes discussed in the focus groups included video recording, screenshots, written memos, hand draw pictures, pictures took on the phone.
Table 5  
*Complete Frequency of Codes for Starting Points*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Frequency count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Starting points</strong></td>
<td></td>
</tr>
<tr>
<td>A wanted task</td>
<td>7, 5, 3, 2</td>
</tr>
<tr>
<td>Basic functions</td>
<td>1, 2, 4, 3</td>
</tr>
<tr>
<td>Others' recommendations</td>
<td>4, 6, 5, 4</td>
</tr>
<tr>
<td>Systems' default</td>
<td>0, 1, 2, 4</td>
</tr>
<tr>
<td><strong>Total (Starting points)</strong></td>
<td>12, 14, 14, 13</td>
</tr>
</tbody>
</table>

*Note.* The list of themes is sorted alphabetically.

Table 6  
*Complete Frequency of Codes for User Needs*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Frequency count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>User needs</strong></td>
<td></td>
</tr>
<tr>
<td>24/7 accessible QuickStart</td>
<td>1, 0</td>
</tr>
<tr>
<td>Customized learning progress</td>
<td>1, 0</td>
</tr>
<tr>
<td>Function glossary</td>
<td>2, 2</td>
</tr>
<tr>
<td>Interface for notes-keeping</td>
<td>1, 1</td>
</tr>
<tr>
<td>Results foreshadowing</td>
<td>4, 5</td>
</tr>
<tr>
<td>Self-defined icon/button</td>
<td>3, 1</td>
</tr>
<tr>
<td>Smart search</td>
<td>2, 0</td>
</tr>
<tr>
<td>Undo button</td>
<td>2, 3</td>
</tr>
<tr>
<td><strong>Total (User needs)</strong></td>
<td>16, 12</td>
</tr>
</tbody>
</table>

*Note.* The list of themes is sorted alphabetically. Only participants in the competent group and the proficient group made comments in this category.
Appendix F

Overview of All Categories and Themes in Study 1 (Chapter 3)
Appendix G

IRB Approval Letter (and renewal) for Study 2 (Chapter 4)

Date: 29Mar2019

Study Title: Interaction Design of New Technologies for Older Adults: From the Ease of Learning Perspective (Demo/Prototype Learnability Testing)

NC State eIRB #: 12726

Funding Source: N/A

Dear Hongyang Liu,

The project listed above has been reviewed and approved by the NC State Institutional Review Board for the Use of Human Subjects in Research. This project received approval via expedited procedures as outlined in 4 CFR 46.110 under category 7. 

This protocol was approved on: 05Oct2018

NOTE:

1. This board complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU the Assurance Number is: FWA00003429.

2. Any changes to the protocol and supporting documents must be submitted and approved by the IRB prior to implementation.

3. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days by completing and submitting the unanticipated problem form on the IRB website.

4. Your approval for this study lasts for one year from the review date. If your study extends beyond that time, including data analysis, you must obtain continuing review from the IRB.

Sincerely,

Jennie Ofstein
IRB Director
Institutional Review Board (IRB)
irb-director@ncsu.edu
919.515.8754
North Carolina State University
Date: 18Sep2019

Study Title: Interaction Design of New Technologies for Older Adults: From the Ease of Learning Perspective (Demo/Prototype Learnability Testing)

NC State eIRB #: 12726

Funding Source: N/A

Dear Sharon Melissa Jone’s and Hongyang Liu,

The renewal for the project listed above has been reviewed and approved by the NC State Institutional Review Board for the Use of Human Subjects in Research. This project received approval via expedited procedures as outlined in 4 CFR 46.110 under category 7. Approval for this study does not expire.

This protocol renewal was approved on: 17Sep2019

NOTE:

1. This board complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU the Assurance Number is: FWA00003429.

2. Any changes to the protocol and supporting documents must be submitted and approved by the IRB prior to implementation.

3. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days by completing and submitting the unanticipated problem form on the IRB website.

Sincerely,

Jennie Ofstein
IRB Director
Institutional Review Board (IRB)
irb-director@ncsu.edu
919.515.8754
North Carolina State University
## Appendix H

### Reliability of the Questionnaires in Study 2 (Chapter 4)

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>N of Items</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-task questionnaire</td>
<td>4</td>
<td>.72</td>
</tr>
<tr>
<td>Technological self-efficacy questionnaire</td>
<td>3</td>
<td>.91</td>
</tr>
</tbody>
</table>

*Note.* Considering the technological self-efficacy questionnaire and the post-task questionnaire were designed for the context of this study only, a pilot study was conducted (with 8 undergraduate students and 22 graduate students) to test the reliability of the questionnaires. Cronbach’s alpha was used to measure the internal consistency of two questionnaires. Based on the results, all questionnaires demonstrated relatively high internal consistency. (A reliability coefficient of .70 or higher is considered “acceptable” in most social science research situations.)
Appendix I

Demographics Questionnaire for Study 2 (Chapter 4)
(modified from Czaja et al., 2006)

Demographics Questionnaire

1. Gender: Male □ Female □

2. Age: _____

3. What is your highest level of education?
   □ No formal education
   □ Grade school
   □ High school graduate/GED
   □ Vocational training
   □ Some college/Associate’s degree
   □ Bachelor’s degree (BA, BS)
   □ Master’s degree (or other post-graduate training)
   □ Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)

4. Nationality: ____________
   If your nationality is not the U.S., how long have you lived in the U.S.? _____

5. What is your primary occupation? __________________________
   If you are retired, what was your primary occupation? __________________________

6. In general, would you say your health is:
   □1 Poor □2 Fair □3 Good □4 Very Good □5 Excellent

7. Compared to other people your own age, would you say our health is:
   □1 Poor □2 Fair □3 Good □4 Very Good □5 Excellent

8. Pertinent Health Information: _______________________________________

---

9. Overall Personal State (Initial):
   Please indicate whether you agree or disagree with this statement “I feel comfortable”.
   □1 Strongly Disagree □2 Disagree Tend to □3 Disagree □4 Agree Tend to □5 Agree Strongly □6 Agree

---

*This part is to be filled at the end of the session*

10. Overall Personal State (End of Session):
   Please indicate whether you agree or disagree with this statement “I feel comfortable”.
   □1 Strongly Disagree □2 Disagree Tend to □3 Disagree □4 Agree Tend to □5 Agree Strongly □6 Agree
Appendix J

Technological Self-Efficacy Questionnaire for Study 2 (Chapter 4)

Instruction: Please rate how much you agree or disagree with the following statements. There are no right or wrong answers.

1. I can quickly learn new technology.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

2. I can usually deal with most difficulties I encountered when using technology.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

3. I find working with technology very easy.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Appendix K

Post-Task Questionnaire for Study 2 (Chapter 4)

Prototype: Online food ordering
LFF:

Instruction: Please rate how much you agree or disagree with the following statements based on your experience with the specific feature you just interacted with.

1. This feature improved my effectiveness in online food ordering.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

2. This feature made it easier to search for and select the food I want to order.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

3. I find this feature made my food ordering process unnecessarily complicated.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

4. Overall, I am satisfied with the function this feature provided.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Instruction: Please rate how much you agree or disagree with the following statements based on your experience with the specific feature you just interacted with.

1. **This feature improved my effectiveness in device pairing.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

2. **This feature made it easier to search and pair the devices I want to connect.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

3. **I find this feature made my device pairing process unnecessarily complicated.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

4. **Overall, I am satisfied with the function this feature provided.**

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Appendix L

Learnability Focused Features (LFFs) in Study 2 (Chapter 4)
Appendix M

Prototypes in Study 2 (Chapter 4)

Figure 1. An overview of the interfaces in the mock-up online food ordering system.
Figure 2. An overview of the interfaces in the mock-up device pairing system.
Appendix N

Structured Interview Script for Study 2 (Chapter 4)

Participant Number: _____________

Now that you have seen all the demos and operated all the prototypes in this study, I would like you to answer a few questions regarding your experience with those features in the mock-up systems. There are no right or wrong answers, please just provide your opinion. Thank you very much.

Let’s start from the post-task questionnaires you finished for each prototype you’ve experienced.

You rated that #_________ improved your effectiveness in online food ordering (or in device pairing). Could you tell me why do you think the feature improved your effectiveness?

You rated that #_________ made it easier to search for and select the food you want to order (or search and pair the devices you want to connect). Could you tell me why do you think the feature made it easier for the process?

You rated that #_________ made the process unnecessarily complicated. Could you tell me why do you think the feature made the process unnecessarily complicated?

I’ve noticed that you were commenting that ___ (insert notes) ____ while you were interacting with #_________. Are there any barriers you encountered during the session?

You ranked #_________ is the most preferred feature and #_________ is the least preferred feature in the preferences questionnaire. Could you please explain your choices for the most preferred and the least preferred feature types?

Please choose one feature that you think your friends (similar age, average education level, health condition level, and technology experience level) would like the most. Could you please explain why you think he/she would like that feature?

Do you have other comments about the six feature demos and the two prototype you’ve seen today? Any question about the research study?

Here is the gift card. Thank you so much for your participation.
Appendix O

Rating Results (between prototypes) in Study 2 (Chapter 4)

Figure 1. Comparison of rating results in effectiveness between the two prototypes (PF and PB).

Figure 2. Comparison of rating results in efficiency between the two prototypes (PF and PB).
Figure 3. Comparison of rating results in complexity between the two prototypes (PF and PB).

Figure 4. Comparison of rating results in overall satisfaction between the two prototypes (PF and PB).
Appendix P

IRB Exempt Approval Letter for Study 3 (Chapter 5)

From: Amanda Hockney, IRB Analyst
North Carolina State University
Institutional Review Board

Date: 5/23/19

Title: Interaction Design of New Technologies for Older Adults: From the Ease of Learning Perspective (Design Features Evaluation)

IRB#: 16794

Dear Hongyang Liu and Sharon Melissa Joines,

The research proposal named above has received administrative review and has been approved on 5/10/19 as exempt from the policy as outlined in the Code of Federal Regulations (Exemption: 46.104, d. 2). Provided that the only participation of the subjects is as described in the proposal narrative, this project is exempt from further review. This approval does not expire, but any changes must be approved by the IRB prior to implementation.

NOTE:
1. This committee complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU projects, the Assurance Number is: FWA00003429.

2. Any changes to the research must be submitted and approved by the IRB prior to implementation.

3. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days.

Please forward a copy of this letter to your faculty sponsor, if applicable.
Thank you.

Sincerely,

Jennie Ofstein
IRB Director
Institutional Review Board (IRB)
irb-director@ncsu.edu
919.515.8754
North Carolina State University