RECONCEPTUALIZING THE ENGAGEMENT OF OLDER ADULTS IN THE USE OF INTERACTIVE TECHNOLOGY

by

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ABSTRACT

LINA LEE. Reconceptualizing the Engagement of Older Adults in the Use of Interactive Technology. (Under the direction of DR. MARY LOU MAHER)

A "silver tsunami" is on its way. Silver tsunami refers to the rapid aging of the population and, in particular, of the baby boomer generation. This demographic shift has moved the focus of researchers, designers, health care providers, and policymakers from ascertaining ways to extend the lifespan to ways to improve the quality of life. The aging population constitutes one of the most significant social transformations in the 21st century, making technology essential for the senior community to integrate with the outside world. However, the focus of recent research in designing technology for older adults lies in its usability and ability to monitor health. Despite the increasing number of studies in the field of aging and technology, there is insufficient research on understanding the practical issues of user focus, adoption, and engagement with respect to interactive technologies among older adults. In this study, we used four technological interventions (Move and Paint, Savi, uDraw, and GrandPad) that are new to older adults to stimulate and increase their initial engagement with technology use. We employed a mixed-method approach involving focus group discussions, in-depth interviews, observations, and diary study to understand the technology-related perceptions and behaviors of older adults and identify factors affecting their initial engagement with interactive technology. This study points out the lack of research on initial engagement among older adults and highlights the importance of the same in the use of new interactive technology. Initial engagement, which affects long-term engagement, is more important than need and usability and poses different challenges among older adults based on their behaviors toward interactive technology. The contributions of this study are 1) a new model for older adults' engagement with interactive technology, 2) an active-passive spectrum of older adults' behaviors to-

ward interactive technology, and 3) the identification of key factors that influence the initial engagement of older adults. We present new expectations of initial engagement in Human Computer Interaction (HCI) and suggest new research directions in the use of interactive technology by older adults.

DEDICATION

This work is dedicated to my daughter, Erin Kim. You have made me stronger, better, and more fulfilled than I could have ever imagined. You are my inspiration to achieve greatness. Without you, I would not be where I am today. I love you so much.

To Jin Goog Kim, my beloved husband who always loves me and sacrifices himself for me. Thank you for being my leader, my strength when I am weak, my calm where I am angry, my sane where I am crazy, my everything I need. Love you forever.

My world is my parents I cannot express their love and dedication. To Mom (Hae Sook Choi) and Dad (Myeung Suk Lee), this achievement is yours. Your support, encouragement, and constant love have sustained me throughout my life.

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LIST OF ABBREVIATIONS

AC Affective Computing.

ADLs Activities of Daily Living.

AIP Aging in Place.

ALFs Assisted Living Facilities.

AmI the Application of Ambient Intelligence.

AR Augmented Reality.

EU the European Union.

HCI Human Computer Interaction.

ICT Information and Communications Technology.

IRB the Institutional Review Board.

SIGCHI the ACM Special Interest Group on Computer-Human Interaction.

UX User Experience.

VR Virtual Reality.

CHAPTER 1: INTRODUCTION

Long life expectancies and falling birth rates have resulted in changes in world demographics over the past two decades [1]. A "silver tsunami" is on its way-a metaphor referring to the rapidly aging population, particularly the baby boomer generation. Alongside this change, the past decades have witnessed a substantial increase in the use of technology in all aspects of daily living. The application of technology to the aging process can help people "age well" and stay active [2, 3]. In this regard, various technological inventions have been developed to help the aging persons to independently perform the most essential activities and live comfortably as well as keep themselves connected to family members and friends [4, 5, 6]. Utilizing interactive technology offers convenience, interconnection with family and friends, improved and reliable security, comfort, etc. Technology is essential for the senior community to integrate with the outside world [7, 6]. Further, technological literacy is increasingly required for seniors to live in retirement communities because of the various ways in which technology is now being used, including webcams to connect with family and friends, entertainment via online gaming and quizzes to help stimulate a person's mind, and rehabilitation programs enabled by technology. In short, older adults are exposed to technology from their living environments, regardless of their level of willingness to use the same [8].

The COVID-19 pandemic has triggered an urgent need to address the societal changes of the aging population due to the need for health care and social isolation [9, 10]. Thus, there is an increased demand for using interactive technologies. There is also a need to design technologies that mitigate the negative effects of virtual life and social isolation for older adults during the pandemic as well as build an in-depth

understanding of older adults' perceptions and preferences. The shifting demographics and current pandemic have moved researchers, designers, and developers' focus from discovering ways to extend one's lifespan to ways to increase the levels of engagement with technology to improve the quality of life. Age-related changes such as reduced mobility and health issues prevent older adults from fully participating in the activities which are essential for their wellness. Many scholars expected that technological solutions could improve the physical and mental health of older adults (see Section 2.3), thus resolving their discomfort [11, 12, 13]. Although emerging technology developed for older adults does stimulate their interest and facilitates their initial utilization of the technology, it fails to attract or retain their interest and promote long-term adoption. We found that many studies in HCI tend to evaluate the feasibility or usability of technology [14]. Researchers have conducted user studies with older adults, relying on self-report methods. The results show that older adults often assess the technology as positive; however, there is a lack of clear evidence to show that older adults will adopt the emerging technology and integrate it with their lives [15, 16, 17]. Despite the increasing number of studies in the field of aging and technology [18, 19], insufficient research has been conducted to understand the practical issues of user focus, adoption, and engagement with respect to interactive technologies among older adults. Thus, this study points out the lack of research on initial engagement in older adults and highlights the importance of initial engagement in the use of new technology. We begin to address that gap by asking the following overarching research question: What are the factors that engage the older population in the use of technology to adapt and live well in the digitized world? The goal of this thesis is to re-conceptualize designing engaging technologies and user experiences for older adults in the use of interactive technology. First, we propose a new concept or definition of older adults' engagement to promote better usage of interactive technology for them. Second, we present the active-passive spectrum of the behaviors of

older adults toward technology relevant to their initial engagement with interactive technology in public and private settings. Last, we identify key factors that influence the initial engagement of older adults and suggest new research directions in the field of aging and technology.

1.1 Motivation

My personal motivation to research the field of aging and technology began when I took a design studio class as part of my PhD studies. As a team, we designed the Smart Walker, a device intended to encourage the residents of a retirement community to be more active. Our prototype does this by automatically keeping track of the user's distance walked. It also integrates with and adds to the existing Walk Across America program, thereby letting the residents individually explore the cities their group reaches as they progress around the country. To keep track of the distance that a user has traveled, the Smart Walker counts the number of times that one of its back wheels has rotated. It does this by using a reed switch mounted to a frame, which opens and closes as a magnet mounted on one of the rear wheels turns. As the magnet turns, a signal is sent up to the Arduino, which is mounted underneath the seat of the walker. The Arduino keeps count of the rotations the wheel makes. We conducted several user studies to determine if we were meeting our design goals in a manner that was consistent with the needs of our target group. During the interview, our participants gave positive feedback on the Smart Walker system. However, when we asked the question "If our system can be installed on your own walker, are you willing to use this system for daily use?" two out of four participants gave the answers "don't know" and "not for me, but would recommend to others." Due to this, I was curious about how they can incorporate such technologies into their daily lifestyle and how to ensure that they sustain their engagement with the system without losing interest. I continue to be personally interested in creating engaging digital experiences for older adults.

With the above aims, I began going through the existing literature and studying the interactive technologies designed for older adults. We live in a society surrounded by various interactive technologies. Numerous studies have shown positive correlations between technology use and subjective well-being [20], highlighting that engagement with new technologies might be of importance for successful and active aging. However, designing new technology for older adults is challenging [21]. I learned that new technologies which were designed without understanding the characteristics of older adults that impeded their experiences with these technologies or even cause harm to vulnerable users. When people grow older, they inevitably experience a significant decrease in their physical, cognitive, and sensory capabilities, which leads them to develop negative attitudes towards technology [19, 22]. In reality, studies on diverse technological interventions tend to focus on utilitarian factors, such as usability and monitoring physical experiences [23], and rarely mention engagement and positive social affects [24]. Many studies overlook the fact that the positive mindset of older people has a positive impact on their physical and mental health. A sense of burden regarding the use of interactive technology, a technology with which they are unfamiliar, could make them more passive in adopting it, resulting in a reluctance to use other technologies in their life. Most previous studies on interactions among old adults have defined an elderly individual using the criterion of age or inability [25, 26, 27, 28], but age is not a predictor for the use of interactive technology. It is a fact that physical ability decreases as one becomes old. Older adults are usually overlooked when developing new systems. It is necessary to recognize the fact that older adults have various preferences and needs as well and to understand their characteristics. Each older person has a different level of skills and capability.

Several interactive systems have been developed with little consideration for older adults because the assumption has been that the older population hasn't much interest in the use of information and communication technologies [18]. There is a need to

examine the reasons behind this resistance to interactive technologies among older adults despite the benefits accrued from such innovations. Although the interfaces are designed to be simple enough for anyone to use, even older adults, there are many challenges in the initial engagement process, especially regarding the retention of interest and ease of using the interfaces. Although older adults occasionally use devices, they only rely on several functions that can be easily used, with the others hidden in manuals or consisting of many steps that are ignored and unused regardless of their value. Moreover, although older adults recognize how to operate some useful functions, they may find it difficult to relearn the functions for repeated use. Hence, it is necessary to consider how to help older adults engage with technology while providing a positive experience in the stage of designing such systems.

Designers are asked to create engaging digital experiences. Human-computer interaction studies have emphasized the need to move beyond usability to understand and design for more engaging experiences [29, 30, 31]. Successful technologies are not just usable; they engage users. The question is no longer only whether an application is efficient, effective, or satisfying but how well it is able to engage users and provide them with a fulfilling experience [32, 33]. However, technology for older adults is still designed without considering their engagement. In this paper, I discuss older adults' attitudinal characteristics when using interactive technologies according to different characteristics, demonstrating the physical, cognitive, and affective components of user experiences. I also present an investigation of engagement factors for older adults' use of interactive technologies.

1.2 Research Focus

Aging is a field of great interest in HCI venues. As aging is a multifaceted and complex phenomenon, it cannot be understood without a holistic view of various research disciplines that should be combined and studied [14]. Older adults form a heterogeneous group, and it is difficult to generalize the characteristics of their tech-

nology use due to various physical, psychological, emotional, social, and economic factors [34]. Many studies have been conducted to understand the social, economic, and health concerns facing older adults and, thereby, obtain technology-based solutions for the same [14]. Researchers have conducted studies to understand what older adults expect from technology to maintain their independence [35]. The field of HCI focuses on users, rather than technological software or development, to understand the problems, needs, or ability of users to use technology [36]. Many studies focus on older adults' needs rather than trying to understand why, how, and when older adults want to initially engage in using technology. It is essential to develop HCI research trends that focus on older adults who need to supplement their physical ability, the ones who need assistance in life due to dementia, or those who are socially isolated; it is crucial to their needs in special circumstances. However, it is also important to study the general context of aging and the desires of older adults since they will be required to depend on technology for several aspects of their life, irrespective of whether they want to.

Vines et al. [14] performed a systematic review with 644 archived publications from the ACM Special Interest Group on Computer-Human Interaction (SIGCHI) publications related to aging. He framed the "problems" faced by older adults and how they can be managed by technologies. He identified four dominant discourses related to aging in the SIGCHI community and suggested research directions for HCI researchers. We chose this review paper to organize our research focus and review a sufficient number of papers to identify the issues and trends of HCI research related to aging. Our research focus is well aligned with future HCI research directions that Vines et al. [14] pointed out in their review paper.

First, the problem of funding placement is a reason why many studies focus on health economics. Since the 20th century, funding has focused only on biomedical issues of aging in gerontology [37], and a lack of funding has been a problem for the

fields of psychological and behavioral sciences and humanities [38]. Vines et al. [14] described the first future HCI research direction, stating the "HCI research community should reflect on and be critical about where the motivations for researching aging come from (p. 17)". Thus, rather than suggesting practical and economical solutions to older adults, the present research was focused on exploring the essential behavioral characteristics and engagement of older adults with technology (Chapter 5 and 6).

Second, homogeneity is pointed out as a problem of HCI research. Older adults treated in HCI are considered the same group regardless of their characteristics, abilities, or experiences with technology [25, 26, 27, 28]. The second research direction was as follows: "Critically engage with the context of aging across an individual's life course and reflect upon how their personal histories impact on technology use now and in the future (p. 19)" [14]. Our study classifies older adults with various experiences across various ages into five cases. We conducted an extensive review to understand older adults' unique characteristics as they age (Chapter 2 and 3). We design our study to conduct in-depth qualitative analyses of various phenomena surrounding each use of technology, rather than a lab study of the usability of the technology (Chapter 4).

Finally, Vines et al. [14] pointed out the problem of many HCI studies that always determine older adults are deficient and in need of assistance [39, 40, 41, 42]. The last future HCI direction was as follows: "By engaging with older adults before the design process, embrace alternative measures and attributes of "success" in later life (p. 20)" [14]. Our research focuses more on designing interactive technologies to support fun and engaging experiences to older adults using technology, rather than targeting older adults who lack essential factors in their lives or providing technology to satisfy the deficiencies (Chapter 4). It emphasizes the need to overcome the barriers that older adults encounter when they try the system for the first time and strives to elicit a desire to try new technology that older adults have not experienced before. There-

fore, we identify the key factors of initial engagement of older adults in the use of interactive technology (Chapter 6).

Thesis Statement

Initial engagement, which affects long-term engagement, is more important than need and usability and has different challenges for older adults based on their behaviors toward interactive technology.

When designing interactive technology for older adults, considering the factors that enable older adults' engagement with technology should precede the design of interactions or consideration of usability issues. We claim in this dissertation that initial engagement is more important than need and usability and has different challenges for older adults based on their behavior with interactive technology. Initial engagement, need, and usability are part of user experience and help the user have a more positive experience. The boundaries between them are not clear. Our understanding of the notion of initial engagement and need discussed in this dissertation is that they are both cognitive processes of the user, but usability is a physical process that is more related to actual usage. Usability becomes critical and encompasses a lot of what the user feels after they decide to use the system. To distinguish between initial engagement and need, we need to understand what older adults want versus what older adults need. Older adults would be more engaged in using technology when they are provided with the technology they want rather than the technology that designers think they need. We need to distinguish the needs from the wants of older adults. As many studies merely focus on determining the needs of older adults, the interactive systems for older adults are mainly inclined toward devices to compensate for their physical and mental shortages. To understand the initial engagement of older adults, a "want-finding" process needs to be performed when designing interactive technolo-

gies for older adults in order to lead to satisfactory and enjoyable experiences. Older adults might prefer using virtual reality (VR) games just for fun instead of wearing a wearable device to monitor their health and track fitness. Wearable technology may be a "required" system for older adults, but it might not be the system "wanted" by older adults.

Research Questions

- **RQ1:** How can we go beyond need and usability in conceptualizing engagement to address the gap in studying older adults' initial engagement with interactive technology?
- **RQ2:** How is the active-passive spectrum of the behaviors of older adults toward technology relevant to their initial engagement with interactive technology?
- **RQ3:** What are the factors for initial engagement among older adults in the use of interactive technology?

1.3 Methods and Evaluation

A mixed-method approach was adopted to address and explore the research questions above, comprising three main activities: 1) reviewing literature to develop the research framework and highlight the importance of initial engagement for older adults in the use of interactive technology. 2) designing technological interventions to understand older adults' motivation to use technology and evaluating their technological behaviors on the spectrum of active and passive, 3) analyzing older adults' initial engagement through ethnographic approach in the real-world context. We used four technological interventions (Move and Paint, Savi, uDraw, and GrandPad) that are new to older adults for stimulating and increasing the initial engagement in using technology. Move and Paint and the uDraw Game Tablet are embodied interactive

technologies that facilitate social creative expression by allowing users to create free form drawings, artwork, and games. Savi and GrandPad are communication technologies that enable older adults to easily communicate with their loved ones. We designed Move and Paint and Savi. uDraw and GrandPad are commercial products which have similar design goals and usage to Move and Paint and Savi. We performed a series of evaluation to investigate older adults' behavior and initial engagement towards the use of technology. The methodologies considered for this dissertation were focus group discussion, in-depth interview, diary studies, observations, in-situ, and field study.

New model of engagement of older adults with interactive technology (RQ 1)

To gain a basic understanding of aging and technology, we reviewed age-related theories, physical, cognitive, and psychological challenges older adults face while using interactive technology, and factors influencing their usage and adoption of technology. By reviewing the existing concept of user engagement with basic understanding of older adults' use of technology, we identified the research gap and conceptualized engagement in studying older adults' initial engagement with interactive technology in Chapter 3.

The active-passive spectrum of the behaviors of older adults (RQ 2)

To identify various use cases and the active-passive spectrum of the behaviors of older adults relevant to their initial engagement with interactive technology, our research team designed and developed the Move and Paint and Savi systems to encourage older adults to try new technology. To understand older adults' usage and behavior, in-situ studies to observe natural behaviors around the systems and qualitative studies such as focus group discussions, and interviews to receive their feedback to the systems were planned. We present the factors influencing older adults' tech-

nology usage and their behavioral spectrum in Chapter 5.

Factors for initial engagement among older adults (RQ 3)

With insights gained from the formative studies described in Chapter 5, we identified the uDraw and GrandPad systems and planned to conduct an ethnographic study to understand older adults' initial engagement with interactive technology. We stayed in the senior communities and actively communicated with family members with older adults over six months to identify the initial engagement factors. The results of the same have been presented in Chapter 6.

1.4 Contributions

The contributions of this study are as follows:

- Development of a new model for older adults' engagement with interactive technology (Chapter 3)
- Analysis of an active-passive spectrum of behaviors of older adults toward interactive technology (Chapter 5)
- Identification of the key factors that influence the initial engagement of older adults (Chapter 6)

First, we propose a new concept of engagement for older adults in the use of interactive technology. Unlike studies that focus on enhancing long-term engagement in older adults, one contribution of this dissertation is to describe the importance of understanding the nature and characteristics of older adults' engagement in the use of the technology itself.

Second, in studies evaluating the use of technology of older adults, older adults are generally classified as a single group based on biological characteristics. The contribution of this dissertation is to introduce a new way of categorizing this demographic

based on the active-passive spectrum of behaviors to present diverse use cases with interactive technology.

Last, ethnographic studies have identified the key factors that influence the initial engagement of older adults. The contribution of this dissertation is to present new expectations of initial engagement in HCI. These results suggest new research directions in the use of interactive technology by older adults.

1.5 Thesis Overview

The dissertation is organized as follows: Chapter 1 presents the purpose of the study, the research questions to be investigated, and the significance of the study. Chapter 2 reviews related work including theoretical age-related characteristics that are relevant to adopt the technology. This chapter additionally presents challenges and barriers faced by older adults and the factors influencing continued usage and adoption of technology by older adults. Chapter 3 reviews engagement factors with age-related challenges in the use of technology. Then, a new model for older adults' engagement with interactive technology is presented and the importance of initial engagement among older adults highlighted. Chapter 4 describes the four technological interventions that were used for this study. Two gesture-based interactive technologies for social creative expression in a community center and two communication technologies that enable emotional connections in a family setting are introduced. Then, the application of the research methods used for this study are described. Chapter 5 examines general attitudes towards interactive technologies and present factors influencing technology usage that emerged from the Move and Paint and Savi studies. Subsequently, a new way of categorizing older adults in the passive-active spectrum and diverse use cases of the Move and Paint and Savi systems are presented. Chapter 6 presents five case studies with nine initial engagement factors that emerge from empirical observations of initial engagement with technology; new initial engagement values that emerged from our case studies are proposed. Finally, Chapter 7 contains

the discussion and recommendations for future work.

CHAPTER 2: RELATED WORK

2.1 Summary

This chapter begins with a description of theoretical age-related characteristics related to older adults' long-term engagement, which are relevant in their adoption of technology. We present the basic characteristics of older adults in late adulthood that influence their technology usage, particularly attempting to understand their cognitive changes and abilities rather than their physical abilities. Then, based on these characteristics, we describe the challenges they face and the factors that prevent older adults from effectively engaging with technology. Challenges and barriers that they face in using interactive technologies have been largely divided into six categories in Section 2.3. Each challenge helps us better understand older adults' use of technology. Section 2.4 presents the factors that affect their continued use of and adaptation to new technologies. The notions that we discussed in this chapter will be used to create a new engagement model for older adults in Chapter 3. We created a new engagement model for older adults (Chapter 3) by discussing factors from the existing studies (Chapter 2) and adding new initial engagement factors that emerged in this study (Chapter 6).

2.2 Theoretical Age-related Characteristics Relevant in Adopting Technology

This section describes the underlying characteristics of older adults as they grow to understand the long-term engagement of older adults with age-related theories. Understanding the theoretical age-related characteristics requires us to first unravel the puzzle surrounding aging. Aging presents a certain dynamism in every sphere of life, whether social, psychological, economic, or physiological. Aging being concep-

tualized as one cycle of an eternal process that significantly involves transitions is inevitable [43]. From a psychological viewpoint, changes are experienced in behavior, emotions, personality, and attitudes. When people's health and cognitive faculties or physical functioning begin to decline, they might opt for supportive care environments [44]. Coupled with this is the idea of losing loved ones and the attempt to redefine themselves in the violent face of disability and other challenges that come with aging. Older adults' changing roles and relationships within a society impact their perceptions and choices about their technological needs [45, 46, 47]. Understanding the aging process, involving not only the physical or cognitive functioning changes, but also the complex phenomena surrounding it will enable researchers and designers to predict and provide the processes to develop engaging technologies for older adults. These age-related characteristics affect the attitudes and perceptions of older adults in their acceptance of technology, and thus need to be considered carefully.

2.2.1 Aging adults still want to be active in their later life

Remaining active is important for aging adults in limiting the adverse impacts of aging. The activity theory states that the idea of staying busy and occupied is a requisite for a fulfilling late life [48, 49]. Other researchers refute the theory by arguing that it fails to consider the limitations of physical and financial capabilities among older adults [50, 51]. However, they contend that older adults will only pursue an active life within their own conditions [52]. This active hobby must be one that fits within its economic and social boundaries. Another socioemotional theory of motivation argues that as people grow old, they become selective with needs and activities [53, 54, 55], opting for emotionally meaningful endeavors. Older adults would most often attach value to the quality of an activity and not the quantity [53]. Additionally, other proponents of this theory hold that researchers often misunderstand older people as a generation that struggles with guilt, shame, or depression due to dependency. However, this is because many studies overlook that these individuals still pursue an

active life but one that suits them [56]. A direct relationship between being active and life satisfaction on the part of older people [53, 57]. Ideally, many studies show that several older adults have long-term interest in continuing various activities but are unable to do so due to these activities' physical constraints [58, 59]. Therefore, they seek other ways to remain active. The researcher's efforts should be directed toward using technology to find a suitable activity for older adults. This aspect can be a design goal when designing interactive technology for older adults. We designed a gesture-based painting application for older adults to support their creative activity. The details of this can be found in Section 4.4.1.

2.2.2 Aging adults form a unique subculture within society

As people approach old age, they tend to develop unique subcultures within their society [60]. They consistently defend themselves against society's negative attitudes towards aging and the consequential loss of status. American researchers hold that the resentment and neglect of the older adults by loved ones and the society depicted through stereotyping and disdain has a serious repercussion on their self-esteem and emotional well-being. Therefore, more often than not, it reduces a person's motivation to live [61]. To a point, these members of society begin to view themselves as useless, dependent, and non-contributing to the affairs of their community. Given several factors such as beliefs, cultural norms, and standards, aging can present itself as undesirable [62, 63]. For some older adults, it causes them to stop caring for themselves, while for others, this is an indication that they are moving closer to death. Though aging comes with an accumulation of wisdom and a status worthy of respect [64], they feel this is not the case. As a result, many older adults do not easily reconcile with others within society; hence, they remain isolated. Some critics present a contrasting idea to that of activity theorists. They argue that aging is characterized by a gradual disengagement from society and other relationships [65]. A proposition has been presented asserts that this disengagement makes older adults free from other

social obligations and creates an atmosphere of perfect internal self-reflection around them. In this manner, a balance that is ideally satisfying to both the young and the old is achieved [60]. Additionally, Rose [60] contends that social statuses are nourished by health and mobility instead of occupation, education, and income. Going by this school of thought, social connectedness and support is the central part of a positive aging plan [66]. A pivotal part of positive aging is maintaining social connectedness and social support. Therefore, this notion affects our decision to select the research field for our ethnographic study. We selected a senior community to observe their subculture within society.

2.2.3 Needs are changing for successful aging and creating a meaningful life after retirement

As people age, they become more dependent on others [67]. They require assistance as they have never done before. After losing touch with their friends, families, or loved ones, older adults find contentment with their loneliness [68, 69]. This is a situation that is said to have detrimental implications, health wise and emotionally. For some, it is a chance to begin involving themselves in positive hobbies or joining retirement communities [70, 71, 72]. As people grow old, they become more attached to either family members, relatives, caregivers, or professionals. This results in others spending their late years in assisted living facilities or nursing homes, which crucially impacts their social and emotional well-being.

Sometimes there are frequent relocations during old age. Moving from retirement communities with desirable amenities to smaller, more affordable houses, or even to their siblings' or adult children's houses, reduces the costs and burden of upkeep [73]. This relocation should be planned as well. Older adults who respond poorly to relocation often end up living lonely and miserable lives; socially isolated, poor, and depressed.

Older people experience profound changes in their late life. These changes ne-

cessitate adjustments in people's requirements and activities [74]. We must strive to understand these people because they need to be supported and freed from the feeling of helplessness and depression. They should not be excluded from society. To ensure this, we should consider avenues through which older adults can be awarded a meaningful life according to their needs [75]. To facilitate a meaningful later life, our study focuses on older adults' behavioral characteristics and cognitive activity toward interactive technology. We aim to understand older adults' needs and preferences when utilizing technology for enhancing their long-term engagement.

2.2.4 Aging adults desire to maintain high levels of affective well-being

Older adults are inclined toward maintaining a high level of affective well-being in the midst of several challenges, which include physical illnesses, social losses, psychological discomforts, and increased dependencies [76]. This depends on the longevity of their emotional adjustment. There are normative variances in the emotional goals and strategies during adulthood, as explained in the emotional-motivational life span development theory. For instance, anticipating the idea of an end to a lifetime is the fundamental principle that enhances emotionally fulfilling experiences at a point in time and not the rewards [77]. As a biological process, aging draws people closer to the end of their lives; therefore, this theory suggests that motivations change with age [78]. On the other hand, the dynamic integration theory holds that as the cognitive capacities associated with age diminish, it gets difficult for individuals to integrate and accept negative feelings [79]. In line with Section 2.2.1, we made efforts to design engaging experiences for older adults while using four technological interventions. The details of the four technological interventions we used for this dissertation have been presented in Chapter 4.

This chapter presents four theoretical age-related characteristics that have been discussed in the existing literature. The theoretical characteristics of older adults are those that must be considered when introducing new technologies to older adults. If

designers, developers, or researchers in the field of aging and technology understand the characteristics, an environment can be set up wherein older adults can enjoy technology in a simple and easy manner. Older adults take care of their later life to be positive, so they do not feel the need to embrace new technologies. Nevertheless, since there is a desire to enjoy the rest of their lives, it would be beneficial to provide them with technology that they can utilize for this purpose. When designing interactive technology for older adults, these theoretical age-related characteristics should be understood and considered to promote the long-term engagement of older adults. Therefore, the natural characteristics of older adults discussed in this chapter are a basis for understanding the challenges and barriers to and factors influencing the use of technology, which have been described in the following sections.

2.3 Challenges and Barriers Faced by Older Adults in the Use of Technology

There is a growing body of literature supporting the view that technological support can positively impact older people. Peek et al. [80] noted that there are several technological devices that are designed to facilitate the aging process, including various health applications, sensor-based networks for monitoring activities, fall and wandering detectors as well as those that help them stay in touch with families and friends. However, the use of new technology is more complex for older adults than the younger generation, which can be attributed to the fact that the older people were not exposed to technology during their formative years [80]. Decline in cognition due to age-related factors is viewed as negatively impacting technology usage. This section discusses the challenges faced by older adults when using technology, including the reasons older adults are hesitant to utilize new technology. The causes have been explained in detail by utilizing the existing system. The challenges and barriers faced by older adults in the use of technology, which have been discussed in this section, have been taken as a component of before engagement of the new engagement model in Chapter 3.

2.3.1 Physical and cognitive constraints

A substantial amount of research has been carried out to understand the physical and cognitive challenges and barriers that older adults face in the use of technology [81, 82, 83, 84]. When people start aging, their abilities tend to slowly reduce and gradually end, which, in turn, forces them to start developing negative attitudes towards interactive technologies [85]. The diminishing functional capacity of older adults in terms of cognition, vision, and hearing is a major factor which impacts how technology and software should be designed for older adults [86, 87, 23]. For example, color vision fades as individuals grow older, and it becomes difficult for them to distinguish colors that have even a slight resemblance. An individual's hearing ability also deteriorates as they grow older, in addition to their cognitive abilities being affected. They start experiencing memory losses, and their perceptive ability and thought processes worsen. Aging adults find it harder to absorb new information. They rely on the redundancy of new information to be able to encode, grasp, and store it, and eventually take longer time in retrieving the data [23]. Older adults believe that the use of interactive technology is hard to manage and practically utilize [80]. Several studies highlight that usability and design issues are major obstacles for the older population to interact with technologies [19, 88, 89]. When designing technology for older adults, age-related changes in cognitive and physical abilities are important considerations [23]. However, the following sections focus more on the problems from the cognitive aspect, and less on the issues caused by the physical change of older adults. Physical decline can be resolved somehow by changing the design elements. For example, in terms of vision, designers will pay attention to high contrast with text or avoid smaller font sizes. Further, age-related factors such as memory, attention, cognitive abilities need to be considered to fundamentally understand cognitive decline. However, the following cognitive factors and their characteristics are not easy to understand or to apply them to the design.

2.3.2 Negative emotional response due to lack of experience

Older adults lack the basic knowledge and experience to interact with technology effectively (Steele et al., 2009). They exhibit enhanced anxiety related to their confidence, effectiveness, and ability in utilizing new technology as compared with their younger counterparts [90, 91]. This may be drawn from prior experiences with technology, which may have been confusing, frustrating, or complicated. There are studies that confirm that older adults have lower expectations when it comes to the execution of tasks and the use of interactive systems [92].

The SilverFit system is an example of a technology for older adults designed by Rademaker et al. [93]. It is specially targeted for virtual rehabilitation and was aimed for older users who want to exercise as part of their rehabilitation program. To encourage senior patients to adhere to their rehabilitation program, the system uses games that facilitate stimulation and motivation. SilverFit specifically uses a 3D gesture recognition technology. The study stated that the proposed system required one person to help older adults to correct the posture while a second person helped the patient understand and operate the system. Despite the system providing feedback, senior patients did not even try to operate the system without the help of an external aid. From this fact, we can see that the fear of technology resided in the mind of older adults. TAIZO, a simple robot for demonstration purposes, was developed by Matsusaka et al. [94] to be used by trainers of small groups to demonstrate simple arm exercises. TAIZO lacked autonomy in that it was controlled by the voice of the trainer and required a key input. It also lacked sensors for the perception of the behavior of the users, a feature that prevented it from providing real-time feedback, personalized training, and active guidance to the training group. It is expected that exploration of technological developments such as TAIZO would meet a lot of hesitance from the older people.

Since familiarity is a concern of older adults, appearance is an important aspect

to consider when developing current technology. Another example of technology developed for older adults is Paro [95], a mental commit robot that provides social, physiological, and psychological effects to its users by means of physical interactions. Paro is designed to resemble animals, such as seals and cats. The mental commit robot [96] was used by older adults at a day service center to assist them with their daily activities. A study investigating the effects of the robot's influence on the participants' social and emotional well-being, including social interaction and depression, found that the mental robotic technology was widely accepted among older adults, and they did not show anxiety when using it. From this viewpoint, technological design must consider the manner in which the items will be used, as well as the context of use. Unfamiliar environments tend to make older adults stressed. They are sensitive to even minimal environmental transformations. Further, they prefer technological devices that fit in with their surroundings. According to Peek et al. [80], older adults are concerned with technology's appearance and may dislike technology that appears too noticeable or blatant in their homes. Assistive technologies for use in homes, for instance, must be designed such that they are unobtrusive and effectively fit in the home environment. Berkowsky et al. [97] showed that failure to meet the criteria negatively impacts on the adoption of technology. Norman [98] cited that a lack of consistency and prominent appearance may lead to the technological devices being broken and ignored.

2.3.3 Low expectations of their ability to learn or use technology

There is research to indicate that older adults often regard the fear or perception of complexity as the fault of the user (themselves) and not as a failure in the design of the technology [91]. However, a study by Starner et al. [99] shows that the gesture pendant, a technological innovation, is not well accepted by the older adult population. The gesture pendant uses a wireless technology and is commanded using hand gestures or movements. It can also be used for monitoring purposes, in addition to

an input device. As the user moves their hand, the tremor generated is registered by the device. To activate the gesture pendant, the user must press a button on the device. It is worn around the neck and has sensors for both motion and camera. The device can be used for monitoring the activities of its users, take commands from the user, and can request help for its user in emergency situations. Given all these commands and features, gesture pendant is a complicated system that might pose many challenges for older adults, as they cannot remember all the controls and commands. Davies et al. [100] demonstrated that symbols can lead to poorer comprehension of their meaning by older people than the younger generation, probably due to inefficiencies in the former's working memory. More precisely, the inefficiencies affect the speed of elaboration, as well as the basic elaboration in the retrieval of new information [101]. These are the reasons that older adults have misgivings about technology. They may need more time to recall the specific gesture needed to operate a system or to make the gesture. Moreover, if a system does not recognize the gesture properly due to a certain malfunction, older adults may take it as their own fault instead of the system's. It may take them an extended time to figure out what went wrong; these problems can make older adults avoid using these devices. The use of the gesture pendant might give older adults an additional task and extra burden.

Older adults have an embedded negative belief that they are less skilled when it comes to operating new technology [91]. For example, when the DanceAlong project technological innovation was investigated by Keyani et al. [102], it was found to not be well-received by the users. DanceAlong project is a technological innovation that allows older adults to select familiar music and dance sequences from movies and then perform them. For example, a person would select a song they like, such as old musicals, and the project would provide them with a projection of the footprints on the floor indicating where and when to step. However, the senior participants had a problem with placing their foot on the ground while concentrating on the projection

by the device. The willingness of the older users to use DanceAlong project was even further reduced when it came to complicated dance moves. This study reported that the older adults did not actively participate in it, but they watched others use it or listened to the music. This indicates that they have negative self-efficacy. However, this characteristic can be overcome by committing to changes in behavior, a discipline to follow through with the process, acquisition of the right skills and knowledge to accomplish the objective as well as an ability to direct their willpower and energy to the set goal [103]. To eliminate negative feelings about technology and instill confidence, it is necessary for older adults to receive precise instructions.

Langdon et al. [104] demonstrated that there is a relationship between age and cognitive ability with regard to the time taken to complete tasks, as well as to learn about interfaces. Wickens et al. [105] documented that the functions conducted by the working memory, such as storage, processing, and rehearsing, are influenced by conditions that are stressful. People dealing with extreme stress lack the ability to access the available actions and thoughts due to the unavailability of information processing that is usually executed by the working memory. Besides age and cognitive ability, training further helps in the proper utilization of technology. Older adults are dependent on environmental support and external prompts to identify whether they have the memory of the right responses; it is vital to provide more evidence to serve as the link between stimuli and the learned responses, particularly for those users who have learning difficulties. Users are more likely to explore the interactive abilities of a technological device if it provides visual feedback or is consistent with other forms of interactive features that alert and induce the users. Older adults can fail to determine the association between their actions and results on the screen if they are not alerted through efficient feedback. Providing appropriate feedback enhances their utilization and adoption of new technologies.

The European Union (EU) funded the development of Eldergames [106] to improve

the social, functional, and cognitive skills of older adults. The project makes use of advanced visualization and interaction interfaces. Eldergames provides a mixed reality platform aimed at improving the well-being and the cognitive skills of its users. Additionally, the project offers unusual experiences for older adults to communicate with other users who may be located in other countries, regardless of their languages. However, older adults are not familiar with technologies applied to the game, such as mixed reality and image processing. The game rules for older adults should be designed differently from general systems with consideration for the cognitive ability of older adults taken into account. It is necessary to check if a game uses an unsuitable game object, requires a rapid reaction, or provides an inappropriate sound effect or visual feedback. To design technologies that will be widely accepted among older adults, the cognitive abilities that deteriorate with age should be considered by designers. Such cognitive abilities include memory, attention, perception, and decision making. More importantly, designers should make available all information that older adults require on the interface of their devices as well as eliminate the need for the users to memorize commands and other forms of inputs.

2.3.4 Effect of age-related stereotypes in the use of technology

Peek et al. [80] argued that the utilization of new technologies by the aged is heavily influenced by certain stereotypes and expectations. There are cases where stereotypes work to the disadvantage of the users, affecting their performance and motivation [107]. In line with this argument, there are studies that have indicated that older adults do not utilize technologies to the scope that the younger generation does due to stereotypes [108, 109]. Other developers such, as Zelinski and Reyes [110], have introduced digital action games that have immense cognitive benefits for older adults. The game makes use of strategies that not only improve the visual speed of recognition but also the memory and reasoning abilities of older adults. Despite many advantages, older adults do not use these systems continuously due to the fixed

idea they have regarding modern technology. Older adults are reluctant to attempt new functions in a cell phone, a personal computer, or even home appliances. They tend to use only the features they are already familiar with. They are afraid of breaking devices or are reluctant to learn new techniques, which are generally hard to operate. To avoid these stereotypical assumptions concerning new technology, designers must understand and address the difficulties faced by older adults when learning new technologies.

In the process of exploring new technology, older adults show discomfort when having to expend the effort needed to understand the way a it functions. They are very concerned about their health. Therefore, if a device has any element that threatens their health, they will never accept the device into their lives. Starner et al. [99] reported that people required wearing the gesture pendant all the time to control the function of a home. However, the study showed that older adults were hesitant to wear the device all the time because they believed that the electromagnetic waves from the device could be harmful to their health. Moreover, they were not interested to invest additional time to learn the gestures for controlling the system. Consequently, older adults may not use a system continually if it requires many additional abilities to operate it, as the gesture pendant does. Trust is enhanced as older individuals become more familiar with the technology, are consistent in using it, and build a successful history of technology utilization [111].

2.3.5 Maintain self-respect and privacy

Maintaining self-respect and privacy is an important factor for older adults in deciding to use interactive technology [112, 113]. Dishman [114] developed a system that assisted older adults in preparing a cup of tea and provided a monitoring function for the entire process. Additionally, the system could quantify the amount of help that was needed, the frequency with which it was needed, and the areas where users faced challenges. This data makes it possible for developers to determine the type

of cognitive decline and detect the rate of such decline. Olivier et al. [115] further describes another technology referred to as The Ambient Kitchen which can be used to assist older adults perform activities in the kitchen by detecting the need for such help. The Ambient Kitchen uses several input devices such as accelerometers, radio frequency ID tags, integrated cameras, and sensors to perform this function. It also uses video projectors and speakers to provide audible and visual clues throughout the kitchen. The main benefits of these systems are that the user does not need to worry about how to use the system since it will automatically track the user's behavior. However, it may invade the privacy of older adults. Nonetheless, Peek et al. [80] found that older adults do not care about privacy if the utilization of technology is more advantageous.

Normally, older people do not like being videotaped and they do not like being monitored. SoundPainter does not record video or audio, which is fairly unusual for a monitoring tool. The paint display is generated from immediate sound input only. Moreover, it is not possible to trace back to see what audio prompted the formation of a certain paint design, since the location of the dots is random and there is no way to ascertain what dots appeared in what order [116]. By having to utilize only the simple logic of possibly complex innovative technologies, older adults obtain a sense of security and protection with respect to their families, and the families in turn can be assured about their elderly's welfare. This protects the privacy of SoundPainter users. Such devices that involve some form of monitoring, but are designed with reciprocity in mind, are more likely to be accepted. SoundPainter is designed to be run between two networked computers. One touchscreen is placed in the household of the aging parent and the other is placed in the household of their children. When SoundPainter runs in both households, the respective members can see the paint display generated from each other's households. The painted display will fade every fifteen minutes so that the most recent activity is obvious. Viewing evidence of activity in the aging

parent's household via SoundPainter will lessen their children's concern their parent and promote a sense of connection between each other [116]. Older adults do not care about privacy only if they get appropriate compensation. The recognition aspects and data collected by Move and Paint is of lesser concern than the benefits acquired from the regular use of it; therefore, users may not be bothered about the camera recording them.

2.4 Factors Influencing Continued Usage and Adoption of Technology by Older Adults

Factors influencing the continued usage and adoption of technology by older adults, which have been discussed in this section, have been considered as a component of after engagement in the new engagement model in Chapter 3. The importance of understanding the adoption of interactive technology by older adults is rapidly increasing. Many scholars show a lower level of innovative technology adoption by older adults [117, 83, 118, 119]. Older adults' acceptance of interactive technology depends on relationships between the cognitive and emotional aspects [120]. Interactive technologies for older adults should be planned and made with an emphasis on providing efficiency, effectiveness, and satisfaction and as well as the engagement of older adults and enhancing positive experiences. To make interactive technologies more acceptable, the notion of usability, independence, convenience, devices to support physical activity, technology training and education, the role of caregiver, innovation (focus on developing new features), and potential or continued benefit have been explored by many scholars over the past decades. However, we would like to highlight that many studies still focus on technologies that are usable or adoptable and suitable for continued use, but they often ignore providing pleasurable and positive experiences to encourage initial engagement and keep users engaged. In the previous section, we presented age-related challenges to understand the characteristics of older adults through the literature review, found the importance of the cognitive elements, and

examined the older adults' attitudes and perceptions in the use of technology. These elements are fundamental ones and are expected to be considered in the development of technology for older adults. With this understanding, we want to highlight factors influencing the continued usage and adoption of technology by older adults in this section.

2.4.1 Promote wellness

Older adults are likely to adopt interactive technology to maintain their independence and convenience at the end of life. Interactive technologies developed for older adults tend to focus on maximizing the convenience and independence of their life for promoting their physical, psychological, and environmental wellness. Various smart services and technologies have been developed to support older adults' wellness, make their daily tasks easier, and enhance their overall quality of life. Various types of living environments are also available for older adults. Most older adults prefer to live independently in a familiar home setting as long as possible [121, 122]. This lifestyle choice is known as "Aging in Place" (AIP). Assisted living facilities (ALFs) are characterized as housing-and-services settings that ensure safe and healthy living conditions are maintained [123]. AIP enables older adults to live in a familiar environment and maintain current social networks and social interactions with close family members Further, their mental functions remain healthy through interactions with their friends in this environment. In addition, a comfortable, familiar environment provides them with emotional stability. In the case of ALFs, price may be a burden, but tailored services can lead to a more convenient life [123]. Providing a safe, secure, and comfortable living environment is important to improve the well-being and happiness of older adults [124, 125]. Thus, understanding the functions needed to support well-being based on their patterns of living and behavioral characteristics is critical [126]. Studies have shown that emerging technologies, especially assistive technologies, are most useful for older adults who have perceived, learned, adopted, and accepted them

as essential for their activities of daily living (ADLs) [123]. Social independence is possible through routines and specialized living environments-an area that developers have found to be an effective use of technology [127, 123, 128]. Tech developers, designers, or researchers consider designing interactive technologies to ensure the desirable level of independence among older adults. For instance, new technologies have automation capabilities, which enable older adults who are physically weak or cognitively impaired to live independently, i.e., they do not exclusively rely on caregivers to do all ADLs [129, 130].

2.4.2 Innovation

To make interactive technologies more acceptable for older adults, many studies have emphasized the need to use information and communications technology (ICT) technologies [131]. Recently, as an alternative to the technology for older adults, the field of Positive Technology has emerged and received attention [132]. For the purpose of promoting users' well-being, satisfaction, and contentment rather than usability, Positive Technology ultimately aims to improve the quality of their overall life. To promote the well-being of older adults, various innovative technologies have been reviewed. Acampora et al. [133] explored the application of ambient intelligence (AmI) in the health care domain from various perspectives. They believe that AmI systems have the potential to help one lead a healthier lifestyle and enhance physical well-being. Concern about the impact of long-term exposure to an environment in which many sensors are embedded, security or infrastructure issues, and social and ethical issues are introduced as the challenges AmI should overcome. Luneski et al. [134] presented the potential benefits of research in affective computing (AC). AC investigates the relationship between human emotions and computers, which has a positive impact on social, cognitive, physical, and other levels of human behaviors. Tapus et al. [135] reviewed the way in which a robot understands the natural interaction between people and responds to that correctly from various perspectives.

Broadbent et al. [136] reviewed the potential user's needs and expectations for the robot's help for the independence of older adults and improvement of the health outcome. Considering the benefits of the same, the use of robots has been proposed to support physical, social, and emotional wellness. Further, many studies explore innovative solutions to provide appropriately designed living environments for older adults fitted with embedded sensors and voice-activated services [137]. The development of ICT helps users control the smart technologies in their homes [138]. This idea is generally known as ambient intelligence or the innovative and smart environment. Such an environment combines modern computing, networking, and smart and innovative devices by helping users to communicate with their homes and other users through special interfaces in general. Within the context of the smart environment, numerous sensors are connected to the individual's house. These sensors can measure physical and physiological functions and monitor all activities, and they provide the user real-time warnings about malfunctioning devices. A smart home is an environment that adopts ICT to collect and share information, analyze, and monitor residents' behavioral patterns, and improve residents' quality of life [8, 139]. It is clear that smart technology has a positive effect on overall life because it helps older adults to easily perform essential activities in their living space with minimal energy.

To support the independence of older adults, smart home systems include automation capabilities that allow them to have control over their living environment and monitor it. This approach can maintain the privacy of older adults in their living space, and their everyday life remains the same. Several devices are integrated into smart homes, in particular, for video surveillance, intrusion detection, entertainment, smoke and fire detection, and health monitoring. These technologies demonstrate the possibility of providing physical and psychological support by collecting information about the occupants' behaviors and predicting the behavior patterns in smart environments [140]. In the near future, these innovative technological interventions

will be required to automate everything in the house and make older adults' life better. Developing innovative technology is heavily considered for older adults for their continued usage and adoption.

2.4.3 Enhance usability

Many studies consider enhancing usability first as a way for older adults to adopt and use interactive technology. The existing studies on interactive technologies for older adults are limited because they focus on how to enhance innovative designs and usability [141, 142] with little regard for the potential older adult users. Efforts to conduct research on them are often hampered by a lack of understanding of the abilities, requirements, and preferences of this population. Due to the natural characteristics of these individuals, an accurate understanding of the likely challenges would make it possible to provide them with better designs and user experiences. Many studies explore technologies and contexts that are important for the extension of the lives of older adults [127, 143]. While this is a positive implication, the learning process is an extra burden for older adults. Most scholars have indicated that usability is a critical issue to help older adults to learn how to use the interactive systems independently. For example, to improve usability, some studies [144, 145] have taken into consideration the idea of affordances to help in the provision of a clear and targeted perception of the possible interactions between the system and user. Interactive technologies should be designed to allow older adults to communicate with technologies easily rather than having to learn complex technical languages and commands [146].

2.4.4 Mitigate physical and cognitive challenges

Older adults are interested in using technology if it can support both their physical and mental health conditions. Older adults constitute a highly diverse group covering a wide age range and with varied characteristics, behaviors, and needs. When people age, they experience a significant decrease in their physical, cognitive, and sensory

capabilities, and many of them might have negative attitudes toward technological innovations [147, 109]. One of the many stereotypes around aging is that seniors are resistant to new ideas and advances in technology. Older adults express less comfort and confidence in their ability to successfully use these systems. These unique physical and cognitive characteristics could act as interfering factors for their engagement with interactive technologies. Many challenges exist in the process by which they develop interest in, give attention to, and thus, easily use, interactive technologies. Researchers in both design and computing have taken an interest in the utilization of technology to help aging adults. Staying physically active is important for older adults in using technology [3]. As fine motor skills deteriorate and energy decreases, it is increasingly hard but equally important to incorporate physical activity into daily tasks. There are many ways in which ubiquitous and mobile technology can motivate people of all ages to be more active. Most of these are tracking tools, which use sensors to keep track of physical activity [148, 149]. These tracking tools motivate activity by providing a dashboard that displays progress over time or using a quantified reward system. Many studies report that older adults enjoy using VR or AR applications. VR and AR applications have the merit of simulating various situations for health training and performance testing [150, 151, 152]. Physical well-being of older adults refers to the state in which they are capable of performing physical activities or social roles; further, a series of such activities should be free from physical limitations. Physical well-being is an important issue in AR and VR studies, encompassing "motivation," "training," "reminder," and "accessibility." VR and AR are concerned with four types of perspectives to support the physical well-being of older adults. First, training for their lack of ability; second, encouraging an interest in physical activity by applying an engaging factor to the design; third, providing a reminder related to health combined with interaction modality, such as a wearable or mobile device, and last, providing good accessibility for them to use

AR or VR technologies. These emerging technologies have gradually expanded to include the purposes of assisting people with disabilities, older adults, and those with reduced capabilities to enrich the living environment, improve comfort, and facilitate well-being [148, 153, 137]. In the process, older adults will adopt new technology to support their physical and cognitive functions and to obtain usable, affordable options.

2.4.5 Importance of training and education

Training is another important factor that influences older adults' adoption of technology [117]. To make older adults aware of and encourage them to perceive, learn, adapt, and accept interactive technologies, providing training and education to support them with easy-to-use technology is increasingly important [154, 155]. Hargreaves et al. [146] identified that the task of learning how to use smart technologies is demanding and time-consuming. They point out that older adults still do not understand the benefits of smart technologies. No matter how helpful smart systems can be for their daily life, these systems are futile if older adults do not use them. Efforts should be made to make them fully understand the benefits of using these systems. Advancements in technology continue to open up new opportunities for sales and development to support the positive aging of older members in the society. It is important to note that, today, older people are more excited to use technologies that are practical to their lives. One's level of education, age, technical knowledge, and technological anxiety, however, tends to affect the interest in the new technologies. The presence or absence of widespread internet connectivity and education are regarded as the major factors hindering the successful involvement of older adults in the use of innovative technologies. According to Gatto and Tak [156]; McCausland and Falk [157], the availability of more relevant and accessible technologies for our older populations will ensure that it is universally accessible. It is important to note that the fast-changing technological landscape has made most of the older population have

to face a steep learning curve. However, one thing is positive; as their experience with technology improves, their comfort level with using the different technologies increases accordingly.

2.4.6 Importance of community, family, and communication with others

Many scholars have additionally highlighted that the role of caregivers is important for older adults' use of technology [127, 158]. Many technologies have been developed to assist with the caregiver's duties [159, 160]. Older adults' well-being in their later life is increasingly influenced by connections to other people. Sustaining enhanced connections is an important feature when it comes to acceptance of technology [80, 112]. Accordingly, some of the designers of senior programs have made efforts to ensure that older adults do not struggle with the new technology. The significance of concern about the children of older adults, for instance, can influence the use of technology, as it provides services that enhance their contact. Acceptance of technology by the older population is further dependent on its acceptance by others within the social circle, such as professional caregivers, friends, family, and peers. Usage of technology by an individual is strongly influenced when those within his or her social circles have embraced it [80]. According to Hirsch et al. [161] the feeling of connection between older adults and other people increases their quality of life, even as their functional ability decreases. For this reason, a lot of technologies and robotics have been developed to enhance communication between older adults and their families, relatives, friends, nurses, and doctors to support social interaction. Wang et al. [113] note that older adults' interests towards technology will increase when provided with companionship, and when they overcome loneliness, anxiety, and depression. For these reasons, the failure of developers of new and innovative technologies to take into consideration the emotional and social aspects of older adults in their technologies can be a cause for many missed opportunities. Technology should not be viewed in isolation; rather, it should be articulated as an integrated system

that can improve on the existing social networks [162]. Figure 2.1 summarizes the factors discussed in this chapter. These factors are used to build a new engagement model for older adults in Chapter 3.

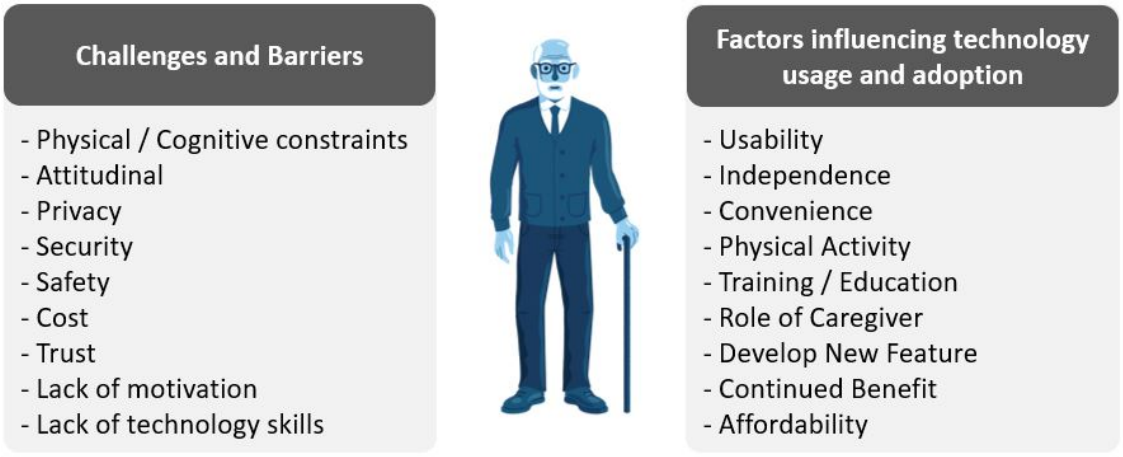


Figure 2.1: Left: Challenges and barriers faced by older adults in the use of technology discussed in section 2.3. / Right: Factors influencing technology continued usage and adoption by older adults discussed in section 2.4

2.5 Discussion

This chapter presented the existing research on the characteristics and attitudes of older adults in the use of interactive technology. Since older adults have unique characteristics, research is needed to explore ways to attract and motivate older adults towards technology. There is no denial that technology improves their overall health and well-being. However, in this case, there are still some drawbacks that need to be considered and addressed for older adults to use interactive technology. In conclusion, many theoretical perspectives have been used to explain aging dimensions (Section 2.2). Overall, these indicate that aging is a complex phenomenon, and a lot is yet to be discovered. Psychological or biological theories do not have the holistic view and specificity required to provide a comprehensive guide in the design and engagement of technology for older adults. This theoretical understanding of aging adults will provide a basis for identifying engagement in the use of interactive technologies for

older adults. Moreover, the factors described in section 2.3 are the challenges people face due to aging. These factors can be disadvantageous in using new technologies. To appropriately design technology to meet the needs of older adults, it is necessary to understand the characteristics that separate this age group from their younger counterparts. Older adults tend to have negative, preconceived notions that new technology is difficult to use or unnecessary, and they do not trust their ability to have control over the systems. An interactive system that is not designed to recognize older adults and their intentions can lead to negative responses and a lack of use. Section 2.4 explained that much effort has been made to encourage the use of technology for older adults. However, we can see that a lot has been neglected concerning the older adults' lack of adoption of current technologies. With the help of HCI designers and researchers, older adults can identify meaningful experiences around them to eliminate the feeling of despair that is often associated with old age. Aging is normally a challenging experience, but with the help of technology, older adults can turn their aging period into an enjoyable one. Considering the volume of existing research about older adults using technology, we identify research gaps and new areas of research related to initial engagement. In the following section, we highlight the importance of initial engagement for older adults and present a new engagement model for them. The notions and aspects related to age-related characteristics discussed in this chapter have been considered as factors of before and after engagement among the three stages of the engagement model of older adults to create a new engagement model for them.

CHAPTER 3: A NEW MODEL OF ENGAGEMENT FOR OLDER ADULTS

3.1 Summary

This chapter describes the importance of initial engagement among older adults in their use of interactive technology. Section 3.2 summarizes the current definition of user engagement, which has been widely discussed in HCI. It presents the attributes of the engagement for older adults with age-related characteristics reviewed in Chapter 2. We have described the difficulties in engaging older adults to use interactive technology due to their age-related characteristics through the existing literature. Accordingly, with the insights from the literature review about aging-related theories, challenges older adults face as they grow, factors influencing technology usage and adoption, we have identified the research gap and a new research approach about older adults' engagement towards technology in Section 3.4. Finally, we have presented a new model of engagement of older adults with interactive technology.

3.2 Existing Definition of User Engagement

The need to create engaging experiences has been given importance in several strategies and designs to develop technologies, not only older adults but other users. According to O'Brien and Toms [30], there is a need to review the existing literature to determine what exactly constitutes an engaging experience. Even when there is sufficient motivation to design technologies that provide user-friendly engagement, this endeavor would not be adequately achieved without a clear understanding of what user engagement is and how it is measured [163]. Usually, the design of the technologies does not consider the emotional, cognitive, and behavioral characteristics of older adults. Therefore, without the conscious intent to define engagement, it would

be challenging to clearly delineate what aspects of interaction would actually engage older adults.

User engagement has been evolving since 1980 in how it is defined. One of the definitions discusses user engagement as being the system's ability to "capture the interest and attention of the user" [164, 165]. The system does this by motivating the user to utilize it, thereby encouraging interaction [163]. It also creates a feeling of excitement to boost the user's interest [32]. It is generally felt that engagement can be carried out by employing various attributes. An attribute is "a characteristic of the user-computer interaction that influences or is a component of the engagement" [30, 163]. The main focus of user experience should be on its flow, play mode, and theories on aesthetics [166]. These aspects tend to rely on various attributes, including "motivation, awareness, perceived control and time, interactivity, novelty, feedback, sensory and aesthetic appeal, challenge, interest and affect" [30, 167]. These attributes form the foundation required to comprehend user engagement. Some aspects, such as aesthetic appeal and durability, have an effect on the user. These aspects affect the user's behavioral, cognitive, and emotional involvement with a particular technology. It has been the goal of many researchers to identify these attributes' effect on the technological engagement of older adults.

3.3 Engagement Attributes with Age-related Challenges in the Usage of Technology

In general, user engagement refers to the energy, time, and emotions that users invest in using the system. Older adults do not easily engage with interactive technologies. They are not a generation that has grown up with technology; thus, their ability to understand technology, thought processes, and mental models toward technology are different from those of the younger population [168, 169]. As older adults prepare for the later part of their lives, their attitudes towards technology and the value they assign to it are different from those of the younger population. The impor-

tance of technology in the lives of older adults is different from that of the younger population. For example, older adults do not feel discomfort when they do not have a cell phone, unlike young people [18]. This chapter presents the attributes of the engagement for older adults with age-related characteristics reviewed in Chapter 2. We have explained the difficulties to engage older adults to use interactive technology due to their age-related characteristics through the existing literature.

3.3.1 Focused attention

Due to the depreciation of attentional capacity, older adults might not be able to stay focused while digital contents; therefore, they might not be able to engage interactive technology.

According to O'Brien and Toms [30], being engaged with technology may involve being focused on it to the extent of excluding other activities. Often, as the users get more engaged, the more they may be underestimated in terms of the passage of time. According to Csikszentmihalyi [170], the flow theory is associated with high concentration levels in areas such as absorption, distortion, and concentration of the subjective passage of time. In this case, the flow denotes a mental condition where users fully participate in what they do [163]. Attention refers to the ability to focus on components deemed essential in the execution of a task. It can also be defined as the ability or energy to facilitate cognitive processing [171]. However, older adults' ability to be immersed in something new or unfamiliar might be poor due to the lack of attentional capacity. The changes in attention among older adults are attributed to several behavioral inefficiencies while using technological devices. The main trait associated with attention is that it signifies a human capacity to coordinate tasks from the environment with stored data and knowledge. The difficulties experienced by older adults when executing concurrent activities may be due to the depreciation of attentional capacity [172]. Researchers mention that older adults lack the ability to single out significant information from irrelevant or distracting data [173, 174, 172].

McDowd and Craik [175] highlight different studies which show that older adults find it challenging trying to divide their attention between different sources of data, focusing on one source of data, while at the same time holding onto another different source. Thus, they take a lot of time to complete complicated tasks [175].

3.3.2 Positive affect

Owing to negative emotional responses that have been inherent regarding interactive technology, older adults might not be able to emotionally experience or intrinsically motivate themselves to use technology; therefore, they might not be able to engage in using interactive technology.

The term affect refers to emotional involvement during the interaction. In essence, this means that users who are engaged are effectively involved [30]. Some age-related factors have a positive effect. To a great extent, this encourages emotional involvement, which, in turn, will enhance user loyalty. It can, therefore, be said that affective states such as enjoyment and fun are very critical to user involvement. Hindrances such as frustrations and negative emotions usually bring about disengagement [30]. Arousing positive emotions, such as fun, happiness, or satisfaction, while using interactive technology is an important factor when designing interactive technology. It is also crucial to support the older adults' insufficient ability so that they can lead an independent life. Many studies focus on developing interesting digital content to attract users. An effort must be made to develop content in which older adults may be interested. Visual prompts, signifiers, and virtual feedback that allow them to have fun need to be identified. Designers and researchers should consider both the positive and negative emotions of older adults. Due to their negative emotions towards technology, it is hard to induce in older adults the desire to participate. Boletsis and McCallum [176] described the need to consider age-related cognitive changes when designing a system for older users. System errors can easily confuse older adults and cause negative feelings of uncertainty, confusion, and tension. As

such, it is imperative to design the system to prevent these errors and ensure that any errors that do arise can be easily managed. Interaction issues, such as errors and complexity, may negatively affect users' perception, cognition, and emotional state, and consequently have major effects on the targeted cognitive stimulation. Long-term motivation, engagement, and social interaction should be examined in further investigations of interactive applications.

3.3.3 Aesthetic appeal

Due to physical and sensory limitations, older adults might not be able to receive information or understand design elements correctly; therefore, they might have difficulty in stimulating or promoting focused attention by sensory, visual appeal of interface.

Aesthetic appeal refers to the visual and sensory appeal within the interactive system. This is regarded as an important factor for engagement [163]. The aesthetics are seen to be pronounced in the graphics, screen layout, and use of design principles such as balance and symmetry. On the other hand, multimedia applications include aesthetics that result in positive effects [177]. Moreover, aesthetics generally refer to a concept that promotes focused attention as well as stimulated curiosity. This will further determine a user's potential engagement with technology. However, physical and sensory limitations impair older adults' ability to receive information or understand design elements. Progressive aging often impairs different sensory-motor abilities and cognitive skills. This decline is not always constant and tends to vary among different individuals [18]. Li and Lindenberger [178] state that degraded sensory damage consequently reflects on one's intellectual functioning.

3.3.4 Endurability

Due to negative self-efficacy and willpower that influence the attitude of older adults, older adults might not want to repeat using technology later; therefore, they might not

be able to have memorable, enjoyable, useful, and engaging experiences in the use of interactive technology.

The endurability concept refers to the creation of engaging experiences that are not only memorable but also worthwhile. This engagement attribute is concerned with reliving the experience generated by using technology in the future [179]. Additionally, this idea refers to the way user perception has been operationalized and whether such experiences meet their expectations in terms of success, being rewarding, and worthwhile, thus making them willing to share it with others [180]. On the other hand, the concept of endurability relates to the focus on maintaining the users' attention as well as motivating them to use the technology again. However, Eisma [91] indicated that older adults convey negative self-efficacy, thus feeling too old to adopt new technology. Besides, the lack of will power among older adults is another challenge. Enhancing endurability is a challenge for older adults. This characteristic can be overcome by committing to changes in behavior, a discipline to follow through with the process, acquisition of the right skills and knowledge to accomplish the objective as well as the ability to direct their willpower and energy to the set goal [103]. To eliminate negative feelings about technology and encourage confidence, it is necessary for older adults to receive precise instructions.

3.3.5 Novelty

Because of the different facets of technology, prior experiences and mental models that older adults have, they might not be able to encourage inquisitive behavior; therefore, they might not be motivated toward repeated engagement in the use of interactive technology.

A novelty in system development is a term used to denote the creative designing of technology that gives the users surprising, unfamiliar, or unexpected appeal through attracting their curiosity, inquisitive behavior, and re-engagement [180]. The older population has not been exposed to the same level of technology as the younger

generation [181]. Many interactive systems are new to older adults. Low exposure may evoke older adults' curiosity. In contrast, this results in the elderly not having an accurate mental representation or conceptual model of how interactive technology works, or what it can and cannot do [182]. Several researchers have explored the importance of understanding the impact of mental models and prior experience on interaction design for older adults [183]. Older adults' prior experience will have a positive or negative impact on novelty. Prior experience is acquired from past behavior and these experiences make knowledge more accessible in memory [184]. In other words, the more knowledge one has about technology, the easier it is to acquire new knowledge about it. However, because of generational effects, older people normally have a low knowledge base to fully accommodate modern technologies. [181]. A study conducted by O'Brien [180] investigated how prior knowledge in technology affects different ages and experience levels. It suggests that the most effective way to resolve the problem of technology use or involvement is the combination of early technology experience and an understanding regarding where the world is heading to. Finding a balance between familiarity and novelty is important [163].

3.3.6 Richness and control

Because of low expectations of older adults' ability to use technology, older adults might not be able to control technology properly; therefore, they might not be able to achieve their goal in the use of technology.

The framework predicated on Richness, Control, and Engagement [185] helps explicate the levels of engagement in relation to control, and the richness of the features of the application. The term 'richness' encompasses the users' growth in their thought processes, actions, and perceptions as evoked by the activities. The need for cognitive abilities is non-negotiable given the complexity of technology [186, 19, 104]. Older adults are required to utilize heightened working memory resources and effort, which thus impacts their utilization of new technologies [24, 18]. According to

Deakin et al. [187], aging is related to diminished risk-taking, poor decision-making, and longer time spent in deliberation. Older people are much slower when it comes to decision-making [188, 189]. 'Control' is the degree to which a user is able to meet expectations in effort and goals [166]. There are many limitations to older adults' level of engagement in terms of the levels of richness and control when interacting with technology [163]. Their fear of technology is often informed by the concerns that they lack control over the activation and deactivation of the system [111]. For example, older adults tend to abandon the use of such systems because they are uncertain of its overall operation methods such as how to initiate the system and how to return to a previous step when an error occurs. Research has demonstrated that older people often blame themselves for being afraid of technology or for finding it complex, rather than blaming the technology's design [91]. This may be drawn from prior experiences with technology, which may have been confusing, frustrating, or complicated. To engage, rich experiences are worthwhile but having control over it would make it more interesting.

3.3.7 Reputation, trust, and expectation

Due to the fear of stigmatization, embarrassment, and perceptions of self-worth, older adults might not be able to trust, invest time or effect to use technology; therefore, they might not be able to engage in using interactive technology.

Trust is a necessary condition of user engagement. Reputation is viewed as the trust that users have over a technology [163]. This trust will drive them to invest in the technology [190]. The level of trust varies depending upon the fact that human beings are also unique with different desires. Trust is enhanced as individuals become more familiar with the technology, are consistent in using it, and build a successful history of technology utilization [191]. Older adults fear how other people perceive them. Porter [192] precisely stated that the fear of stigmatization is quite overwhelming. As such, older adults will be cautious when using or wearing assistive technologies for

themselves, because they do not want other people to view them as frail, weak, or poor in health. Assistive technologies have been widely used to improve the sense of identity and functional abilities of older people. Although these technologies have the potential to increase one's functional abilities, they can stigmatize or humiliate older people [161]. Further, the aged population is concerned about portable health monitoring sensors, due to the fear that they might lose them or forget to use them. These fears are heightened when older adults have to use these devices in public spaces, away from the comforts of their homes, due to the embarrassment of being dependent on assistive technologies to cope with life. As such, it is significant to consider the emotional and social aspects of assistive technologies to keep the usage and interaction with the target population high [193, 194, 195]. According to Hirsch et al [161], to design assistive technologies, designers should think about both how to raise the functional ability of systems and enhance the elderly's perceptions of self-worth [161]. Older adults are very concerned about their health. Therefore, if a device has any element that threatens their health, they will never accept it into their lives [99]. Failure to respect individual rights besides allowing an individual to age with dignity are reasons enough to reject technology for older adults [112]. Main concerns include privacy implications, whereby the technology should essentially be non-intrusive [113]. Older adults are uncomfortable when interactive devices require many sensors and cameras detecting the behaviors and location of older adults continuously. This system may invade their privacy. Trust, reputation, and expectations have an effect on whether we wish to engage with an application over the longer-term, and the level to which we decide to engage.

3.3.8 User context, motivation, incentives, and benefits

Because the importance and values of life change a lot as older adults grow, older they might not be able to obtain incentive and benefits from technology targeting the younger generation; therefore, they might not be able to be motivated to use the new

or emerging technology.

The users' engagement with technology is dependent on the motivations, incentives, and benefits provided by the system or application. This engagement is context-dependent; however, the experience, consequence, and engagement often differ depending on the circumstances [196]. Connection with other people is a factor that strongly influences older adults' motivation. Sixsmith [107] stated that older adults are often concerned by innovative technology that might further diminish the level of interaction between people. The quality of life of an individual is increasingly influenced by connections to other people. Sustaining enhanced connections is an important feature when it comes to acceptance of technology [80, 112]. Technology should not be viewed in isolation; rather, it should be articulated as an integrated system that can improve on the existing social networks [162]. Wang et al.[113] recommended that older adults should be encouraged to sustain interaction with their current contacts by keeping them informed on some of their interests and upcoming events.

Older adults are more likely to perceive technology as useful when they are convinced that it is consistent with this perceived usefulness [80]. Subsequently, Switzler [103] asserted that older adults can stay motivated through the development of reward and incentive plans in their behavior change process. Other benefits of technology among older adults include enhanced safety, a diminished burden on caregivers and family as well as increased independence. Peek et al. [80] stated that older adults are willing to embrace technology in light of a perceived personal need for technology. This makes it vital to comprehend the range of capabilities, desires, and needs that technology can offer within a background of individual differences among older adults [80]. Melenhorst et al.[197] showed that the aged are motivated to invest in modern communication technology upon perceiving that the technology aligns with their purposes.

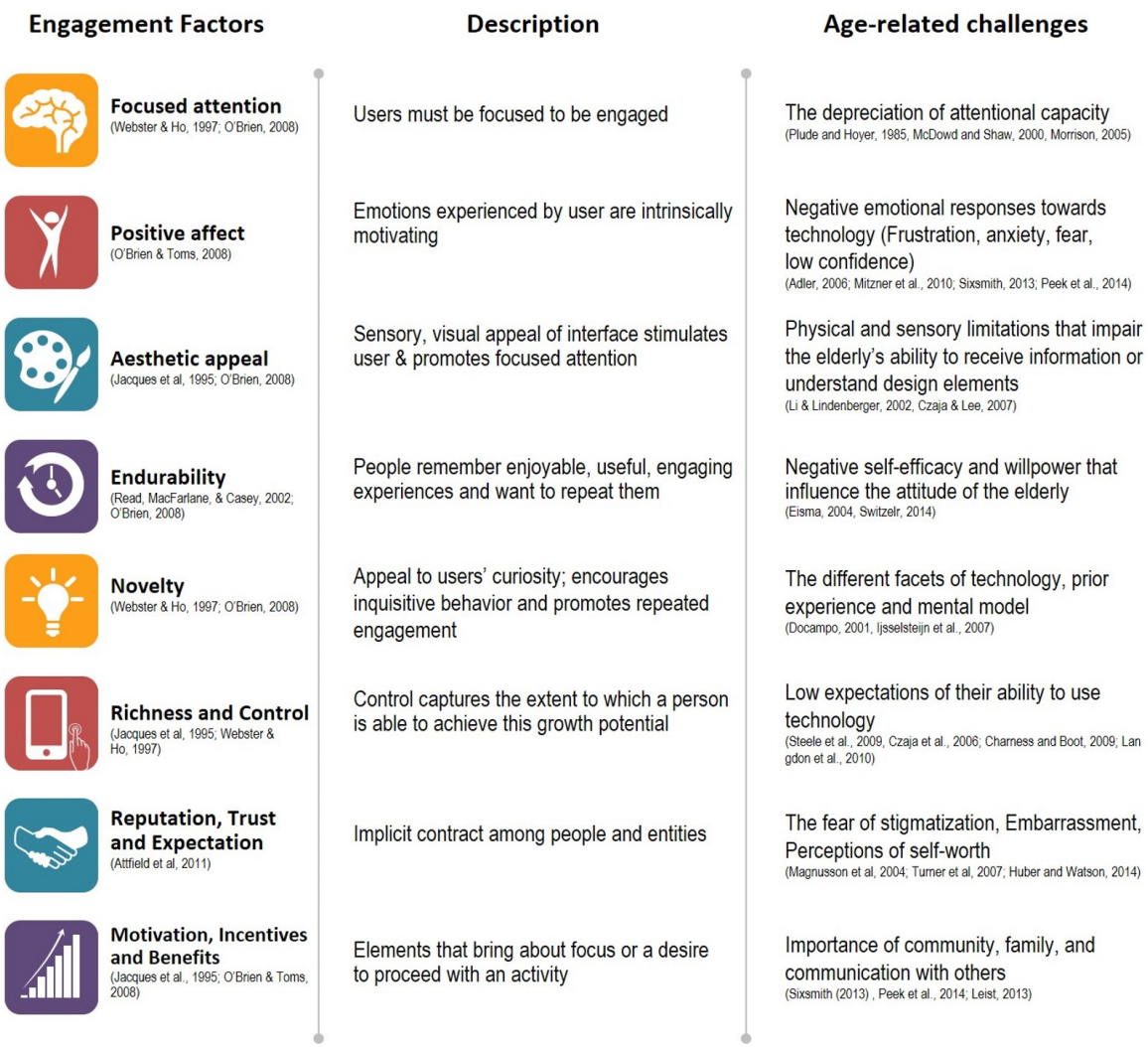


Figure 3.1: Summary of existing engagement attributes with age related challenges

3.4 New Approach about Older Adults' Initial Engagement towards Technology

In the existing research, despite various studies being done to understand the attributes of the engagement for older adults, the definition of older adults' technological engagement is not clear. In addition, the current research is insufficient and mainly focuses on evaluating how they use technology. The eight engagement attributes we introduced in this chapter are widely cited attributes to describe user engagement in HCI. However, it is difficult to apply these attributes to the engagement of older adults in the use of technology. The attributes mentioned above have been summarized as

follows:

- **Focused Attention:** Because of the depreciation of attentional capacity, older adults might not be able to be focused using digital contents, therefore they might not be able to engage in using interactive technology.
- **Positive Affect:** Because of negative emotional responses that have been inherent towards interactive technology, older adults might not be able to emotionally experience or intrinsically motivate themselves to use technology, therefore they might not be able to engage in using interactive technology.
- **Aesthetic Appeal:** Because of physical and sensory limitations, older adults might not be able to receive information or understand design elements correctly, therefore they might have difficulty in stimulating or promoting focused attention by sensory, visual appeal of interface.
- **Endurability:** Because of negative self-efficacy and willpower that influence the attitude of older adults, older adults might not want to repeat using technology later, therefore they might not be able to have memorable, enjoyable, useful, engaging experiences in the use of interactive technology.
- **Novelty:** Because of the different facets of technology, prior experiences and mental model that older adults have, older adults might not be able to encourage inquisitive behavior, therefore they might not be promoted to repeated engagement in the use of interactive technology.
- **Richness and Control:** Because of low expectations of older adults' ability to use technology, they might not be able to control technology properly, therefore they might not be able to achieve their goal in the use of technology.
- **Trust and Expectation:** Because of the fear of stigmatization, embarrassment, and perceptions of self-worth, older adults might not be able to trust,

invest time or effect to use technology, therefore they might not be able to engage in using interactive technology.

- **Motivation, Incentives and Benefits:** Because of the importance and values of life change a lot as older adults grow, older adults might not be able to obtain incentive and benefits from technology targeting the younger generation, therefore they might not be able to be motivated to use the new or emerging technology.

A list of engagement attributes is fundamental for understanding older adults' engagement. We are not claiming that the existing engagement attributes are completely unsuitable for understanding user engagement for older adults. However, we argue that it is necessary to consider the unique characteristics of older adults and the need for research on engagement from their perspective. We have redefined older adults' engagement in the use of interactive technology as follows:

User engagement for older adults is defined as the value older adults find in using the technology. In this study, initial engagement for older adults is associated with fun, interests, and positive emotions while initially approaching and interacting with interactive technologies. Once older adults initially engage with the system, they want to use it and change their attitudes in a positive direction.

There are different types of long-term engagement among older adults, such as lifestyle engagement, occupational engagement, health-care engagement, and social engagement, etc. [198, 199, 200]. Various research related to aging and technology have been conducted to understand older adults' long-term engagement in their life and enhance their wellness through age-related theories (Section 2.2). To this end, many inventors, designers, and researchers in technology-related fields have paid attention to finding tools and platforms, and technological solutions for older adults.

However, we review that older adults are not easily fascinated by using interactive technology due to age-related characteristics (Section 2.3). To increase the engagement in their later life with the benefit of technology, many studies focus on developing better technologies such as assistive technology, emerging technology, AR and VR, robots, positive technology, and smart technology for older adults. In the real world, new and innovative technological interventions are not well adopted and fully utilized by older adults. Even though older adults adopt new technology, they use only limited functions.

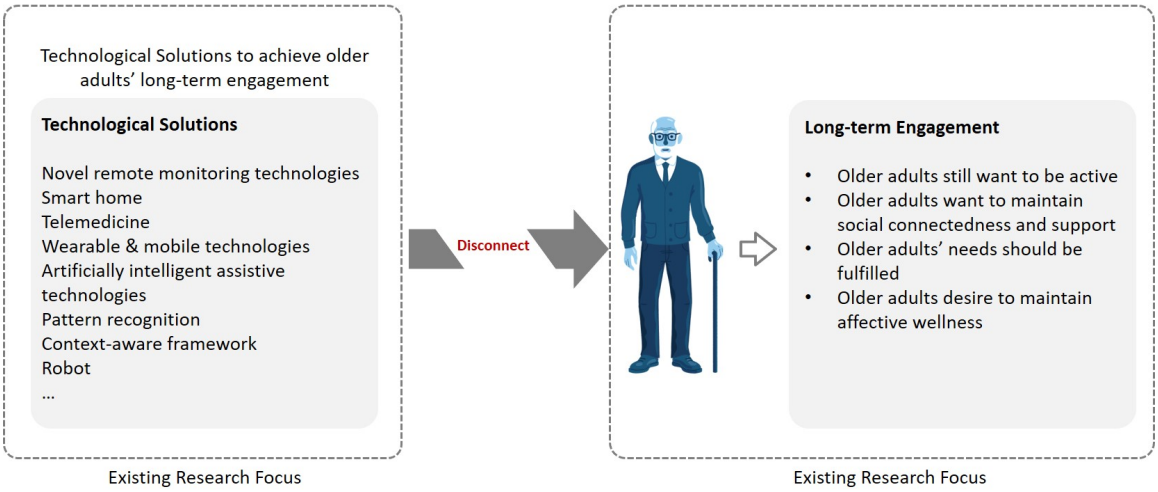


Figure 3.2: The importance of studying older adults' engagement to encourage them to use interactive technology

The foregoing characteristics of older adults must be considered by developers, designers or researcher when developing new technology for them. Understanding the older adults for the new and engaging technology is vital to set up good environments for older adults. Designers, researchers, and developers of new technology need clarity in the needs of older adults. Making these newer innovations simpler, easy to use, and fun enables older people to embrace them as part of having fun late in their lives. However, these very characteristics can hinder older adults from adjusting to new technology. Older adults have the key idea of taking good care of their lives, so

they might not be compelled to embrace new creations. However, they still desire to enjoy the remaining part of their late-life and have fun. The use of technology for the benefit of older adults is, therefore, a worthy cause. We believe that studying engagement for older adults is needed to make a connection between older adults and the use of technology, and help them older adults to obtain the related benefits from technology. Technological solutions developed for older adults to enrich their life are not well-utilized and adopted by older adults.

We found that the existing user engagement attributes (Focused attention, Positive Affect, Aesthetic Appeal, Endurability, Novelty, Richness and Control, Trust and Expectation, and Motivation) have limitations in describing older adults' engagement with technology, due to which further research required to understand the same. In Chapter 2, we found that many studies have been conducted on the challenges affecting older adults' use of interactive technology before they experience the technology (See Section 2.3 and a top-left box labeled Challenges/Barriers in Figure 3.3) and the factors affecting their continuous use of it (See Section 2.4 and a top-right box labeled Factors influencing technology usage/adoption in Figure 3.3). However, older people often have difficulty overcoming the initial barrier to use interactive technology. Despite the initial barrier being the most difficult stage, there is a lack of research to identify the factors necessary to overcome this stage. The main problem in the use of technology by older adults, is that a broad and advanced range of tools and platforms for older adults are being developed, but older adults who actively utilize the technology remain few. Many of them cannot even use or enjoy most functions of smartphones or computers properly. We seek to reduce the gap between older adults and technology by increasing their initial engagement using technological developments. This chapter highlights the necessity of initial engagement, which has not received much attention in the research for HCI and technology in older adults. We have proposed a new approach to understand older adults' engagement by dividing

the engagement process as before, initial, and after engagement. We have created a new engagement model for older adults by discussing the factors from the existing studies and adding new initial engagement factors that emerged from this dissertation. The following chapters present several studies to identify factors affecting older adults' initial engagement in the use of technology.

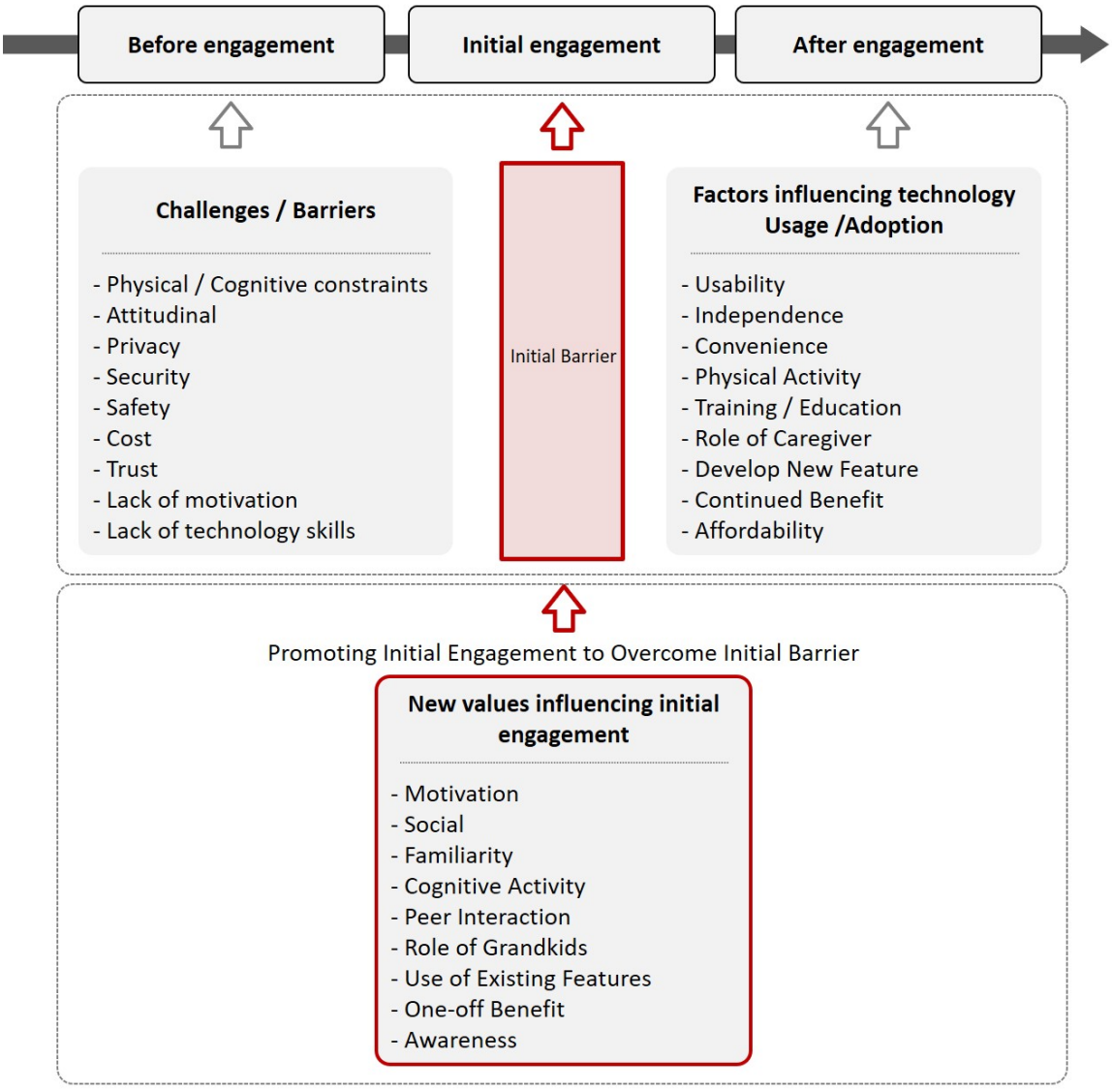


Figure 3.3: New model of engagement of older adults with interactive technology

3.5 Discussion

Older adults are generally satisfied with their existing lives, which do not have much scope for the use of technology, and they may enjoy trying it once out of interest but become reluctant to continue using it. Older people might be more curious or interested than frustrated when attempting to use interactive technology in the early stages. The initial experience of using technology has a great influence on the overall attitude toward future attempts. For the initial attempt, it is important to increase the self-efficacy of older adults by ensuring that the technology is accessible, easy, and safe.

To derive a concept for the engagement of older adults, we reviewed the user engagement previously studied. This chapter explains why the existing study of engagement is insufficient for application to older adults and to emphasize the need for engagement studies for this group of individuals. This chapter presented the research need and direction of this dissertation, based on the insights obtained through the literature review covered in Chapter 2. Although countless studies have been conducted to help older adults gain the benefits of technology, we tried to find the underlying cause of older adults not utilizing various technological interventions in the direction of enriching their lives. We learn that the biggest reason is a lack of understanding of older adults' initial engagement.

The concept of initial engagement we redefined in the earlier section is viewed as a cognitive process in which older adults' interest and engagement in technology change from negative to positive. Factors influencing before and after the initial engagement were classified based on the existing study. The challenges and barriers faced by older adults in Section 2.3 influence not only the usability of users but also user engagement. These challenges and barriers are complex phenomena that naturally occur as people age. These aspects are classified as factors that must be satisfied before engaging in the use of technology. The factors covered in Section 2.4 affect the

technology usage and adoption of older adults. It consists of factors that influence older adults' engagement after they decide to use the technology. These factors are more relevant to the benefits given to older adults. For example, when older adults use technology, various methods to improve usability become useful and beneficial to them. Accordingly, a new model for older adults' initial engagement was proposed in this chapter based on a comprehensive understanding of the existing research. The initial engagement factor revealed in this study is valuable as a starting point for understanding the engagement of older adults. This model should be developed into a more refined engagement model through further research. A study that divides the stages of engagement based on older adults' cognition and identifies factors that affect each stage shows the need to continue in this vein in the future.

CHAPTER 4: FOUR MIXED METHODS STUDIES OF INTERACTIVE TECHNOLOGIES FOR OLDER ADULTS

4.1 Summary

The chapter describes the details of four technological systems and mixed methods studies of interactive technologies for older adults. It begins by summarizing the research demographic for this dissertation. Section 4.3 describes the two main factors that can stimulate the interest of older adults revealed through the pilot study. In this dissertation, we have used four technological interventions to identify the factors to increase older adults' interest and engagement in interactive technology. First, we analyze the general behavioral characteristics of older adults while using two systems (Move and Paint and Savi) designed by ourselves. In Section 4.4, we describe mixed methods studies to analyze the behavioral characteristics and factors influencing technology usage by older adults. Based on the understanding of these general characteristics, Section 4.5 presents a study design to identify the factors affecting the initial engagement of older adults and present empirical observations related to the same. Subsequently, among the mixed qualitative and qualitative studies that we conducted for this dissertation, we have identified the challenges in conducting research with older adults. Then, we have suggested the chosen methodologies to better understand initial engagement for older adults in the use of interactive technology.

4.2 Demographic

Many studies often ignore the heterogeneity of older adults in terms of life expectancy and their perceptions and attitudes towards technology [201, 202]. Older adults, in general, were once considered as one homogeneous group of people over the

age of 65. A rise in life expectancy to the age of 80 and the fully changed conditions today shows that this concept is no longer fair. However, people still adhere to this concept and often ignore the fact that older adults' characteristics, capability, and interests are very diverse no matter their age. This study set the research demographic age at 60 and over, and includes those seniors who are interested in participating in the project and who do not have much experience with technology. A minimum age was set for the participants in our study to limit the participation of the younger generation and middle-aged adults. However, we have acknowledged that age does not merely constitute a biological function or physiological changes due to the number of years one has lived. The study was begun with the expectation of seeing that each participant has a different ability to use interactive technology.

4.3 Pilot Study to Understand Older Adults' Needs for Technology Usage

Initially, our design concept emerged from need-finding interviews with older adults. We conducted a pilot study with five senior residents living in a retirement community to find out the factors that may stimulate their interest in the use of technology. The main topic of the discussion was about activities that interest older adults and how to spend leisure time. We met a program director at Sharon Towers, the institute that we visited, and explained that the residents were provided many activities in which they can take part. However, these activities operate on the model of attending an organized event at a specified date and time, doing the activity, and then going back to their residence or the next event. These activities include various exercise classes, social events, and mental health activities. The necessary information regarding these events is communicated to the residents through a variety of methods including a paper calendar, bulletin boards, and a mobile application. Besides the classes and other events provided to them by the center, residents can create a formal or informal group that they meet with throughout the week. These gatherings can be held in the dining area or other areas around the campus. However, these gatherings only benefit

the social and mental well-being of the residents and do not necessarily promote any activity. Residents also indicated that activities that are collaborative or competitive are enjoyed.

Further, during the visit to Sharon Towers, it was evident that residents enjoyed group activities that are either collaborative or competitive. Many residents who live on the same floor or street act as small groups. Even though they are small tight knit groups, it does not mean that all the members are of the same age and ability. Everyone desires to participate in the activities, and there is a widespread use of technology and physical ability involved in the same. It was determined that often the level of participation is tied to how well a person can travel to an event or course. If a resident is struggling with their mobility, then they often start decreasing their amount of outside activities, which leads to a lower level of well-being. The last activity that was ascertained during the visit was storytelling, which seemed to be a common interest for many of the residents, and they exchanged stories before, during, and after meals. We found that many older adults enjoy being creative, playing games, and being social. From this pilot study, we decided to focus on two user experiences using interactive technology: 1) social creative expression in public space, and 2) emotional attachment in a private setting.

4.3.1 Being creative is an important factor in deciding to use technology

This section explains why we chose to design a gesture-based interactive system to encourage social creative expressions that help older adults transition from passive to active about technology in the public space. Embodied interactive technologies have the potential to offer enjoyable and positive experiences to older adults and enhance opportunities for meaningful social connectivity and engagement in public space [95, 203]. Many studies have pointed out that active participation and engagement in social activities are critical for maintaining a good quality of life for older adults [204, 205, 206]. Embodied interactive technology installed in a public space can

facilitate engagement and connection with others, which can benefit older adults in maintaining psychological, physical, and cognitive health. Embodied interaction is the kind of interaction that recognizes and includes the use of our bodies. It implies designing interaction such that the user can use their body in ways in which they are used to using it in the natural physical world. Embodied interaction requires certain actions and is compelling enough that users are willing to perform those actions to interact with the system. This is not only an attractive approach for the aging population, since it requires less time to learn how to use the system, but it also requires them to move and participate in natural physical activity. In addition, providing opportunities to be creative can draw the attention of older adults. Social creative expression as a design goal for older adults is the correct intervention to transform older adults' technology-related behaviors from passive to active, and in turn increase their interest and engagement in technology.

4.3.2 Family is an important factor in deciding to use technology

This section explains why we chose to design a mobile technology to enable emotional attachment to the family in private setting that will increase older adults' interest and engagement. The main challenges faced by the aging population are social isolation, digital exclusion, lack of digital skills, lack of social contact and high healthcare costs. We designed a mobile technology to encourage older adults to keep connected to their social contacts. A mobile device has the capacity to improve the quality of life of the older population because it helps them to communicate easily with their friends and family [207] and keep up with their health management and community development. Even though younger individuals have a vast knowledge of technology, families play the central role in terms of communication with the older relatives regarding how they can connect to their friends, family, and community resources through mobile technologies. The younger family members should encourage and engage with elderly relatives on using mobile devices to communicate. We believe

that older adults who have a positive interaction with family members are more willing to try mobile devices. Older adults can frequently come in contact with current mobile or computing technology if family ties are strong. The need for technology increases regarding keeping in touch with the family. Through technology, older adults can easily obtain assistance when issues arise. On the other hand, the accessibility and necessity for technology are lesser for older adults who rarely stay in touch with the family or live alone.

4.4 Study Design to Identify Factors Influencing Technology Usage by Older Adults

In this study, we designed two technological interventions to identify the factors influencing technology usage by older adults. To understand the general characteristics of older adults in the use of new interactive technologies, we conducted user studies in the real context as well as in-depth qualitative studies. This chapter describes the system designs and mixed methodologies to build a basic understanding of technological behavior and engagement of older adults.

4.4.1 Move and Paint: Embodied interactive technologies for social creative expression in a community center

This chapter describes the design details of the Move and Paint system, which is an embodied interactive painting application that converts full-body gestures detected by a Kinect sensor to drawings and coloring book actions on a large screen. The chapter begins by summarizing the design rationale for the system and providing an overview of the user interface and experience. Next, we have explained the study methodologies including two user studies, focus group discussions, and in-depth interviews.

4.4.1.1 Move and Paint system design

Our design concept emerged from interviews with senior residents and the evaluation of early prototypes of Move and Paint. We held these interviews in two stages

of early prototyping for Move and Paint with 10 senior residents between the ages of 55 and 85 of an assisted living residence. The data gained from these interviews informed our decision to use full body gesture-based art in a social setting as the conceptual basis for the design. Our system is designed for older adults with the goal of encouraging individual creative expression and strengthening social connections.

1) Initial Design Concept

Older adults in front of interactive displays are generally unaware of their interactive capabilities, i.e., how they can interact with the displays, and whether gestural interaction is supported. Users can quickly lose interest in a display and abandon further attempts to interact with it if they see no immediate system response resulting from their first actions. Real-time and interaction feedback needs to be designed for discoverable interaction systems. The important design rule of an interactive system is visibility. All the controlling gestures should be visible and, therefore, easily discoverable. The user should feel as if they are in control of the experience at all times; they must constantly feel like they are achieving something and be able to view the well-designed results of their interaction. In particular, seniors showed behaviors that indicated they were uncomfortable trying new things or ones that they were hesitant to explore. In order to create design concepts for older adults and to offer an interactive system that can intuitively assist the individuals without requiring them to be tech savvy or proficient with computing, it is necessary for the designer to consider carefully how to make users aware of interactive capabilities. Initially, we had four design concepts which are as follows:

- **Concept 1:** *Mirror-based: Disembodied*

  All users see are the brushes they control on the screen and the lines they make by moving those brushes.

- **Concept 2:** *Mirror-based: Human-centered representation (Direct)*

The human sees a representation of their own body on the screen and it is holding the creative tool. The representation of their body is a shadow of their actual body.

- **Concept 3:** *Mirror-based: Human-centered representation (Indirect)*

  The human sees a representation of their own body, but they see it as an abstract representation, such as a stick figure or a cartoon.

- **Concept 4:** *Not a mirror*

  This concept is a tool-centered embodiment. The human becomes the tool and sees a representation of their body as a creative tool.

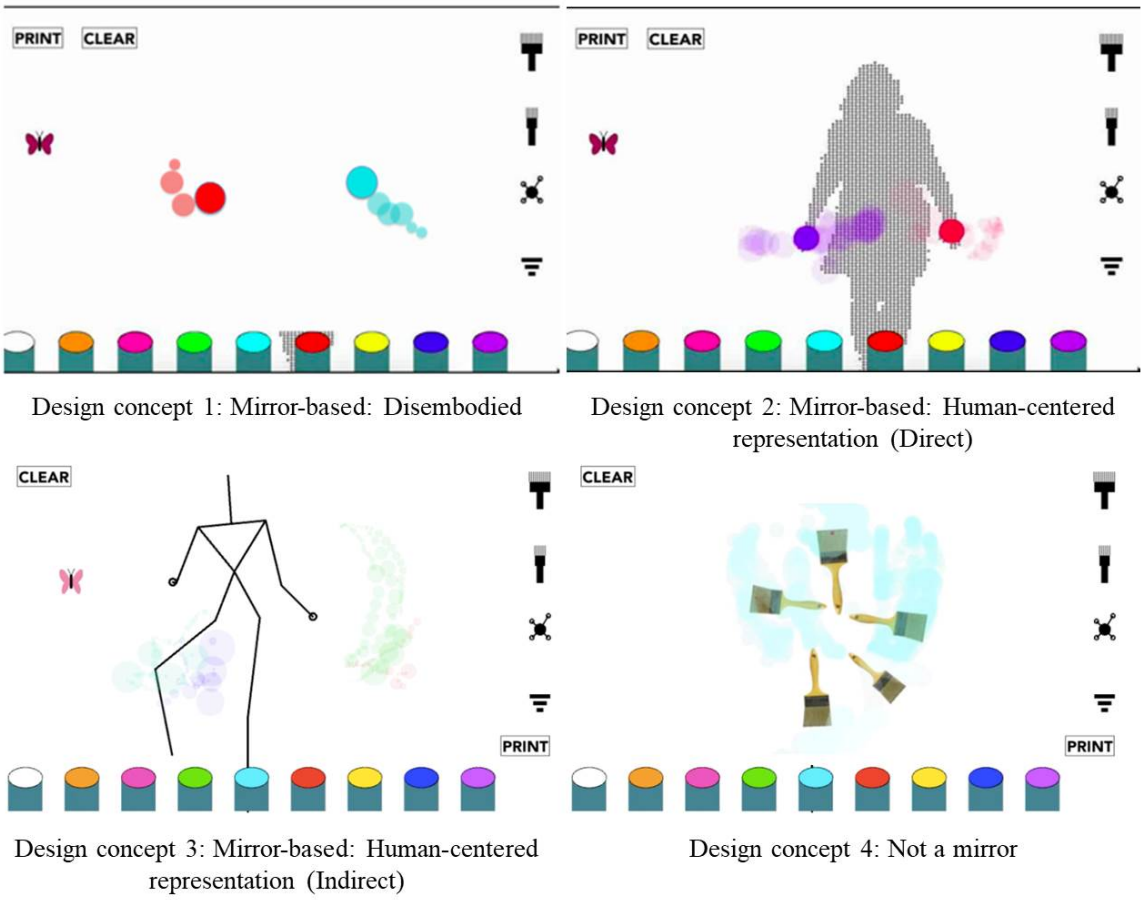


Figure 4.1: Design concepts of Move and Paint system

2) Final Design

We decided to choose the mirror based and direct human centered representation. The metaphor of a mirror can be used as an effective method for positioning users and providing them with a real-time reference. Many researchers have been involved in attracting attention and encouraging interaction from different perspectives. In fact, the mirror concept has widely been applied to encourage interaction on public shows and perform gestures in a bid to control the representation of one's mirror image. The mirror image is an effective method for positioning users, and it provides a real-time reference. People observe their mirror image with great curiosity and experience themselves and their surroundings from new perspectives. Once a passer-by is reflected on the display, they may start to wave a hand in subtle interaction to see how the display reacts; consequently, deeper interaction should be available using different gestures to explore the possibilities of the effect and engage the passer-by for a long time. Figure 4.2 shows our final design.

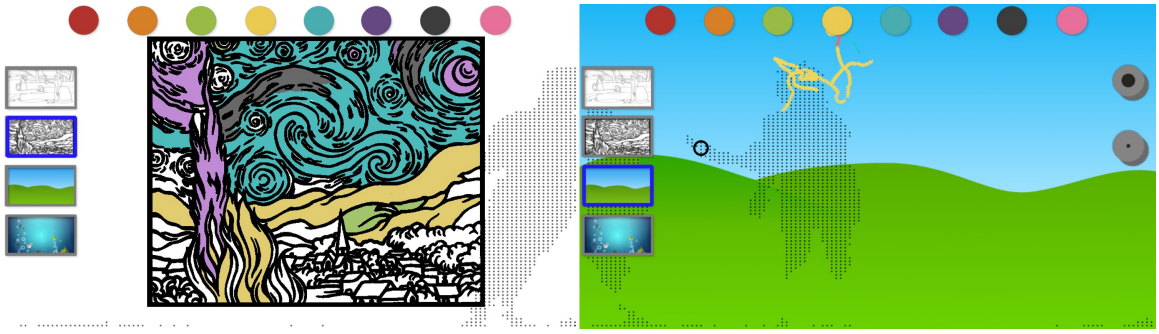


Figure 4.2: Left: Move and Paint in coloring book mode / Right: Move and Paint in free draw mode

Interface Design. The interaction design, as shown in Figure 4.2, uses a palette of colors to add color or a drawing to the canvas on the screen. The user changes the color by waving their hand to move the circle representing the cursor to a color at the top of the screen. Selecting icons on the screen allows the user to change the background, brush thickness, or color. A line on the floor indicates the interaction

area.

Background Options. Move and Paint has two modes: coloring book and free draw. Each mode has two background options, which the user can switch between by hovering the circle controlled by their hand over the icons on the left side of the screen. In the coloring book mode, a sketch of a famous work of art is displayed. The user moves their hand to a section on the sketch to add color. In the drawing mode, users can draw lines and shapes anywhere on the screen by moving their hands.

Brush Interaction. The user can choose between two different brushes-thick and thin. Users switch brushes by hovering the circle controlled by their hand over the brush menu icon on the right side of the screen. The picture is drawn on the screen as the hand moves, mimicking the real-life painting process. The user can stop the brush from drawing by bringing that hand close to their torso, mimicking the physical activity of removing the pen or brush from the paper.

Shadow Design Concept. The user's shadow is shown as grey pixels to provide feedback on the location of their body, and therefore the hand controlling the cursor. This mirror effect has been used to catch a user's attention as they pass by and encourage interaction [208]. The mirrored representation helps users position themselves within the system, understand that the system is interactive, and find out how to interact. The shadow visually represents the current state of the user's relationship to the system.

Instruction Design Concept (with instruction condition). The Move and Paint system has three points at which it provides guidance, as shown in Figure 4.3. The instruction "Come closer" is displayed when there is no one in range of the Kinect. When someone is too close to the screen, the instruction tells them to stand back behind the line on the floor. When one stands in the correct position but does not interact, an instruction tells them to raise their hand to draw. The instructions are performed by a humanoid figure to make them more friendly. Providing instructions

makes the interaction easier.

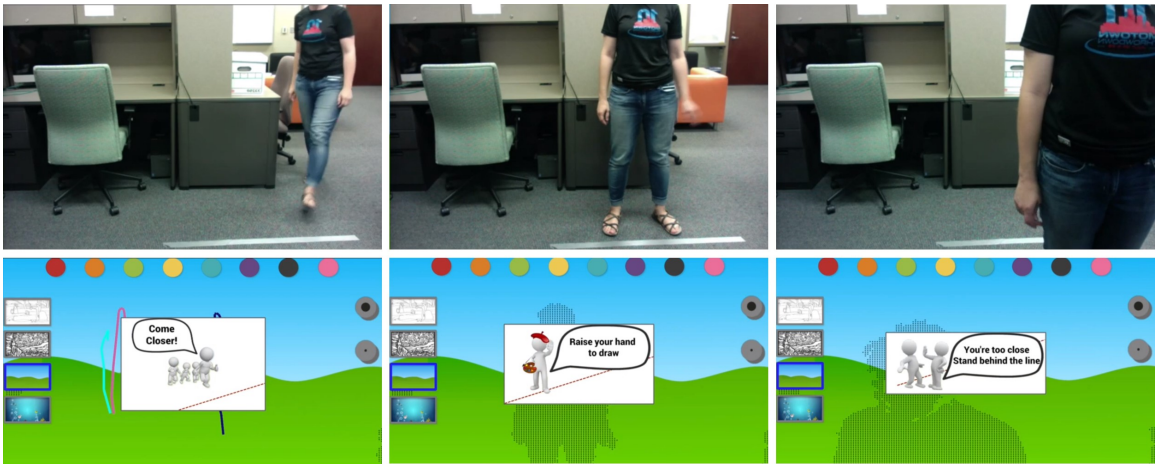


Figure 4.3: Illustration of instructions in with instruction condition

4.4.1.2 Qualitative Study

1) Data Collection

We conducted a qualitative analysis of focus groups and interviews with older adults to understand their general attitude toward the use of gesture-based interactive technology. This analysis is a basic understanding of an evaluation framework to analyze the behavioral characteristics of older adults on the use of Move and Paint. We carried out focus group studies and interviews at a senior community, the Sharon Towers. It is important to note that this senior center is not a residential home, but designed to promote health and offer a community center for the elderly, bringing them together to engage in activities and enjoy services that enhance their dignity, encourage their involvement in community programs, and support their independence. The center offers services intended to support older adults such as counseling, social support services, advocacy, subsidized meals, referrals, and information. It also has various programs, including recreation, education, nutrition, fitness, and volunteer, which are meant to improve social participation and promote the health and well-being of older adults. This study was approved by the Institutional Review Board (IRB) to collect the data. Participants signed a written informed consent. Questions

for the focus group and in-person interview were aimed to understand user experiences and usability issues of older adults. The facilitator took notes and recorded the conversations. The recordings were transcribed to facilitate analysis.

Table 4.1: The semi-structured interview questions for the focus group discussion and in-person interview.

Interview questions
1) Have you ever used a gesture-based interactive system like Move and Paint, which remotely controls the system by using your body?
2) What did you think about this system at first glance?
3) When you first looked at this system, did you want to use it immediately? Or were you unwilling to use it? Explain why?
4) On a scale of 1 to 10, where 10 denotes the most difficulty, how difficult was to use the system?
5) What was your favorite part of this experience?
6) When you were using the system, did you discover the shadow of your body projected on the screen? What do you think the role of the shadow of your body?
7) When you were using the system, can you find an instruction? What do you think of the role of the instruction?
8) Have you used other functions such as modification of backgrounds or drawing modes, in using the system?
9) What did you plan to draw through this system?
10) Did the system properly respond as you intended?
11) What improvements would be required for you to have more interests in the system and continuously use it?

2) Focus Group Study

This senior community includes individuals of 60 years and older, who are provided

various opportunities such as exercise and educational programs to improve their physical and cognitive health. To gain more insights through an active discussion, we visited the aerobics class and recruited participants for a focus group discussion. Older adults who voluntarily participated in the exercise program were judged to be active. The recruited participants were moved to a space in which the Move and Paint system was installed separately for a focus group discussion. The focus group study comprised a one-hour group discussion and the same moderator conducted two focus group discussions. The total number of senior participants in this study was 16: the first group included eight female participants and the second group included two male and six female participants. The researcher explained to older adults how to use the system prior to the discussion and encouraged them to use it freely.

3) Semi-structured Interview

For the interview, the Move and Paint system was installed in the hallway towards the main lobby and gym. Older adults who showed interest in the Move and Paint system and approached it were recruited as participants. The interviews took place over two weeks with a total of 15 participants (three males and 12 females). The participants were encouraged to ask questions about the Move and Paint system while interacting with it. The participants were then asked to answer questions with the facilitator. An interview session took approximately 20 minutes. The questions the study facilitator asked were the same as those from the focus group studies.

4) Analysis

We used thematic coding and other qualitative methods to analyze the focus group interview data. The verbal responses to the interview questions were analyzed to identify design principles and emotional triggers with Move and Paint interaction for older adults. We present the main findings and results in Section 5.2.3.

4.4.1.3 In-the wild User Study

The Move and Paint system has the potential to increase social connectedness and community engagement of older adults. In the qualitative study, it was difficult to observe natural interaction of users, and to observe what kind of social interaction took place naturally around the system. We performed an in-the-wild user study to identify behavior and usage patterns using the Move and Paint system in a natural setting. First, we conducted a comparative analysis with the younger population to identify older adults' unique characteristics while using the Move and Paint system. Second, we only took only the dataset of older adults. We developed an evaluation framework to analyze the engagement and behavioral patterns of older adults while using Move and Paint. Then we conducted a pattern analysis to identify the importance of social engagement in the use of the Move and Paint system.

1) Data Collection

Move and Paint is an embodied interactive painting application that converts full-body gestures detected by a Kinect sensor to drawings and adds color on a large screen. Move and Paint was implemented using a Kinect sensor, a Microsoft 55" display, and a Mac Minicomputer on a vertical mount. The software was developed using processing with SimpleOpenNI for gesture tracking. Move and Paint was left unattended for several weeks for passersby to engage with. All users were able to use it naturally as many times as they wanted. We did not prompt users to use it in any particular way or to try to accomplish any particular task. Two motion-detecting cameras were used to record the people that engaged with the system from different angles. This enabled us to study the natural interactions that occurred around the proposed system. The system also tracked log data about events, such as a user changing color, and took periodic screenshots of the interaction screen.

2) Comparative Study

We performed a 2 x 2 study of Move and Paint in two conditions: with and without

instructions; and two locations: an assisted living retirement community and a college library. We set up the system in a public area and left it unattended. The system was located near the entry of a multi-purpose function room in the retirement community, in which events, movies, exercise classes, and parties were held. In the college library, the location was in a public social study area through which many people pass to get to other areas of the library. We did not have control over the choice of specific location in these facilities and could not control for the context around the display, day of the week, and traffic in the area. These factors likely influenced the number of people who interacted. However, we wanted to study people who were interacting naturally and voluntarily, and, therefore, we were not able to control many of the variables that may have influenced the number of people that noticed and interacted with Move and Paint. We studied two conditions of the system: one with no instructions and one with instructions. In the retirement facility, we first ran the version with no instructions for three and a half weeks and then 11 days with instructions. In the college library, we ran the version with no instructions for four days and then the version with instructions for six days. To normalize, we reported the data from the first three days in each condition. We present the main findings and results in Section 5.2.1.

3) Behavioral Pattern Study

We used the same dataset as a comparative study but only took the dataset from older adult participants for this study to understand older adults' unique behavioral characteristics and their patterns of using the Move and Paint system. We collected data from 66 instances of interaction, and only included older adults who engaged with the system voluntarily and stopped in front of the display either to look at it or to interact with it. We did not include people who looked at or gestured at the display as they were walking past. We classified the evaluation factors affecting older adults to be engaged in using the Move and Paint system largely into five categories

through the focus group discussions and interviews with older adults: emotional, physical, social, creative, and cognitive experiences. We added the factor 'focused interaction time' to the evaluation framework even though there was no mention in the qualitative data analysis. By 'focused interaction time,' we mean not only being in the vicinity of the system or showing interest in it, but actively acting or attempting to act upon it. This is an important factor in judging how much the user is engaged in the system [30]. Each of the six categories of the framework has something to measure and results in a value between 1-10 depending on where the measure falls within the predetermined range (Table 4.2). When we used this framework in our analysis, the data was normalized so that a comparison could be made between the categories, and that each category could be set to the same range. These measures and ranges were determined by the ratio of the time taken up for each category as compared to the total time each user stayed in front of the system. We present the main findings and results in Section 5.2.2.

Table 4.2: Evaluation framework for analyzing engagement and behavior pattern.

Category	**Clarification**
Emotional experience	We measured the emotional changes that occurred during the interaction. The changes in facial expression were examined and the number of positive expressions (happiness) in the dialogue that naturally occurred during the interaction was counted. The total duration that a user stays in the Move and Paint system was measured. The time revealing a positive emotion out of total duration was measured. 1: When the time revealing a positive emotion is less than 10% ... 5: More than 40% and less than 50%

	... 10: More than 90%
Physical Experience	We measured when a user had difficulty in moving themselves or was assisted by a device. The number of times a user experienced physical discomfort while using the Move and Paint system was counted (for example, he/she can't stretch his/her hand higher, or can't maintain for a long time while stretching his/her hand). 1: When a user can stand only with support and are not able to reach to the system or when they feel discomfort more than six times ... 5: When an assistant device such as a walker is needed, or when a user feels discomfort equal to or more than twice and less than four times ... 10: When the movement is natural and there is no physical discomfort in using the system at all
Social Experience	We measured the social interaction occurring around the system. It included cases of receiving help from an acquaintance to find out how to use the system, discussing how to use the system with other users, and connecting to the everyday conversation by using the system usage as a mediator. The time spent for social interactions compared to the total time spent in the system was measured. 1: When the time spent for social interactions is less than 10% ... 5: More than 40% and less than 50% ...

	10: More than 90%
Creative Experience	We measured the occasions when a user showed a creative intent. It included cases of specifying the desired color to paint a picture, showing a clear purpose for painting or clear finality for a target, or finding and playing a shadow. The ratio of time showing creative expression to the total-duration was measured. 1: When the time revealing for creative expression is less than 10% ... 5: More than 40% and less than 50% ... 10: More than 90%
Cognitive Experience	We measured how well a user identified the system at the first encounter. When another interaction modality was used instead of mid-air interaction, it included cases of failing to find a suitable distance for using the system correctly. We measured the percentage of time that a system failed to interact out of the total duration. 1: When the time for difficulty in understanding how to use the Move and Paint system is less than 10% ... 5: More than 40% and less than 50% ... 10: More than 90%
Focused interaction time	We measured the immersed time while using the system. The time of actually actively using the system out of the time staying in front of the system was calculated. If they were talking to someone, watching someone else interact, or simply staring at the system, it did not count as focused interaction time.

	1: When the focused interaction time is less than 10% ... 5: More than 40% and less than 50% ... 10: More than 90%

4.4.2 Savi: Communication technology that enables emotional connections in a family setting

This section details the design of the Savi system, which is specially designed for seniors to stay connected to friends and family. It begins by summarizing the design rationale for the system and providing an overview of the user interface and user experience. Next, we have explained the study methodologies including focus group discussions and in-depth interviews with younger family members who maintain close contact with their grandparents.

4.4.2.1 Savi System Design

Savi is designed to give people freedom from the loneliness and isolation that can often accompany aging. Through this software, seniors can connect with a private family network that protects against spam and other unwanted activity. They can share photos and send messages easily even if they have had little or no experience with mobile devices. The large buttons and intuitive interface makes this process easy for seniors. Based on this design concept, we designed a base system with the prototyp.

1) Initial Design

We designed a suite of apps suitable for older adults called Savi. We minimized the function and designed an easy to use interface with large prompts and print. The Savi apps let older adults stay in touch with family and friends via instant messages or photo sharing. Apart from communication features, older adults can browse the web

through the simple voice search function. Moreover, they can manage their schedule with to-do lists, reminders, and calendar apps. The story painter app is similar to a messaging app in terms of exchanging messages, but it is differentiated by the aspects that voices, not texts, are inputted, and the interactive background and simplified saving and sharing method. This background will respond to the voice and change its color and size to produce a beautiful drawing. Our design consideration to design Savi at this time were improving usability for older adults. Our initial design consideration for Savi was improving usability for older adults. This version of the design presents the failure to engage older adults in the use of mobile technology.

Apps:

Link to the digital prototype: https://indigodesigned.com/share/awemp31zaynq

- Friends (add or manage contacts)
- Message (exchange messages with friends and family)
- Camera (take pictures and record video)
- Pictures (view the pictures and photo sharing)
- Calendar (manage and schedule events and set alarms for the same)
- To-do-list (manage daily schedule through voice)
- Ask a question (browse the web through voice)
- Story Painter (share a story or message with friends or family with interactive drawing)

2) Initial Design Considerations

Content layout design. Extensive use of graphics can cause a lot of confusion to the older people and make it even more challenging to obtain their desired search results. However, we want to make it easier for them. As a result, we have used

simple and meaningful icons with names. Additionally, we have ensured that the icons' position and size are visible enough and labeled to enhance readability. As one ages, the problem of color vision also increases. A large percentage of color defects occur among the older population. In fact, they find it difficult to identify the shades of one color. Therefore, we often avoid using single color shades and instead provide a high contrast between the background and foreground.

Use of interactions. Older adults have slower motor skills which make it harder for them to use technology; therefore, we have tried to keep the interaction as simple as possible. We have provided alternative buttons to support interactions such as scroll, pinch or etc. We have provided enough diagonal space between buttons and reduced the distance between interface elements that are likely to be used in sequence. For older adults who have had inadequate experiences in technology or difficulty in using it, each app has extremely simplified interaction processes, by eliminating unnecessary functions, except for main ones. Various apps with which voice recognition technology can be actively used have been organized to partly resolve difficulties that older adults experience when they try typing.

Remove intellectual load. One of the most common problems associated with old age is memory loss. Improving the simplicity of the applications would help them focus on the key functions of the apps and reduce the functionality layer, consequently increasing the ability of older adults to use the system. For instance, if the user requires memory of the previous actions, we tend to not divide the tasks across multiple screens.

3) Redefining Research Focus for Savi

We performed a pilot study with 80-year-old woman. Initially, we aimed to determine the usability of the system, how well users navigated the information and to understand the overall usage of the system. She was asked to perform a series of tasks relevant to the Savi tablet's functionality, and then answer a series of follow up

questions about her experience with the system. At the beginning of the study, she was given a brief overview of the purpose of the study. However, she was not trained or provided any information on how to use the system. This decision arose out of the intention to infer the thought process of older adults and to ascertain the usability problems from their own experience with the system.

She was given three tasks, which were as follows:

- In the picture app, there is a photo of a cat. Can you find that photo and send it to Karen, a person in the app friends list? Can you find a photo of a dog (they would need to scroll)?
- In the mail app, can you read the mail from Gina? Can you reply to her that you are on holiday in the Bahamas?
- In the friend app, can you find your friend George? When is his birthday? Can you send a mail to George inviting him to join you in the Bahamas? Can you add a new friend and give that friend the name of someone you know?

She failed all three tasks; she did not want to try even a single button. SAVI could be used by older adults. And yet, she shows a passive attitude to technologies and are dependent on younger generations. From this pilot study, we learned that a system should be designed to help older adults feel positively about the technologies they are afraid to use and find difficult. This study intended to understand their needs and look for ideas that could make them happy, by conducting focus group interviews with the family as well as older adults. Family members can understand well what older people want, introduce the necessary technology to them, and help them resolve any problems that may arise while using the same. It is expected that family members have various ideas for designing Savi software for older people based on the experience in technology related to their parents or grandparents. We would

like to develop the design method through which older people can build emotional attachment based on ideas that family members determine for older adults.

3) Second Design

To make the app simple and get older adults interested in using Savi, we only created three apps for older adults' use. Splash screen features and family admin apps were added to the second Savi iteration to foster positive emotions and user experiences in the context of mobile usage for older adults.

Splash Screen. Splash screen is designed to help emotionally inspire older people before they start using Savi apps. When running the Savi app, the system brings and displays messages and pictures, beginning with the most recently saved ones until users click the Start Savi button and move to the Main Page. Seniors can easily and conveniently check the messages or pictures recently saved by their family members without trying to search for them.

Figure 4.4: Savi Splash Screen

Camera and Gallery App. The camera app for Savi has the same functions as general camera apps, and all the unnecessary functions have been removed. The gallery storage is shared with friends or family. The files stored through the camera are shared with people who are on the friends list without needing to send them separately. Everyone who is on the list can add photos and videos to the album whenever desired and get notified when something new is added.

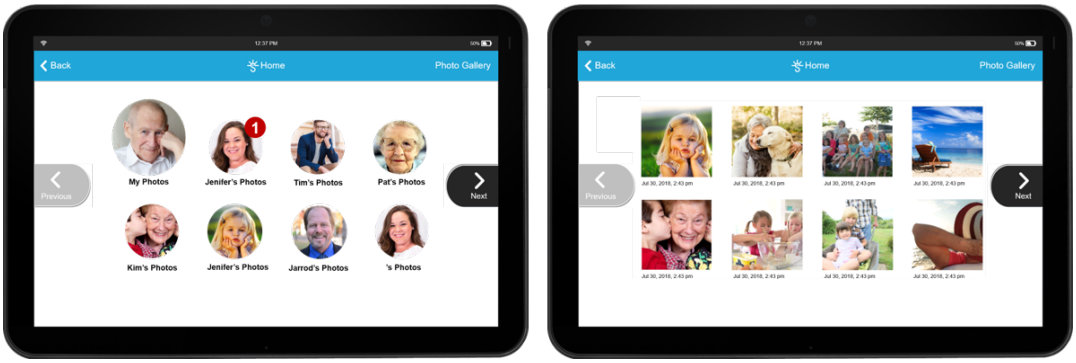


Figure 4.5: Savi Camera and Gallery Apps

Message App. With the Message app, users can easily exchange messages with friends and family. We added a voice messaging feature as well.

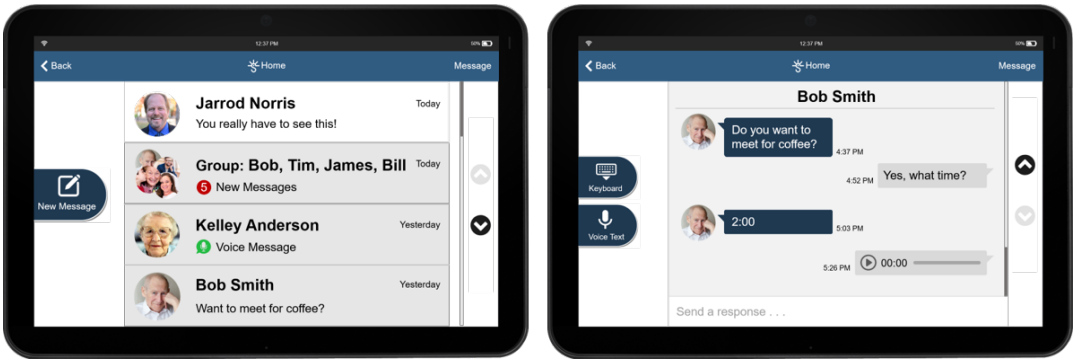


Figure 4.6: Savi Message App

4.4.3 Apps for the family administrator.

We have separate functions for older adults and for the family administrator. It consists of four apps: Profile, Friends, Design Ideas and Setting. This setting is designed for family administrators. Family members manage the system that older people will use. They family administrator invites family and friends, adds personalized content, and assures that seniors remain engaged and secure. When users click the Configuration button on the upper right corner of the Main Screen, they can move to the Setting Page.

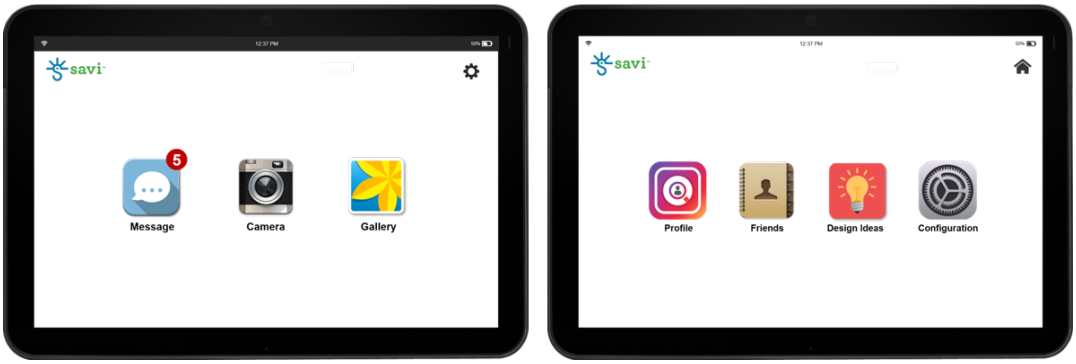


Figure 4.7: Left: Main screen for senior users, Right: Setting screen for the family administrator

4.4.3.1 Qualitative Study

1) Data Collection

We designed a high-fidelity prototype to conduct the focus group study. We used Indigo Studio (prototyping tool) to create a visually rich, powerful prototype full of interactive effects. Participants experience an interaction similar to when they use the final product through the prototype. We provided a group with the tablet device (iPad) on which the Savi prototype was downloaded for use during the focus group study so that they could explore the applications. A preliminary focus group discussion and interview were conducted without IRB approval. Focus group discussions were performed with younger family members with approval from our institution's IRB. We only collected the audio data. To create an active-passive spectrum of older adults to understand behavior and engagement in the use of interactive technology (the results have been presented in Chapter 5), we used the Move and Paint study as the main source and the Savi study as a secondary source. The data analysis from the Savi study was used to understand the general behavioral characteristics of older adults regarding mobile technology in a family setting.

2) Preliminary Study

Focus Group Discussion. The focus group study was designed to facilitate discussion about the range of older adults' technology use and their attitudes about

mobile devices. Focus group interviews were conducted with 20 people aged 65 or older in four groups of five people. Each discussion session lasted for 50 minutes. The goal of this study was to understand the general interest and identify barriers of the mobile device usage of older adults to obtain app design ideas for Savi software. The focus group discussion consisted of three sessions. The first session was to understand the general interests about technology. In the second session, participants were asked to discuss their technology experiences. This objective was based on the understanding that older adults are likely to have low use of mobile phones. They may not be able to utilize the various functions of their mobile phone and use only limited functions such as calling and sending messages. The expectation was to prioritize essential functions of mobile phones based on what functions older adults use and understand and examine whether the app we designed would be helpful for older adults. In the last session, participants discussed technology barriers. Older adults are likely to experience many difficulties in using mobile phones. A direction for improving the SAVI design in the future can be determined by identifying the difficulties and inconveniences experienced by elderly people when using mobile devices.

Interview. We began with the hypothesis that older adults may have many difficulties/ barriers/ frustrations in using their mobile phone. So, they may need new functions and designs to easily understand and use apps. Our target group were seniors. We began to consider the children of the seniors and staff members in elderly facilities as another customer segment. This is because not all elderly people make decisions on their own and are heavily influenced by surrounding family or acquaintances. We interviewed 16 people: 10 seniors, three family members, and three staff members by asking questions regarding the elderly's use of mobile devices and any difficulties observed.

This preliminary study was conducted without IRB approval, and we gained useful insights and changed research directions based on the preliminary investigation of this

study. First, this study enabled us to develop a new way of categorizing older adults toward the use of interactive technology. Second, we identified engagement factors by exploring design ideas that could make older adults happy. Third, we realized the need to study the younger family members who had a close relationship with older adults. We decided to conduct focus group discussions with younger family members. Their responses highlight the factors regarding the families' suggestions as to what could be done differently to increase older adults' engagement in the context of mobile usage.

3) Focus group discussion with younger generation

We conducted a focus group study to identify the factors that influence older adults' engagement in using mobile devices for older adults. It was expected that the factors influencing older adults' engagement would be identified from a thematic analysis of the replies to the posed questions. We conducted a focus group study with younger family members who had a close relationship with the elderly. Family members can understand well what older people want, introduce technology to them, and help them to solve problems that can occur when using technology. It was expected that family members have various ideas for designing Savi software for older people based on their experience in technology related to their parents or grandparents. The focus group discussion consisted of two sessions. The first session involved a discussion of the usability issues of the current Savi design and how it can be modified to provide a positive user experience to older adults. The second session included discussing ideas for designing the better Savi applications in the future to engage older adults. The focus group study comprised one-and-a-half-hour group discussion and the same moderator conducted three focus group discussions. The total number of participants in this study was 16: the first group included four, the second group included five, and the last group included seven participants. They interacted with the Savi digital prototype before the focus group discussion. The questions the study facilitator

asked the group were aimed explicitly at answering the study questions presented above. Since students who have selected the HCI concentration and taken the HCI course have the ability to understand the user experience (UX) design process and the human-centered design process, they were are considered suitable for this focus group study. While designing technology for older adults, we are approached the family members rather than older adults directly.

4) Analysis

We used thematic coding and other qualitative methods to analyze the focus group interview data. The verbal responses to the interview questions were analyzed to identify design principles and emotional triggers with Savi interaction for older adults. We present the main findings and results in Section 5.2.3.

4.5 Study Design to Present Empirical Observations of Initial Engagement for Older Adults

In this study, we used two technological interventions to identify the factors to increase older adults' initial interest and engagement in interactive technology. Unlike the first study (Section 4.4), this one was not aimed at evaluating the usability of technology and obtaining feedback from older adults about technology use. We directly observed older adults' use of technology through a field study on the responses and attitudes when they encounter the new system, and reported the same based on the experience with the older adults as they explored the fundamental factors that influence older adults' engagement with technology.

4.5.1 Reasons to choose commercial products

We chose two commercial products. The uDraw Game Tablet is an embodied interactive technology that facilitates creative social expression by allowing users to create free form drawings, artwork, and games. GrandPad is a communication technology that enables older adults to easily communicate with their loved ones. We carried

out a six-month study to observe the attitudinal characteristics of older adults when they were encouraged towards initial engagement in the use of an interactive system. In the context of a longitudinal study, older adults may lose interest quickly if they feel any difficulty in navigating the information or understanding the overall usage of the system. Since we wanted to observe their attitudes over a few months, we selected commercial technological interventions (uDraw and GranPad) to avoid disinterest due to using a prototype system that might have unexpected usability issues or is an unstable implementation. If the purpose of this study was to propose a practical solution to older adults with a specific problem through technology, the user-related study would have been carried out using technology designed on our own. However, since this research is not intended to evaluate the feasibility of technology or focus on technological solutions but to observe cases in which older adults are engaged when experiencing technology, commercial products were used. These two systems were not randomly selected, but through prior research (Section 4.4), where an observation was made on the potential for creative expression and emotional attachment to increase the engagement of older adults. The two systems were selected as alternatives to complement the participants' design and user experience problems through prior studies.

4.5.2 uDraw: Embodied interactive technologies for social creative expression in a community center

This section describes the design details of the uDraw system and study methodologies. A mixed-methods analysis was conducted to analyze the initial engagement of older adults. With the uDraw Game Tablet, we conducted five focus group discussions and in-depth interviews with four participants in a community center over three months. The uDraw system has the potential to provide positive and engaging experiences to older adults and enhance opportunities for meaningful social connectivity in public space [209, 210].

4.5.2.1 uDraw System

The uDraw Game Tablet is an interactive technology with a stylus that allows users to draw and view their creations on a large screen in public spaces. There is a Wi-Fi remote controller that allows users to play games. Drawing a picture on a tablet screen by using the stylus is very similar to doing a drawing on a paper using a pen, which thus provides a metaphor familiar to older adults. Users can use the available tools and features to draw, paint, color simple shapes, and experiment with different painting styles, layers, and shading under three different modes of play. By doing this, the experience of creative activities of older adults can be maximized. The biggest advantage is to maximize controllability. Since the Move and Paint system did not respond to the intention of older adults, they lost their interest easily. The uDraw Game Tablet is already of commercial quality. We expect that there will be less usability issues than the Savi system we developed. It provides a scenario where older adults can be immersed in the system. The uDraw Game Tablet enables older adults to use it while being seated so that they do not feel any physical inconvenience. Further, the uDraw Studio Instant Artist has art education materials to help players learn how to draw and paint. This system offers interactive tutorials with Remmy, the game's 3D animated host. The uDraw Game tablet is, therefore, suitable for an ethnographic study to understand older adults' characteristics and engagement in the use of embodied interactive systems.

1) Art school

There is an interactive art tutor who guides users through the basics of drawing and painting, with step-by-step interactive instructions. An interactive character shows the user how to select and apply simple concepts to the user's creations. They are enabled to learn drawing skills and create some great pieces of art even if they are a novice user. There is a back and forward arrow to go back or forward one step in case the users forget something.

2) Art play

Drawing toolbar: Users can select different types of brushes and tools including fill bucket, eraser, and eyedropper (this tool can be used to extract a specific color from anywhere in the painting), custom palettes, animated stamps (users can add some motion and fun to the painting). There is a replay mode, to replay the creation stroke by stroke and watch it come to life. This mode is accessible through selecting any of the saved paintings from the gallery as well. Users can save the painting as an image on an SD card and share it with friends and family or print them.

3) Art camp

There are several creative drawing features, which are listed below.

- Coloring book: Users can color in approximately two hundred coloring book images, save drawings, and share them with others.
- Dot drawing: Users can draw lines from number to number and from letter to letter sequentially to reveal the hidden image.
- Number paint: Users can select the corresponding number and color from the number paint toolbar and fill in the painting to reveal some images.
- Tilt Maze: Users can tilt the uDraw game tablet and guide the paint ball through the maze to reach the finish line without running out of paint. The game ends when the ball runs out of paint; further, users should avoid the holes.
- Alien Splat: Users can splat aliens like in a game. They can guide the alien zapper around the canvas by moving the stylus on the drawing area and press down on the stylus down button to splat.
- Tilt coloring: Users can tilt the uDraw game tablet and create artworks using the paint ball trails. There is a challenge mode as well.

4) Gallery

Users can save drawings and share saved paintings with others. They can select backgrounds to see their creations in various backgrounds e.g. from t-shirts hanging on a clothesline to posters on a refrigerator door. Users can replay their saved paintings stroke by stroke.

4.5.2.2 Mixed Methods Studies

1) Data Collection

We collected data at a senior residence over three months, with a facilitator present for several hours per week. The uDraw system was constantly running in a shared community room throughout the research period. Residents were free to try and use the uDraw system. During our research period, we recorded the participants' usage of uDraw. Two video recording devices (Google Nest Cam) were located near the screen to capture the study area. One was directed toward the user and the tablet, to record all behaviors occurring when the system was used, while the other was toward the large public display, to record the social behaviors around the display. The motion activated cameras would turn on and start recording when they detected motion. This study was approved by the IRB to collect data from people walked down the hall or past the interaction area but who had no intention of interacting.

2) Operating help desk for training

We operated a help desk for three months to engage in participant observation and gain insights into the culture of the older adult community. Our insights developed over time and in relation to the social relationships we developed with the older adults. Operating a help desk allowed us to interact with older adults more easily and observe how they managed social activity and used technological interventions in situ rather than in a lab study. Before conducting the focus group discussions, participants were required to undergo one-hour individual training. First, the researchers showed the basic usage of the uDraw tablet. We demonstrated how to play the game ('Catch the

Alien' game with the uDraw tablet) that is most easily encountered and induces older adults to try and draw the interest of their peers. After that, training for drawing was conducted. As individual participants drew a tomato together with a researcher, they learned how to use the palette necessary to draw a tomato, how to draw a line, how to paint a color, how to decorate a painting, and how to save a completed painting. Then, the individual participants further learned the basic concept of digital gallery and how to use the gallery in the uDraw system. The last course of one-hour training was to play color by number in the gaming function.

3) Observation

Participant observation is a central data collection method in ethnographic research [211]. The researchers made three-hours visits to the site thrice a week over three months. We recorded the activities, participant attitudes or behaviors, and noted relevant details. Our initial observations focused on the general, open-ended collection of materials derived from learning the basic cultural rules in the context of an aging community. Everyday events and activities were recorded along with the participants' viewpoints and interpretations.

4) In-depth interview

We conducted in-person interviews to understand general attitudes towards interactive technology with regard to the eight engagement factors previously mentioned. While participant observation gives information on the action and behavior of older adults in the context of interactive technologies, interviews provide us with data on how people directly reflect on their own behavior, circumstances, identities, and events.

5) Focus group discussion

The focus group discussions were conducted every two weeks with four participants. We conducted a total of five focus group discussions. The uDraw Pictionary is an art-based video game in which players can play on a uDraw Game Tablet. This game

was developed based on Pictionary, a popular board game. In uDraw Pictionary, the players refer to a particular subject to draw a picture. The teammates are then tasked with the challenge of guessing the words each image is supposed to portray. We formed a group of four participants for the focus group discussion. Participants used a tablet and a stylus pen to draw the picture. The uDraw studio provides a tutorial for the players to learn how to draw, color, and sketch using the stylus and the tablet. We let participants play this game before participating in the focus group discussion. The interview prompts used in the pre-interview questions (slightly modified) were used for the focus group discussion.

6) Evaluation

During the research period, we immersed ourselves in the senior community and spent time talking directly with the participants and observing their lives and attitudes towards technology. We conducted the empirical analysis and gathered empirical evidence based on the researchers' observation and experiences in the research field through various methodologies as mentioned above. The data was analyzed qualitatively to illustrate five cases. We present five cases and the factors of initial engagement for older adults in Chapter 6.

4.5.3 GrandPad: Communication technology that enables emotional connections in a family setting

4.5.3.1 GrandPad System

GrandPad is a mobile technology to encourage older adults to stay connected with their social circle. The use of mobile devices has been tipped to positively impact the older population. This is because the mobiles have provided a means for frequent communication between the aged and their family members [207]. These devices also help these people keep up with and engage in community development activities, keep in touch with old friends and acquaintances, and take care of their mental health.

1) GrandPad Features

For the ethnographic study, GrandPad was used and it was similar to the goal of Savi. We identified the fact that the most important element regarding engaging older adults in the mobile usage context was the participation of the family and training. The essential apps and services on GrandPad eliminate the clutter, distractions, and complications of Savi. GrandPad enables older adults to view photos and videos, call, video chat, send voice mails, play classic games, music, etc. It supports a private family network so that family members can manage the functions for older adults from the convenient companion app. Every family member can stay in the loop and send emails and photos that the whole family can view. GrandPad has interesting features that may compensate for the negative feedback revealed through previous qualitative studies.

- Tablet interaction: Users can swipe or tap with their finger to navigate or use the stylus pen. This stylus pen can help older adults increase their stability and accuracy.

- Main screen: Users can access all preloaded applications from the home screen. Each colored button opens different apps. A big arrow button is always located on the bottom right side of the screen. Tapping the arrows allows users to see more buttons on the home screen and more content within each app. On nearly every screen, users can see instructions on the bottom of the screen. When in doubt, users can always click on and check the instruction page.

- Call: Users can select the person they would like to call by simply tapping the picture of a person. There are two options: video call, and phone call.

- Email: It uses the same concept as Savi. Users can tap the button to open and read new emails and use the arrows to flip through more pages of the message. Users can send voice messages. Recording automatically begins after a countdown. Users don't need to worry about spam, promotional emails, or other

unwanted email messages. They only exchange email messages from contacts that they have saved.

- Photo and Camera: It uses the same concept as Savi. Photos will be automatically saved in the family folder. Users can choose whether to keep the photo or share it with the entire family. Users can also record a short voice description to help remember the moment. Anyone connected to GrandPad can add voice comments to any family photos or videos. Family members can also add and respond to comments through the GrandPad companion app.

- Weather: Users can simply check the current weather and the five-day forecast of all the GrandPad contacts.

- Music: Users can simply search and manage their favorite songs.

- Games: The games on the GrandPad provide unmistakable visual and audio cues to avoid any mistakes that affect the rest of the game. There are some games that users can play with their grandkid or caretaker. Users can select the option if they would like to play with others. The GrandPad provides training videos. Users can learn how to play by watching a training video and follow the game instruction on the bottom of the screen.

- Help: There is a training video with step-by-step tutorials regarding the features on the GrandPad, a specialist can be contacted to ask any questions.

4.5.3.2 Mixed Methods Studies

1) Data Collection

In this study, the older adults received one GrandPad tablet for three months. Family members could connect to GrandPad's private family network via iPhone, Android phone, or a desktop computer. They could manage the functions for older adults from the convenient companion app. We provided a monthly subscription

including the convenience of unlimited data, Internet browsing, ad-free unlimited streaming music, customization of security options, mobile access for caregivers and family, and more. Older adults could use the GrandPad anywhere and at any time without any limit of the range of use, time, and number of times. We gathered data from the usage log. On the companion app, the summary displayed on the main My Account page of the GrandPad usage enabled us to see how many minutes they used, as well as text messages and web data. Usage records were collected every day. Since knowing their usage was being recorded could affect their behavior, the older adults were not informed of the same. We further gathered data from diary studies submitted by the family member for each older adult with approval from our institution's IRB.

2) Usage Log

The family members can manage the account of older adults and check their use on the Web. The Plans and Usage section of the main My Account page displays a summary of the GrandPad Usage so we can see how many minutes they have used, as well as text messages and web data. Once every two weeks, the researchers collected GrandPad and recorded the usage thus far. Since the knowledge of their usage being recorded could affect their behavior, it was not mentioned to older adults.

3) Diary Study

There are a lot of limitations in conducting a diary study with older adults. Older adults feel that writing a diary is an extra burden, so the likelihood of a negative impact on the use of a GrandPad device cannot be excluded. For this reason, the diary study was conducted with family members. Using mobile diary studies software, the participants wrote a diary about the older adults' GrandPad usage through a smartphone. One or two younger family members who are closely connected to the older adults played a role in sending a prompt to encourage older adults to use the GrandPad. The researcher sent journal prompts to family members through text

or email at 9 am every day; however, younger family members could create their prompts as well. The prompts were created in a way to encourage older adults to actively use the GrandPad App. These prompts were used for seniors to inspire them to be creative, share significant memories, and keep their minds healthy and active.

- Record how your parent or grandparent used GrandPad (The time, content and the features used, in which a usage activity has occurred).
- Write down all the feedback your parent or grandparent mentioned concerning GrandPad.
- If your parent or grandparent asked for help related to the use of GrandPad, write down the problem older adults had, the solution you proposed, the response of older adults to the solution and how the problem was resolved, in detail.

4) In-depth Interview

We conducted in-person interviews with the GrandPad participants to understand general attitudes towards communication technology. We used the same interview questions as the uDraw study.

5) Evaluation

We conducted an empirical analysis and gathered empirical evidence based on the researchers' observation and experiences in the research field through various methodologies mentioned above. Our data was analyzed qualitatively to illustrate five cases. We present five cases and the factors of initial engagement for older adults in Chapter 6.

4.6 Challenges to Conducting Research with Older Adults

This section describes the challenges we experienced while conducting research with older adults. They included recruitment, taking informed consent, getting reliable

responses, communication with older adults, and providing appropriate instruction about research. In the research or design process of interactive technology, agism plays a key part as a potential barrier to technology adoption. A lot of research has been focused on the acceptance models as well as on barriers and predictors of technology adoption. However, little research attention has been accorded to what the older adults want. In other words, there is limited research considering the heterogeneity of older adults with regard to the adoption of technology. It is clear that older people are not incorporated in the design of interactive technology and, even worse, research about what they want in terms of technology adoption. This is normally founded on negative stereotypes. From a technological perspective, older individuals are normally considered a homogenous group who lag behind and experience cognitive decline, needs, and frailty. Such stereotypes tend to draw away interactive technology designers from considering their needs. Even though certain studies indicate that the rate of technology adoption among the elderly is increasing and that they are more positive and excited about using technology, agism and negative stereotypes still shape how interactive technologies for the old are designed and perceived.

4.6.1 Recruitment

We had difficulties recruiting participants for this study. Older adults were willing to be excluded by themselves from the research. While it is no doubt that the exclusion of the older population from the design of interactive technology and research may affect the quality of available data on older adults and lowers the validity, including various older technology users offers a better and extensive understanding of what they need in order to live a better life. We interacted with over 100 older adults and stakeholders surrounding older adults (e.g., program director and staff members in the senior community center, social workers, and volunteers for the activities that provided in the senior center, family members, relatives, or religious group); however, we recruited only a few older adults for this study.

4.6.2 Taking informed consent

Even though obtaining informed consent from the older population can be time-consuming, it is very important. The challenges of remembering details of previous events are a problem for many older people, and this calls for flexibility with the procedures. In this case, there is a need for adequate attention and time commitment to ensure that the adults are considered and understood. Accordingly, we interacted with many older adults who expressed interest in participating in the study but could not be interviewed. Taking our time to talk with them about common topics such as the weather made them feel better. Initially, they felt as if they were forgotten, and our presence meant a lot to them.

4.6.3 Communication with older adults

We knew the importance of taking our time to understand their feelings about exclusion. This is a lesson for researchers to be patient and take additional effort and training to involve all members of society and incorporate their needs in interactive technology design. The research team may consider developing a set of protocols for researchers on responding and dealing with potential responses to ensure consistency and uniformity. Information given to the potential study participants should be clear, appropriate, and formatted such that they can easily see and understand it. We discovered that many older adults were not comfortable with strangers around them, particularly those who could disrupt their daily routine. Older adults commented that they intended to leave residents a note with the time, date, and duration of their next visit with the researcher's details, enabling an understanding of who they are and the institution they come from.

4.6.4 Reliable response

Older adults were not often given a chance to participate in the previous studies, and this made them lose confidence in voicing their opinion. Many of them have not

been interviewed or given the opportunity to take part in the research. Regular focus on the informality of the interviewing process and having a patient and a friendly interviewer can be a form of encouragement and reassurance throughout and enable them to adjust and start enjoying this new experience. We also found that older adults gave positive feedback on the systems just to avoid being interviewed. They were reluctant to reveal their abilities to figure out how to use technology. When asked what difficulties they felt after using Move and Paint, over half of the respondents said they did not feel any difficulties or that they were easy to use. However, we observed that they did encounter difficulties in figuring out the Move and Paint system.

4.6.5 Appropriate instruction

We found that our approaches and test materials were not 'older adult friendly.' We put instructions with figures on the table, and older adults pointed out that researchers should be carefully designed to provide enough details. It is important for older adults to be involved in designing and developing invasive interactive technologies to understand how their privacy will be affected. Providing control measures about who can access one's sensitive information is crucial to prevent privacy intrusion. In fact, technologies should respect the privacy of older adults, particularly in public spaces such as the community center. Many people tend to ignore the harm caused by privacy loss because the benefits of technology tend to overshadow privacy rights. We installed two cameras to record the situation around the system in real time. When a specific activity occurred, the camera would detect movement and record the activity. However, often, older adults were found unplugging the camera. By including older adults, we can create improved guidelines about developing the right balance between privacy and needs. Participants can offer specific feedback about the conditions under which they can compromise their sense of independence.

4.7 Discussion

To better understand the importance of involving adults in the design and use of interactive technologies, efficient and adjustable research methods, tests, and tools for data collection are required. In our case, we used a mixed research method involving observation and self-report diaries, and qualitative approaches, which included extensive interviews and focus group discussions. Among these research methodologies, we learned that ethnographic research is more relevant to better understand initial engagement, which is different from understanding usability and the needs associated with older adults' use of interactive technology.

The key characteristic of an ethnographic study is that it takes place in the real context which was the senior community in this case. Researchers play an active and immersive role. We gained a lot of insights about older adults' engagement in the use of technology that quantitative data would have been unable to capture. We employed various classic tools such as interviews, observations, and focus groups, but our interaction with older adults was casual, and we were involved in their daily activities, engaged in unstructured conversation, and gave them the opportunity to share their feelings and thoughts. Thus, we were able to discover the complexity and details of older adults in the context of technology.

We experienced difficulties in conducting research with older adults in the context of technology described above. Gaining insights from sufficient amounts of data from older adults to generalize the results is difficult especially in the field of aging. A vast quantity of data is powerful in predicting older adults' behavior, identifying patterns of technology usage and helps normalize the results. Qualitative data, specifically the ethnographic approaches we adopted in this dissertation to understand individual behavior, produce deep and valuable insights to understand their engagement in the use of technology. Such an ethnographic approach allows us to empathize with them and make them know how and why their participation with us was very important.

Additionally, connecting with older adults about their engagement with technology gave us the opportunity to obtain a first-hand experience on how our system can be used to impact their lives.

A research environment was provided to better understand the behavioral characteristics of older adults through interaction with not only older adults who directly use the technology but also stakeholders who have an interest in older adults (e.g. staff members in senior center, program director, volunteers for activity programs provided from senior center, family members, and social workers). Observing and evaluating the use of technology by older adults in an artificially created research setting can yield results that differ from the patterns used by older adults in real life situations. Considering that there were differences in usage in the environment where the response was obtained while conducting a focus group or interview, which was configured so that the technology could be used freely. It is possible to uncover the fact that cannot be discovered without observing the use for a long period of time in the field. By observing older adults' use of technology in real environments for a long time, we developed a perspective to critically look at the responses of older adults through qualitative studies. This does not mean that ethnographic qualitative approaches are superior to other qualitative approaches, but it was necessary to comprehensively and holistically engage with the older adults. The research methodologies used in this dissertation are valuable since this study used a mix of qualitative and ethnographic approaches to explore older adults' experiences with technology.

CHAPTER 5: ACTIVE-PASSIVE CATEGORIZATION OF THE BEHAVIORS OF OLDER ADULTS TOWARDS INTERACTIVE TECHNOLOGY

5.1 Summary

This chapter reports the evaluation results of the Move and Paint and Savi systems using multiple methods and studies to address the core research questions put forth in the beginning. Section 5.2 presents general attitudes and usage of the Move and Paint system in a public setting. We conducted a comparative study with the younger population to understand older adults' usage of the system. We have presented four hypotheses to present the difference between how older adults and college students interact with the Move and Paint system. Then the following section presents different behavior patterns using Move and Paint thorough in-the-wild user study, targeting only older adults in the senior community. We identified 10 use cases of the Move and Paint system among older adults. We found that older adults are emotionally engaged in using the system when social interaction occurs around it. Section 5.3 presents general attitudes towards the mobile technology that we designed named Savi in a family setting. We discuss how older adults understand and use mobile technology through the in-person interviews and focus group discussions conducted. Section 5.4 presents seven factors affecting older adults' technology usage and behavior. In Section 5.2 and 5.3 we present the active and passive older adults' behavioral characteristics associated with eight factors that emerged from the preliminary studies.

5.2 General Behavioral Characteristics and Patterns of Older Adults in the Use of Move and Paint System

This section reports the results of the evaluation of the Move and Paint system using the methods of comparative study and behavior pattern study. The data has been shown in Section 4.4.1. The goal of this section is to present the unique behavioral characteristics of older adults toward interactive technology.

5.2.1 Comparative study

We conducted a comparative study with the younger generation to ascertain older adults' unique attitude towards gesture based interactive technologies. This study compared two populations of users, each interacting with two versions of the Move and Paint system (with and without instructions). We analyzed the older adults' behaviors and responses using Move and Paint and compared these against the younger population. The data and research methodology we used for this study is shown in Section 4.4.1.3.

5.2.1.1 Hypothesis

We hypothesized several differences between how elderly residents and members of a university community would interact with the system. As Dourish [212] says, embodied interaction is about physical exploration of the system and constructing an understanding of how it works based on how it responds. Thus, we hypothesized that because of the fact that older adults and the younger population have different expectations and prior experiences, they would form different mental models about how the system works when they act upon it. Specifically, we investigated these hypotheses by looking for the following differences:

- **H1:** *Self Efficacy*

  Elderly residents generally have less experience with public interactive displays, and we hypothesized that this population would approach the system with

apprehension, trying to figure out how it works before acting upon it. University community members would be less apprehensive and start trying to interact with the system right away.

- **H2:** *Learnability*

  Elderly residents, due to lack of previous experience, would need more help from others or specific instruction to learn how to interact with the system. University community members would be more likely to explore the interface elements and interaction space on their own.

- **H3:** *Intentionality*

  Due to the novelty of the gesture interaction design for older adults, they would be more interested in the basic interaction results and not view the system as a creativity tool. Their interactions would be more about learning how to interact and by seeing lines appear on the screen due to their interaction. University community members would come up with more creative uses and interactions.

- **H4:** *Novelty*

  The elderly population would be engaged in different aspects of interactions and focused on playing with the system because it is novel. The college students would be less impressed with the novelty of the interaction and would be more likely to focus on creating interesting drawings and gestures.

5.2.1.2 Analysis

Table 5.1 summarizes the number of people of our target populations who interacted with the system in each location. To normalize our data, we included only people who stopped in front of the display either to look at it or to interact with it. We excluded the ones who simply looked at or gestured at the display as they were walking past. The differences in the number of people who engaged with the system

can be attributed to factors beyond our control such as traffic in the area, days of the week, and differences in the context around the display.

Table 5.1: Number of people in each condition.

Population	Condition	Number of people who engaged
Older Adults	No instructions	26
	With instructions	8
College-age	No instructions	72
	With instructions	160

1) Self-Efficacy (H1)

We observed that elderly residents approached the system with more hesitation than the college students. To investigate the initial approach with the system, we recorded active approaches compared to passive approaches, and summarized these numbers in Table 5.2. Active approaches are when people begin by interacting with the Move and Paint system, and passive approaches are when people stand by to look at the display or watch someone else interacting without joining in. A greater percentage of older adults than college students approached the system passively and did not physically act on the system throughout the length of their engagement with it. Older adults were more likely to stand and stare at the system or watch someone else interacting with the system without instructions rather than physically exploring how it works (see the last column in Table 5.2). College students were more active in their exploration and tried things (albeit sometimes incorrectly) such as waving their hands and touching the various hardware elements of the system. Elderly residents who used a walker tended to approach passively. Out of six such residents in the elderly community that approached Move and Paint across both conditions, with and without instructions, only one successfully completed the body interaction, and

three residents made attempts timidly, but failed to figure it out. The remaining two residents just watched the others using it.

In both populations, many tried different means of interacting, such as touching the screen and picking up or gesturing at the cameras that were recording them. The instructions helped but did not eliminate these happenings (The column labeled "Other interaction" in Table 5.2). Additionally, several elderly participants asked where the mouse was and a pair of elderly residents was so set on finding a mouse that they searched until they found the facilitators' mouse, which was tucked away behind the system.

Table 5.2: The number of people who tried certain actions.

Population	Condition	Other interaction	Learned Mid-air gesture	Did not interact
Older Adults	No instructions	8/26	10/26	11/26
	With instructions	3/8	6/8	1/8
College -age	No instructions	27/73	48/73	12/73
	With instructions	34/160	135/160	15/160

In the no-instructions condition, several elderly residents stared at the system without acting on it, either while they were alone (8/26) or while watching someone else interact (3/26). In the with-instructions condition, no residents stopped to look at the system without interacting and only one resident was a spectator to someone else interacting without making an action themselves. This is shown in Table 5.2 in the column labeled "Did not interact". We performed a Fisher exact test and although the percentages show a decrease in the number of college-aged students that remained passive, it is not deemed as a significant difference.

2) Learnability (H2)

Participants in both populations had a certain degree of difficulty figuring out how to interact with the system. Figure 5.1 shows that elderly residents were less able to figure out the interaction on their own without any external help. In the elderly community, five out of 34 residents were trained by staff well-acquainted with Move and Paint. They found it more interesting to use Move and Paint and stayed longer to interact with the system. Instructions were important for the elderly population. While the study was running without instructions, four of 26 residents who stopped in the interaction area verbalized their desire for instructions or wondered where the instructions were. No college-aged students mentioned the lack of instructions. Instructions increased the number of residents who were able to figure out the interaction on their own (Figure 5.1). They also helped college students figure out the system on their own, albeit with less drastic difference (Figure 5.1). We observed that the elderly residents showed a high degree of concentration on the system. Specifically, they discovered more instructions and tried to follow every instruction in a calm way. At first, the system shows three instructions in total. All the residents found the first instruction properly and behaved as instructed, readjusting their positions after stepping back to the designated line. However, it was observed that not all of them properly understood the following instructions. It was because they were about to start drawing with both the hands put up, but they did not have exact information about their position. Both the conditions had the same problem, and when the residents and college students failed to interact with this system, most of them took a posture of stretching their hands forward, which was not properly detected by the system.

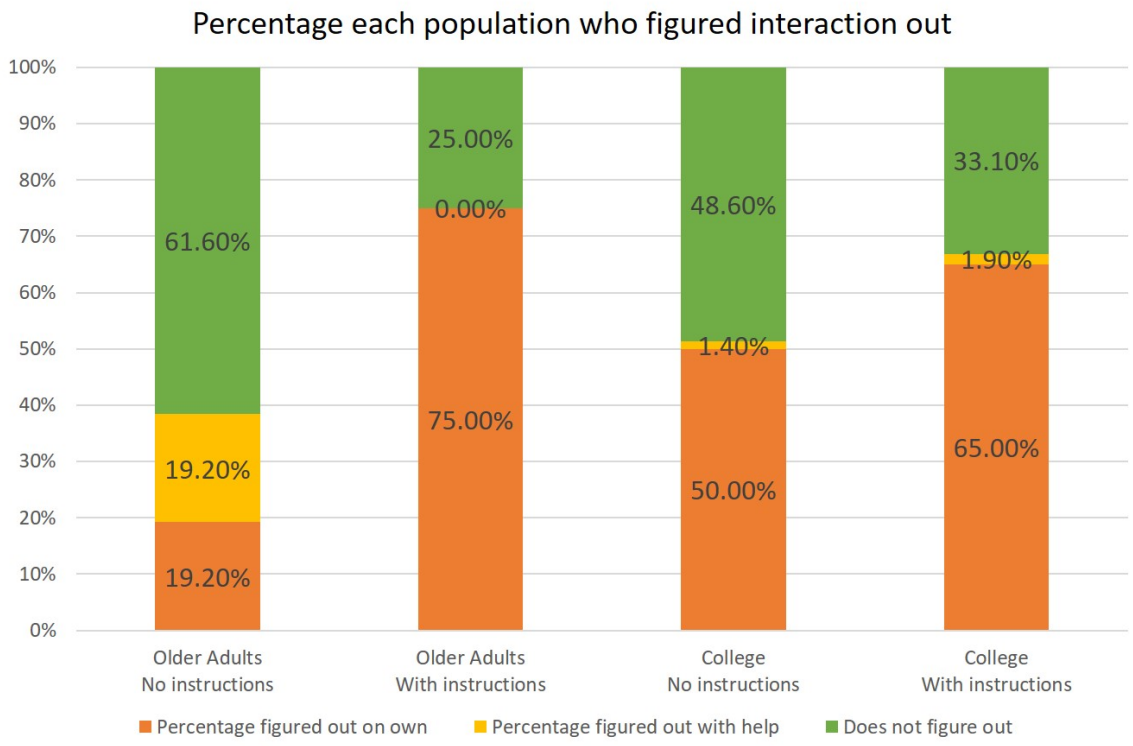


Figure 5.1: The percent of each population who figured out the interaction with and without help from another person. Elderly residents had help from staff members during the first few days the system was running.

3) Intentionality (H3)

For intentionality, we coded instances of two types of creativity: creativity in physical gestures as well as verbal and physical evidence that users were trying to fulfill some sort of creative intent. Creativity in physical gestures included any gesture that deviated from the normal palm facing screen gesture (Figures 5.3). Gestures included dance movements, conducting motions, jumping, throwing, etc. Instances of creative intention include verbal indicators which showed that the participant was trying to do something specific or was focusing on what they were creating as art. To understand creative intention, we also looked at the screenshots of the art residents who were creative.

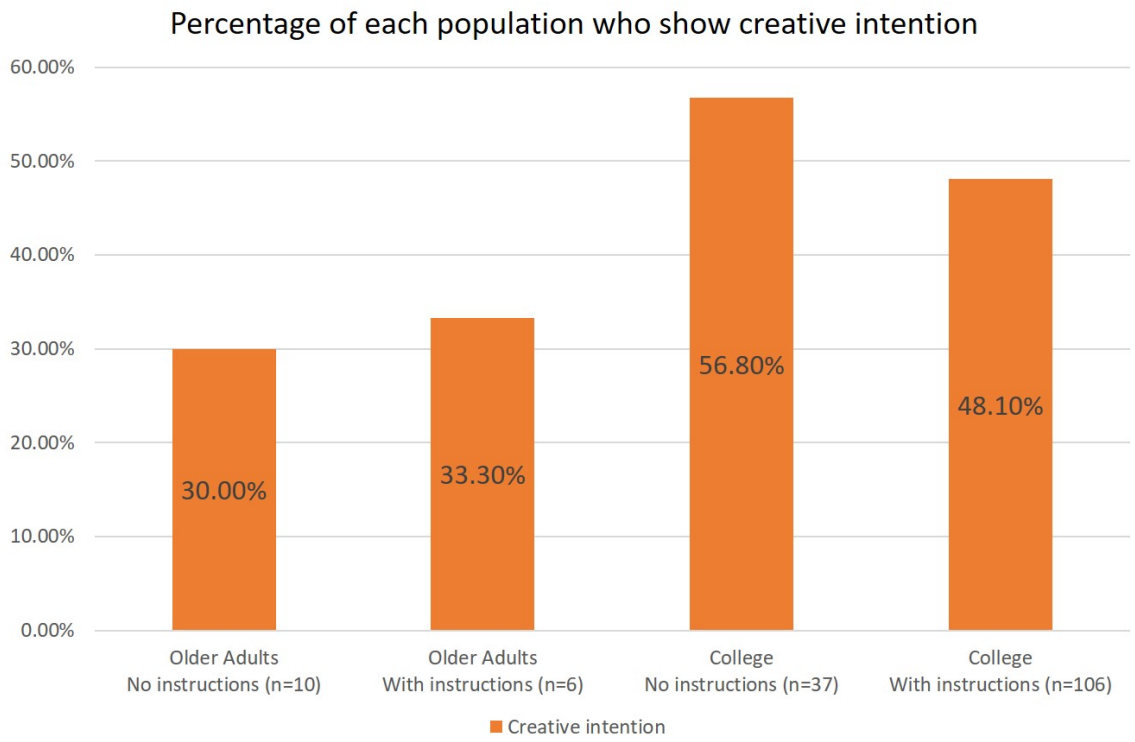


Figure 5.2: The percent in each condition of participants who showed creativity in gestures or in using the system as a creative tool.

Figure 5.2 summarizes the comparison of creative intent across populations. In this analysis, we only included those participants who figured out how to interact with the system. There was a greater percentage of students who exhibited creative intention than elderly residents. The most common gesture was a palm facing to use the Move and Paint system and the most common usage was that user drew random lines with the hand gesture with meaningless intention. We count when user show creative intentionality in using the system, something unique, interesting, different. The usage of the body while drawing lines was different between the populations. Older adults tended to adopt the same physical stance (palm facing screen shown in Figure 5.3-Left), whereas college aged students showed more creative hand positions. We coded the overall instances of creativity in physical gestures, coding any deviation from the standard palm facing screen stance and found a greater number of students (21/72) who exhibited creative interaction than elderly participants (3/26). 3 out of 72 college

students used the system with their mobile phone or took pictures or videos of the appearance along with the shadow. This behavior was not seen among older adults at all. As we had gathered evidence of creative interaction with the mirror concept, we also looked for evidence of creativity in other aspects of the interaction and general system usage. College students were more likely to try to draw something intentional or write words on the screen. Figure 5.4 shows drawings that are representative of what most of the elderly residents drew and shows some of the drawings that college students made.

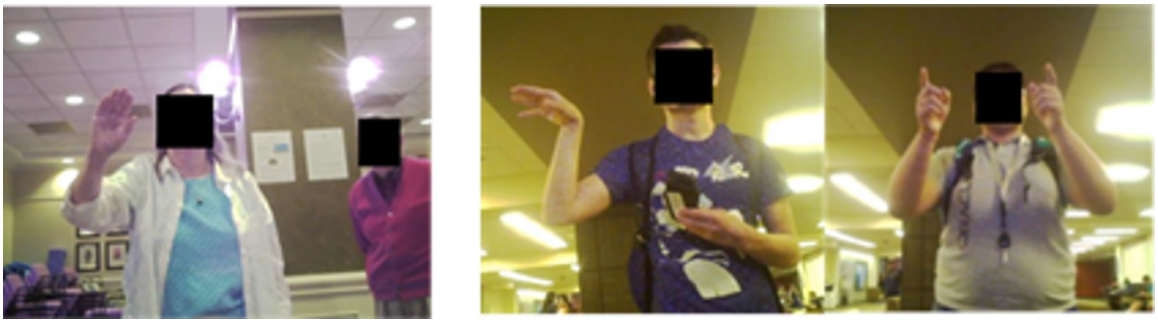


Figure 5.3: Left: Example of non-creative physical gesture: Hand remains upright, palm facing screen, moves up, down, left and right (Older adults) / Right: Examples of creative physical gestures (College students).

Figure 5.4: Left: Drawings from elderly users that are representative of the usage from the aging population / Right: Evidence of creative intentions in the college population.

4) Engagement (H4)

When both elderly and college-aged participants figured out how the interaction worked, their engagement levels were largely the same. Table 5.3 summarizes the total time of interaction for people who successfully figured out the interaction.

Table 5.3: Average time of interaction in the two populations.

Population	Condition	Average time of interaction (min:sec)
Older Adults	No instructions	1:30 (n=13, stdev=00:50)
	With instructions	2:51 (n=6, stdev=2:47)
College-age	No instructions	1:21 (n=38, stdev=1:38)
	With instructions	1:14 (n=106, stdev=1:12)

As a result, it was found that elderly residents show continued interest: four of 34 participants showed interest in Move and Paint and came back to use it for several days. In contrast, the students showed one-time interest; none of students came back to try the system again. In elderly residents, even those who just stared at the system showed constant interest in it. They also asked questions to others nearby about the purpose of the system or how to use it. They seemed to hesitate, showing an anxiety that they might incorrectly use or break the system. In contrast, those college students who showed interest in the system, started interacting with it in different ways right away. On the other hand, some students stared at Move and Paint a couple of times but seemed not to have any interest. Instead, they were observed to make phone calls or wait for users who were using this system. Particularly, the embodied interaction system attracted interest at first, but exposed a limitation by failing to maintain it. Ultimately, this study showed that the older population was more likely to keep using this system as long as they were provided effective instructions and orientation. Although the elderly residents did not notice that the intent of this system was to increase natural body movements, two of the elderly users made a reference to exercise while using this system. Particularly, they mentioned that it was helping them stretch their bodies directly, and they found it interesting, unlike the student group.

Older adults tended to notice that the shadows projected on the screen were their own much later than the college students. For instance, 1 minute 30 seconds after the interaction was successfully completed, one user recognized that the shadow on the screen was his own, and that his shadow was drawing a picture. This finding shows that when elderly users start focusing on one thing, it takes longer for them to recognize another thing. Accordingly, most of them elderly users remark on the shadow, and just focused on lines they were supposed to draw. On the contrary, students found the shadow most interesting in this system. Some of them took pictures or videotaped it, while playing with the shadow in various ways, like dancing or making funny movements. Beyond simply saying that the system is interesting, three students clearly stated that it was more interesting to play with the shadow than to use the drawing function, and that it would be better to create games using the shadow. Both groups showed more active body movements when playing with the shadow. However, when they started drawing, their body movements became rather passive. In addition, when attempting the feature of coloring book drawing, most of the users moved their arms up and down so as to fill in the blank. Therefore, we conclude that Move and Paint is effective in terms of encouraging increased physical activity.

Our main insights from designing and studying Move and Paint in elderly and college communities were related to the four hypotheses (self-efficacy, learning, intentionality, and engagement) presented earlier. We discuss below the key insights related to each of these hypotheses and how they shed light on challenges of designing interaction for older adults.

- **Self-efficacy (H1):** We found that older adults are timider than the college students and have lower self-confidence in their ability to figure out how to interact. Many residents stood and stared at the screen trying to figure it out before acting upon it or asking someone else what it is and how to use it. This is

possibly because their prior experience with other technologies may have been complicated, frustrating, and confusing and they expect the same from new technology they encounter. Even though the interactions with Move and Paint were not particularly difficult to figure out, as is evidenced by how many college students were able to manage it, older adults did not believe they possessed the capacity for the same without external help and did not have the self-efficacy to try. While designing interactive technology for older adults, it needs to be communicated to them that the interaction is not as hard as they expect.

- **Learnability (H2):** We found that instructions are necessary for older adults and using them significantly increased the number of people who were able to figure out the interaction. The dependence on instructions is likely due to prior experience, since elderly residents have a narrower definition of what it means to interact with a computer and might not consider that there are ways of interacting with a screen other than by touch functions or using a mouse. While both college students and older adults showed evidence of trying to interact with the system in the wrong way, elderly residents were less likely to overcome their initial expectations.

  Older adults were also not able to perceive or understand the mirroring concept. As a reminder, the purpose of the mirror was to help communicate to the user that the modality for interaction is embodied and that the system is controlled by body movements. However, the likelihood of understanding the cue of the mirror is influenced by expectations and the mental model begins to construct itself based on those expectations. College students understood more easily that the body on the screen meant that the system was controlled by their body movements, perhaps due to some prior level of familiarity with this modality that the elderly residents did not have.

- **Intentionality (H3):** Older adults stayed longer in the learning mode and did not transition to more intentional or creative usage. As figuring out the interactions themselves was a challenge, they did not explore more uses of Move and Paint or think of creative ways to use the space. This presents a challenge to interaction design because if older adults never develop some level of intentionality with an interface, then they will not be motivated to use it beyond the extent to which basic interactions with it keep them engaged.

- **Engagement (H4):** The length of time of engagement was about the same between the populations for people who figured out the interaction, but the nature of the engagement was different. The college students were engaged in creative activity, whereas older adults were engaged in the interaction itself. The focus of older adults on the interaction itself is, in part, due to the fact that they needed time to learn it as well as their fascination with the novelty of it. This presents a challenge to interaction design because it means that older adults may focus on and engage with one particular aspect of an interaction and not move beyond that to consider whatever the main purpose of the interaction was. The novelty of the interaction itself will wear off eventually, and it is unlikely that the elderly will continue to be engaged after that point.

5.2.2 Behavioral Pattern Study

We analyzed the 66 interaction cases of 47 older adults by using the evaluation framework that we developed (Section 4.4.1.3). Figure 5.5 shows how two individual users used the Move and Paint system differently. A lower numerical value of each factor corresponds to lower engagement with the system. For example, Participant 1 tried not only free drawing but also the coloring mode with changing the background (Usage time: five minutes and 24 seconds). Moreover, she wanted to complete a coloring book using diverse colors. She maintained a positive vibe throughout her

time using the system. If all factors tend towards the high engagement side, we can interpret this case as an active participant. On the other hand, Participant 2 was not interested in the system itself even though the condition of using the system is satisfied because independent mobility is possible (Usage time: 18 seconds). All factors except the physical factor tend towards the low engagement side. In this case, we can interpret them as a passive participant.

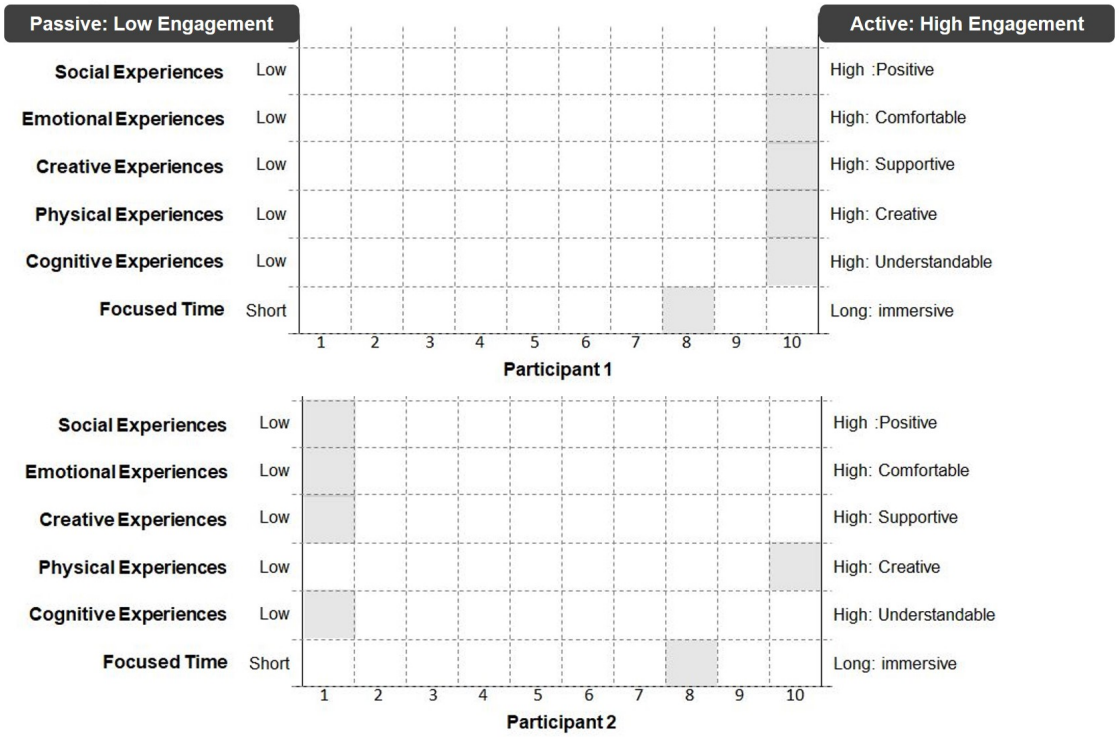


Figure 5.5: Two examples of engagement and behavior pattern while using the Move and Paint system

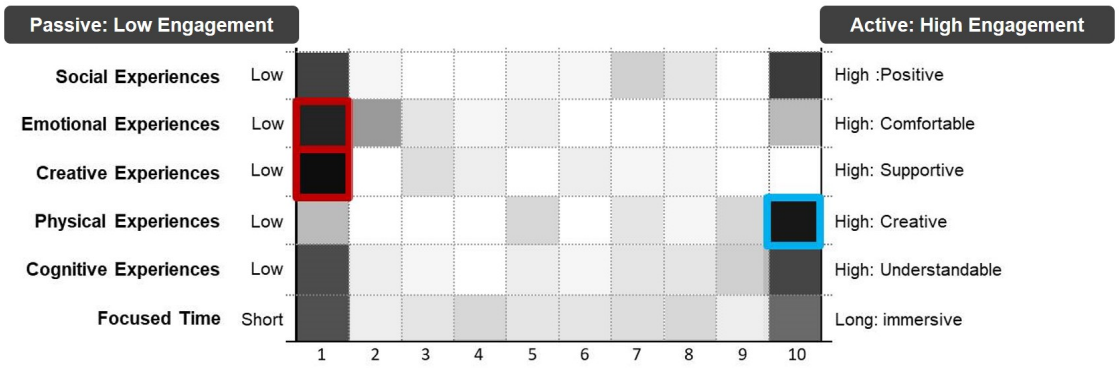
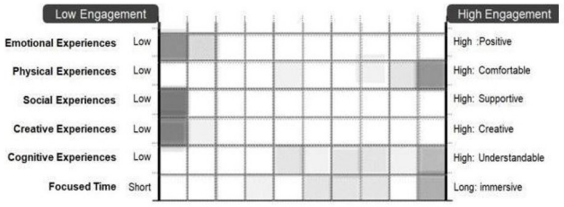


Figure 5.6: Aggregate engagement and behavior pattern of 66 use cases in the use of the Move and Paint system (n=66)

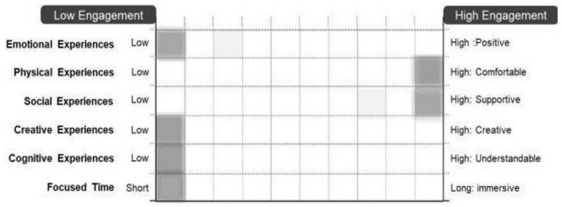
Using this framework enables us to not only visualize the engagement and behavior pattern of each individual user but find out the behavioral characteristics of older adults by aggregating the pattern of all participants who used the Move and Paint system. Overall, the use of the system by older adults shows a polarized pattern (Figure 5.6). Individual users' scores fall on the low or high engagement side, with little distribution in the middle. Participants tend to show either active or passive behavior to the Move and Paint system. Positive emotions and creative expressions are both low overall (highlighted in red, Figure 5.6). On the other hand, physical comfort was generally high (highlighted in blue, Figure 5.6). There is a tendency that social experiences, cognitive experience, and focused interaction time are comparatively distributed evenly on both sides. The rate of the use of the system in cooperation with others (n = 38) is higher than that of the use of it alone (n = 28).

10 usage cases using the embodied interactive technology were defined by identifying where older adults using the Move and Paint system are distributed in the suggested spectrum. Fourteen cases were classified as Case 1 among 66 cases, which was the most abundant type. Case 1 is a single-user interaction that does not generate social activities during an interaction. Users in this type do not show a positive emotion. Users in case 2 do not use the system directly and only watch other people

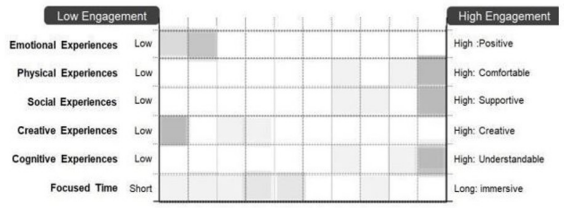
use it. Case 3 represents a usage type that focuses on social activities more than using the systems. They discuss how to use the system for a long time before using the system. In case 4, all factors except the physical factor are distributed on the low engagement side. An example of this case involves users who are not interested in the system itself even though the condition of using the system is satisfied because independent mobility is possible. Case 5 is when all items are distributed on the high engagement side. Although it shows a similar pattern with Case 1, Case 6 has the cognitive experience, which is required to identify how to use a system, biased towards low. Users in this case are completely immersed while using the system; however, on the contrary, they cannot identify how to use it on their own. All factors are distributed on the low engagement side. All three users in this case used a walker and did not try to interact at all. Case 9 shows a pattern quite similar to the previous case (Case 8). The difference with the previous case is that the latter involves social activities. In Case 9, users actively interact with other people while using the system. They do not experience any physical discomfort in using the system nor any difficulty in using the system by moving the arms. All users in this case maintain an appropriate distance to the system and use the system correctly with having the arms raised. However, they do not consider the system satisfactory. Case 10 shows the pattern similar to Case 9. If Case 9 learns how to use the system through social activities, users who cannot figure out how to use the system even though they ask others how to use it, fall within case 10. Moreover, cases of placing themselves at a wrong interaction-zone while using the system or cases of having the system fail to recognize users because they extend their arms too much are examples of this case.



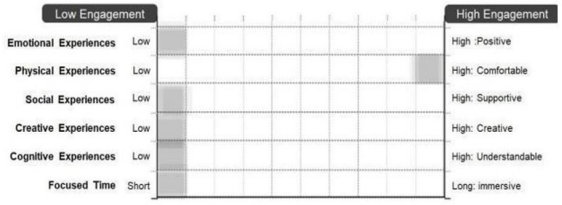
Case 1: Emotion, Social, Creative (Low) / Physical, Cognitive, Focused time (High) (n = 14)



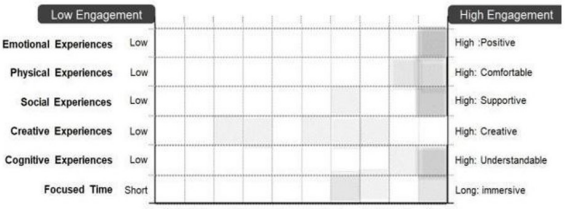
Case 2: Physical, Social (High) / Emotion, Creative, Cognitive, Focused time (Low) (n = 9)



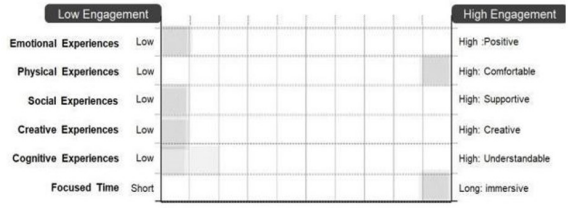
Case 3: Physical, Social, Cognitive (High) / Emotion, Creative, Focused time (Low) (n = 8)



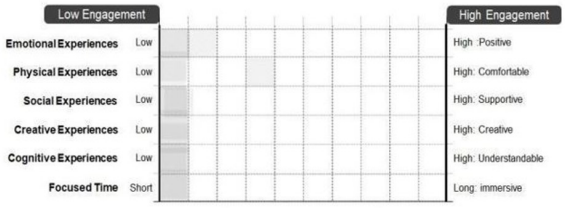
Case 4: Physical (High) / The rest (Low) (n = 5)



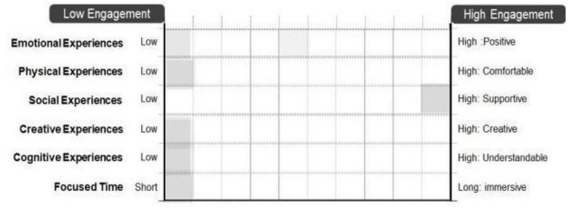
Case 5: All High (n = 5)



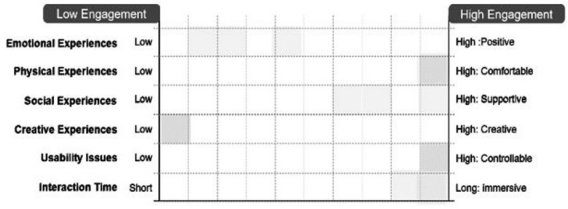
Case 6: Emotion, Social, Creative, Cognitive (Low) / Physical, Focused time (High) (n = 3)



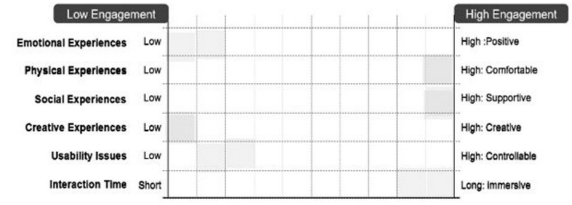
Case 7: All low (n = 3)



Case 8: Social (high) / Rest (low) (n = 3)



Case 9: Physical, Social, Cognitive, Focused time (High) / Emotion, Creative (Low) (n = 3)



Case 10: Emotion, Creative, Cognitive (Low) / Physical, Social, Focused time (High) (n = 2)

Figure 5.7: Ten usage cases using the Move and Paint system.

We identified 10 cases of behavior patterns of older adults using the Move and Paint system. We learned that the Move and Paint system has the potential to create positive social experiences for older adults in a public space. We discovered that there are positive relationships between social and emotional, creative experiences. In the following paragraphs, we have particularly explored three different cases: single-user interaction with no social interaction, user interaction with high social experience, and user interaction with limited social interaction. The reason examining the same is to study the relationship between the amount of social interaction and the engagement factors.

Single-user interaction with no social connectedness while interacting with the system has 28 cases which are highlighted in blue in Figure 5.8. Users in this category hardly showed any positive emotion. Five users out of 28 cases only smiled once for a short time and they did not verbalize their emotions. Users in this category tended not to interact with the system in a creative way and did not react explicitly to their shadow image on the screen (highlighted in red, Figure 5.8). The actual time of using the system was 43 seconds on average.

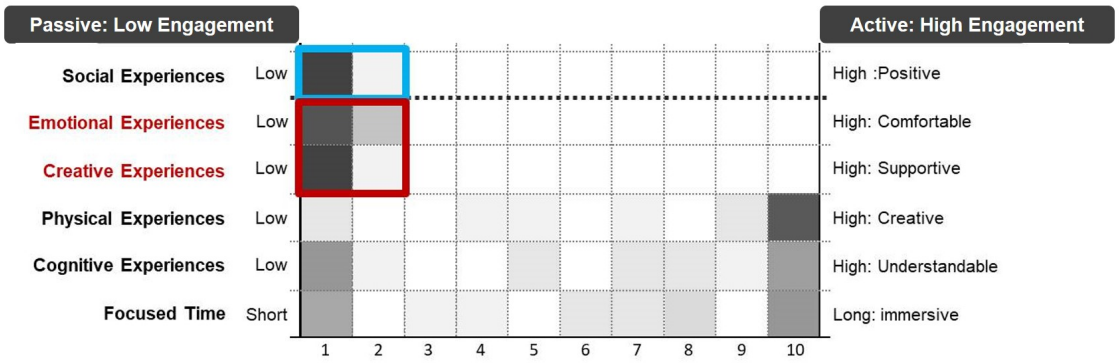


Figure 5.8: Engagement and behavior pattern on cases with no social interaction while using the Move and Paint system (n=28).

High social engagement while interacting with the system has 27 cases, as shown in Figure 5.9. Users in this case interacted with others during the whole time they

were in the vicinity of the system (highlighted in blue, Figure 5.9). There are a few different cases within this category: the case in which multiple users found the system and tried to use it together; the case in which one used the system first, and did not figure out how to use it, and brought another person for help; the case in which one used the system first, found it interesting and introduced it to another person; or the case in which one came alone to try to use the system, which instantly attracted the attention of other people in the space and made them involved as well. There was social interaction for 197 seconds on average. The actual time of using the system was 82 seconds on average, which shows that they invested more time in interacting with people than using the system. Compared to the previous case of single user and no social interaction, the most notable difference is the pattern in which the emotional and creative factor is distributed more between low and high engagement (highlighted in red, Figure 5.9). There are five users who exhibited creative intent while using the system, specifying the object they wanted to paint such as flowers, trees, sun, etc. Moreover, they tried not only free drawing but also the coloring mode with changing the background. Further, users in this case wanted to complete a coloring book with diverse colors. Sometimes, they discussed design ideas to be more creative. They made many positive comments about the system. In this case, users used the system for a relatively longer period (159.8 seconds on average).

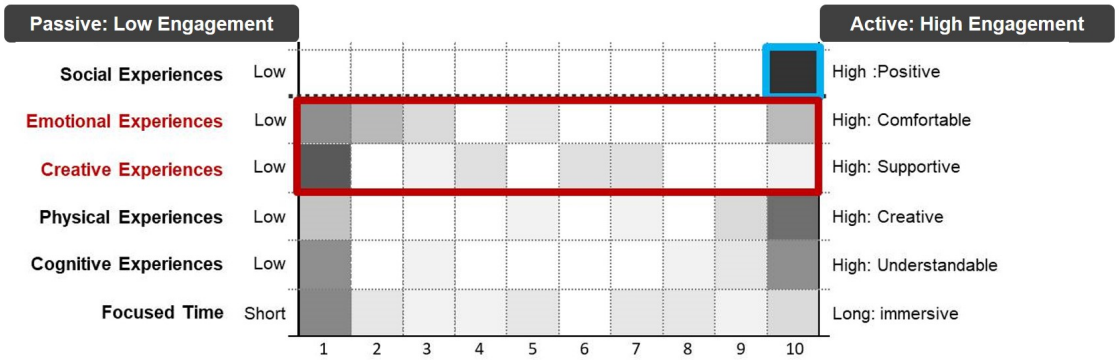


Figure 5.9: Engagement and behavior pattern on cases with social interaction while using the Move and Paint system (n=27).

Limited social interaction, when the participants were social only during a percentage of the total time while using the system, has 11 cases as shown in Figure 5.10. The focused interaction time, a subset of the total time in front of the system, was 119 seconds on average. Even though a social interaction took place naturally around the system, users in this case were not easily distracted by others. They needed help from the staff members or others who knew the system well, and then used it alone for the rest of the time. However, nine users expressed negative feelings about the Move and Paint system. From this visualization, we see that when older adults use the system with limited social interaction, the six behavioral factors are much more evenly distributed.

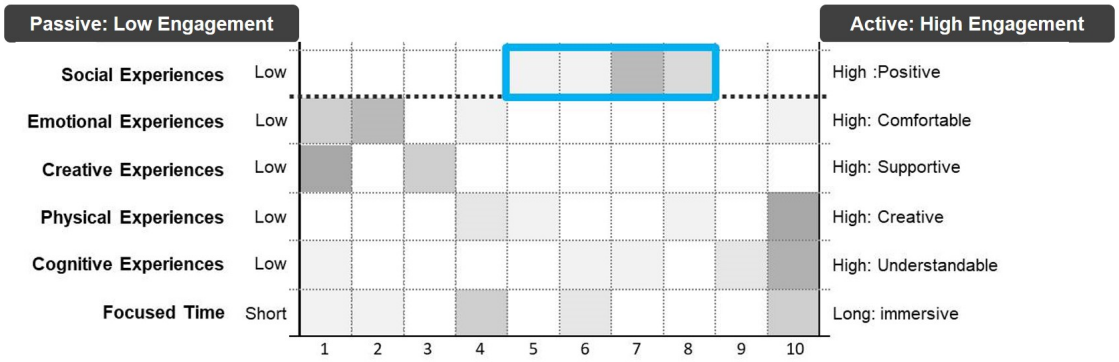


Figure 5.10: Engagement and behavior pattern on cases that social interaction takes place only during a certain period of time (n=11).

In this study, we saw that as social interaction occurred around the system, older adults were more likely to express positive affect about the system and use the system in a creative way. Similarly, elderly participants were found to be less likely to figure out the interaction on their own. When another person showed a senior person how to use Move and Paint, they found it more interesting and stayed longer to interact with the system. A gesture-based interactive system installed in a public space can be a vehicle to improve on the existing social networks. When designing an embodied interactive technology, sustaining enhanced connections to others is an important

consideration to increase engagement with the system.

5.2.3 Limitations

Section 5.2 focuses on analyzing the natural behavior with the Move and Paint system and the behavioral patterns of older adults in terms of the spectrum from low engagement (passive) to high engagement (active) by using an evaluation framework. One limitation of comparative study is that the number of elderly participants is not large enough to compare with the younger population. There were only eight elderly residents in the "with instruction" condition; if a larger number of older adults were involved, it might have been possible to report different results. However, compared to the younger population, we learned a distinct difference in the behavioral characteristics of older adults rather than the numerical results.

One limitation of behavioral pattern study is that most of the users used the system only one time. Perhaps the one-time users had a positive experience because using Move and Paint was a special or unusual opportunity for them, rather than being due to their interactive experience. We found many active cases where users who engaged in social interaction while interacting with Move and Paint also showed positive emotions, exhibited creative expressions, and stayed more focused on using the system. We might be able to present different results and more diverse use cases if we conduct a longitudinal study. In the current study, we have made the contribution of presenting active and passive use cases in the use of the Move and Paint systems. To identify the behavior and engagement factors of older adults, we conducted a qualitative study, including focus group discussions and an in-depth interview regarding the Move and Paint and Savi systems. The data and methods are shown in Sections 4.4.1.1 (Move and Paint qualitative study) and 4.4.2.2 (Savi qualitative study).

5.3 Extracting Behavioral and Engagement Factors from Qualitative Analysis

This section presents the results of the qualitative analysis of the Move and Paint study and the Savi study conducted to extract the behavioral and engagement factors of older adults. We identified six factors from the Move and Paint qualitative study and six factors from the Savi qualitative study. These factors helped us develop a new way of categorizing the aging population in the passive and active spectrum toward the use of interactive technology.

5.3.1 Qualitative Study of the Move and Paint System

We conducted a thematic analysis of the data collected in the focus groups and interviews. Several themes emerged from the topics discussed in the focus groups and the questions and answers during the interviews. These themes help identify the factors that influence older adults' motivation and competence and understand their behavioral characteristics in relation to the Move and Paint system. For focus group discussions, we conduct two focus group discussions. The first group included eight female participants, and the second group included two male and six female participants. For in-person interviews, a total of 15 participants (three males and twelve females) were called in. The data collected from and the research methodology used in this study has been discussed in Section 4.4.1.1.

1) Emotional experiences: Curiosity

This section describes the emotions mentioned while older adults use the Move and Paint system. We found that our participants felt motivated to try something new. 15/15 of interview participants had not used a gesture based interactive system like Move and Paint before. 11/15 participants responded that they do not have many opportunities to access technology. They have difficulties using their mobile phones or computer and tend not to use them very often. 8/15 participants said that they had heard of the Wii but had never experienced it in person. 5/8 participants said

they wanted to use the Wii system but had had no opportunity. They looked very excited even before using the Move and Paint system. One participant said,

> "I've been wondering when you'd ask me for an interview, because I really wanted to try this one."

For the interview, 5/15 participants said the first word that crossed their mind was "curiosity," "fun," or "interesting." Their initial approach and attitude towards the Move and Paint system was positive. In the first focus group study, they expressed an interest in the appearance of the system and showed curiosity when other people were using it. They found it very interesting that pictures could be drawn using a different method without pen and paper. We expected that older adults' lack of experience would cause them to resist the system, but surprisingly, they adults were curious to try it even though they had never used an embodied interaction system before. These reactions lead us to infer that embodied interactive technology has a potential to deliver new and positive emotions from older adults.

2) Social experiences: Personal support

We found that the older adults might be more inclined to engage with the embodied interactive technology when they are able to use it without any burden and feel the support from others. In both focus group sessions, 16/16 participants agreed that they needed external help to figure out the system. When the participants encountered the system for the first time, they said mentioned wanting someone to help them in the same way the focus group study was implemented. All participants said they would not attempt to use the system on their own without outside help. One participant said,

> "Are you going to come every day and teach me how to use it? I am not like you. I am pretty sure I won't be able to use this system by myself."

Personal support may be required as a supplement to the system as older adults

connect differently with human beings than machines. Personal support may also be necessary not as instructions but, rather, to increase confidence or reduce self-consciousness. This implies that interactions with other people are needed to encourage older adults to use the system. They also said that they would continue to use the system and maintain their interests if they could use it with their grandchildren. They made many comments about their family when the facilitator explained that the system supports multiple simultaneous interactions. For example, one participant said,

> "Can multiple people use this simultaneously? Is there any way that I can have this system at my home? I am dying to show this to my grandchild and play with him."

Using the Move and Paint system with others may be an accelerator that stimulates the interest of older adults. Through this, we infer that the role of the external environment is important for older adults to make a decision about whether to use the Move and Paint system.

3) Creative experiences: Desire for creative activity

There were specific interactive elements the participants mentioned that would maintain their interest and engagement. In the second focus group study, participants discussed that the system could be designed in a more interesting way by using more diverse colors. 15/15 participants said that it is interesting to observe the drawings and the changing colors. 6/15 participants preferred to watch the varied movements of the colors other people worked on than to use the system personally. 15/15 participants said that they felt happy when they saw various colors. 3/15 participants responded that they were grateful that the system makes them move. For example, one participant mentioned,

> "It is really interesting to see the color change whenever the hand is mov-

ing."

In the first focus group discussion, participants especially noted that there are too few options for the background and would like to see more images. A game format could be introduced for the coloring book, so that completion of each level can lead to a more complex picture. Participants also discussed that it would be nice to make Christmas cards using the system. In that case, they said they would expect additional features such as choosing cards, decorating cards with stamps, coloring, and inserting text, and mentioned that stamps would be much easier to use than brushes. We were unsure if older adults would have continued interest in the system after the initial novelty, but given the variety of use cases older adults proposed such as making cards and playing with grandchildren, we found that designing for creative activity and open-ended interaction is a worthwhile pursuit to ensure that older adults do not prematurely lose attention and to sustain engagement with the system.

4) Physical experiences: Physical ability

Move and Paint requires constant active motion of the body. Large motions are required to choose a color or draw on the entire canvas. 5/15 participants reported physical shortcomings as the major cause for hesitating to use the system. They answered they could not use it readily out of the difficulty in having to stand for a long time. However, they also responded they would actively use the system if they can be seated to use it. We saw that older adults often did not succeed in reaching the color even though they were making a full stretch. One participant said,

"I am too short to reach the color."

6/15 participants commented that their arms and legs felt strained when they returned to their seats after using the system. 2/15 participants said that their vision problems made it hard for them to identify small icons or illustrations in the background. They pointed out that clear text feedback would be much more useful than illustrations.

One participant also expressed that it would be good to listen to narrative instructions while standing in the designated position to use the system. A design that is more physically comfortable will be more likely to engage older adults. Since we found that differences in physical ability not only prevented some participants from performing certain actions but also made them feel discouraged, the system should be designed by correctly understanding the physical ability of older adults.

5) Cognitive experience: Discoverability

The system should be designed to help them easily discover and perceive its functions. We found that older adults did not automatically know the functions of buttons and did not explore with gestures on their own unless prompted. This impacts the discoverability of the system for older adults when compared to other populations. We found that providing instructions has a positive effect on older adults' exploration (Figure 4.3). Interview results revealed that only 5/15 participants were able to discover the instructions. They said they had difficulty finding the instructions, but that it was of great help in learning how to use the system once found out. These five participants said that different types of feedback such as that a video or pop up image are necessary, and that consistent feedback can improve the usability of the system. Older adults had difficulty understanding the function of the Move and Paint system. For example, one participant commented,

> "I've looked around the system for information on how to use it, but I couldn't find it. I only figured out that the video is being recorded. How do you expect me to use this without any information on it?"

11/15 participants responded that they could not recognize the functions except for the color palette. For example, one participant remarked,

> "Is it possible to change the brush? I've never thought it possible until you told me about it."

2/15 participants pointed out issues with the interface layout. One participant said she faced difficulty in discovering other drawing functions located at the edge of the screen because her attention was focused on the center of the screen.

6) Cognitive experience: Controllability

In the focus group discussion, most of the participants expressed their difficulty in understanding the concept of the shadow. 2/8 participants responded that the purpose of the shadow is to give feedback to the user about his/her current location but added that the element itself was not interesting at all. Rather, they commented that the shadow interferes with drawing. One person said,

> "I thought the grey color (shadow) is me, because it followed me every time I moved. But it always got in my way whenever I colored it."

In the interview, one participant mentioned the difficulty to recognize the shadow because its form of was not clear. Perceiving the shadow movement was difficult because more focus is on the color changing on the screen than the shadow. The shadow concept, which was originally designed to draw older adults' interest, may in fact distract them. Older adults lose interest when the system does not respond as they expected. One person said,

> "Why on earth does that color keep changing? I didn't want this color."

In both focus groups, participants discussed that the lower part of the screen did not sense their movements properly nor responded to their coloring. They said that the upper part of the screen was very responsive and that their interest would be sustained if the lower part of the screen would be equally responsive and sensitive to encourage their free movements. While using the system, 7/15 participants said that they clearly had an object they wished to draw or a color they wished to apply, but they could not execute it because they were unable to control the system as they intended. 11/15 participants pointed out this problem as a major issue and they

said that if it's not improved, they would not continue to use the system. Since the usability issue has a great effect on understanding a system's functions, the gesture-based interactive system should be designed to help older adults easily discover and perceive its functions.

5.3.2 Qualitative Analysis of the Savi Study

We conducted a qualitative analysis of focus groups with older adults and younger family members to understand the behavioral factors for engaging older adults in mobile use. The total number of younger family member participants in this study was 16: The first group had four participants, the second group had five, and the last group had seven participants. The total number of senior participants was 20. The data and research methodology we used for this study has been discussed in Section 4.4.2.2.

1) Comfort

The behavioral factor that was significant in all group discussions was the 'elderly-friendly design'. The user journey of older adults needs to be understood, and unnecessary functions need to be removed. Moreover, the location of the back-button home buttons was pointed out. Other buttons are located in the thumb area of the users, but these buttons are located at the upper part of the screen, meaning that the users need to press the button with difficulty while supporting the tablet with one hand. Further, the importance of consistency regarding the location of all the buttons was mentioned. In particular, the album must be arranged in the order that older adults are familiar with, and the position must be identically maintained to enhance the learnability and discoverability of older adults. We learned that older adults' comfort level to mobile technology is diverse. The cognitive ability of the passive seniors to use mobile phones was more of an impediment than we had expected. The passive seniors had much less interest in mobile phones than expected. They did not have a will to learn new things and evaluate themselves regarding their abilities being

hampered when using their mobile devices. There are limitations in using technology if physical or cognitive health is poor. Additionally, when it came to the questions about experiences, difficulties etc. that they had in using a mobile phone, it was difficult to continue the interview because this group had a very low frequency in using a mobile phone and didn't utilize its functions. On the other hand, the active senior group was using a wider variety of functions than we had expected so that they were not excluded from social activities. Despite being old, they were proud of themselves for actively using these functions. They said learning new things itself gave them the motivation to live. They felt the happiest when exchanging messages with their family. They showed considerable confidence in using a mobile phone and said that they did not feel any considerable restriction or difficulty in using it. However, they had a negative outlook toward the voice search, and mentioning that accepting such new functions would be rather more inconvenient since they were already familiar with the keyboard feature.

2) Discoverability

In the focus group discussions with younger family members, Groups 1 and 3 discussed how difficult it is for older adults to understand technology-related terms and icons that the younger population is familiar with. For example, older adults are more familiar with 'photo album' than 'gallery'. In case of the button design, designing the icons that fit the metaphor of the items that older adults used in the 1950's and 1960's could help them feel more familiar with the system.

In the focus group discussions with older adults, 9 out of 20 did not know well or remember the details when asked about the last time of using a mobile phone, whom the last person they had talked to, etc. 3 out of 20 seniors mentioned that they knew how to take a photo, but they hardly used the function. Two participants knew that they could exchange photos and there was a messenger function to contact their children, but they never used it. When observing their mobile phones, in case of

a person who uses a smartphone, frequent contacts were set up as a speed dial on the wallpaper. The person said that it is convenient since it required pressing only one button without searching the contacts. Two participants answered yes to the question of whether they would use it if they could use the corresponding function with only one button without the complicated procedure of other functions. Additionally, they did not voluntarily perform any function of input on the mobile phone but only received calls and checked the phone when an alarm rang.

Learning how to use the phone overall or even just the speed dial can be difficult. New and unknown things tend to create anxiety. Passive seniors are afraid that they will somehow break their mobile devices. With such novel technology, they might feel unable to control what happens around them, and this can lead to severe frustration and even fear. Simplified instructions are often written by children or grandchildren to their elderly parents. Older adults' capacity to memorize new things slows down; patience and repetition are required in teaching, and this is often best provided by friends or relatives.

3) Perceived usefulness and benefits

All the groups mentioned that a Savi system that is usable and investment-worthy can engage older adults. Participants pointed out that designers need to understand the user experience level. Users with a diverse experience level or skills get to use Savi together. Diverse classes of people, including older adults who do not have experience with the technology, older adults who can utilize diverse functions without much difficulty, and the younger population with lots of technology experiences use Savi. A UX design that all users can comfortably use is necessary. Older adults felt that the quality of their lives was improved or there was an incentive through using the Savi system. Privacy was the most important design issue for groups 1 and 3. Photo sharing was the most interesting idea, and it received the most support and criticism from the focus group participants. Group 3 discussed that it is important to

understand how older adults feel about revealing their photographs to other people. The function that allows older adults to manage the people that they want to share the photographs with should be provided in the setting. Cost was the issue mentioned by group 3. The current version of the app is too simple, and it is not sufficient to draw the interest of older adults. Besides, the users who are already using a smartphone would be reluctant to make financial investments. The opinion is that to use the Savi application, apps that make it worth it to purchase the tablets are necessary. Moreover, the frequency of Wi-Fi usage needs to be investigated. Older adults do not desire the hassle of having to request for Wi-Fi in order to use Savi.

To arouse positive emotions in older adults, it is necessary to examine their fundamental interest, concerning the things they do when they feel happiest. Out of the passive seniors who were interviewed, we found that although they were somewhat proficient at using mobile devices, the usage was not regular. In the interview, two older adult participants used a smartphone, and eight of them used a flip phone. Even though their children had recommended them to use a smartphone, they did not feel any necessity because they could not utilize even a flip phone properly, and smartphones are expensive. Further, they did not use social media to stay in touch. A lack of communication seems to be prevalent between the generations. Active seniors showed interest in new features, whereas passive seniors did not have the willingness to learn new things.

4) The necessity of training

All groups mentioned the importance of training, and except for three participants who had tech-savvy grandparents, all had difficulties with explaining the functions to older adults. Until older adults became familiar with the functions, most of them kept forgetting, or couldn't understand at all even after repeated explanations. One participant mentioned that it took more than two hours to explain a simple function that takes minutes to understand. In spite of that, all participants agreed that the

best way to train older adults is to meet them and show the method of usage in person. They mentioned that the interface must be designed in a way that is easy to explain. Group 1 explained that it is important to present the functions to older adults in a gradual manner. It is important to give older adults confidence by explaining the functions in the order of difficulty, from the easy to the complex.

Diverse design ideas that can support the elderly with difficulties when using Savi were discussed such as 'Periodic reminder', 'Video instruction', 'Screen share' , 'Help button', and 'AI tutorial'. The method of providing instructions was mentioned. All groups discussed the method of giving periodical reminders. Repeated learning is important for older adults, and the method of providing instructions like news feed continuously and repeatedly, even if the contents are the same, was mentioned. As for the design idea of the help button, a function that provides immediate support to older adults whenever issues arise while using the app was suggested. For this method, groups 2 and 3 suggested the method of sharing the screen with the family administrator, and automatically sending help messages. Even though 4 older adults out of 20 interview participants showed considerable confidence in using a mobile phone, they still needed assistance from their family.

Further, price is considered a very important factor. Older adults are highly price sensitive and consider spending carefully. One interviewee told me about an elderly person, who was not sure if even pushing the buttons of a mobile phone or keeping it switched on would cost something. Three interviewees said that they feel their eyes could cope with constant use of a mobile phone, therefore they try to use it as little as possible. Two interviewees mentioned that they were afraid of breaking the devices. They also noted the need to increase the size of the items on the screen the most. One of them said that she knew people who felt stupid or inadequate when trying to figure out how to use the technology.

5) Pleasurable experience

In the focus group discussions of younger family members, all the groups responded that they felt the need to add games as apps. The current functions are too simple, and similar apps with similar functions already exist in the market, leading to a lack of competitiveness. One participant answered that even though their grandparents did not know how to handle mobile devices at all, they still played games. In such ways, gaming apps that can stimulate the interests of older adults can give the momentum to help them continuously use mobile devices. In the focus group discussion with older adults, four older participants mentioned that games which train and maintain brain activities and memory can be simultaneously useful and entertaining.

6) Communication and collaboration with family

Design ideas that allow the users to easily communicate with the family members and carry out activities by collaborating were mentioned frequently. They responded that sharing the moments of apps (music, painting, video, or game) usage with the family members will motivate older adults. When designing a game, a platform such as chess with two players that lets older adults play with their grandchildren is an example. Another example is a painting app, where older adults can collaborate with their family members to complete a painting. Apps such as these will allow older adults to easily engage with technology.

In the interview, 3 senior participants mentioned that they thought a mobile phone was essential for them to continue social activities. They opined that they wanted to learn to use a mobile phone so as to not be separated socially. One obvious reason or benefit for acquiring a mobile phone and using its services is the need to communicate with other people, such as, friends, children, and grandchildren. In the interview, 4 senior participants said that they felt the happiest when exchanging messages with their children and watching a video of their grandchildren doing cute things since their children currently lived abroad. It was found that they had actively utilized eight functions that Savi has as well.

15 out of 20 senior participants were not interested in mobile phones at all. When questioned about the absence of a mobile phone in their daily life, their responses largely centered on the anxiety of not being able to contact their family when they are in distress. They responded that a function of a mobile phone was only to receive a call and that they did not even make a phone call. Even though they were curious about how their families were doing, they were reluctant to call them since they did not want to disturb their families' lives.

A common topic that emerged in the focus group discussion was on who makes the decision to buy a mobile phone or choose the different mobile services to use. Almost every interviewee mentioned their children and grandchildren as those whose opinion impacted them the most. Grandchildren who use a lot of mobile services themselves tend to be more influential than adult children when it comes to the adoption of mobile devices. On the other hand, especially children are worried about their parents' welfare and they often push their parents to buy a mobile phone to be able to contact each other. Passive seniors do not make decisions on their own but are heavily influenced by surrounding family or acquaintances. Therefore, it is important to find measures for simultaneous and effective marketing with both older adults and their children. No matter how much apps are designed for ease of use, it is necessary to seek out methods to provide additional services and support for older adults who have difficulties in using them.

We identified a total of 12 factors, but we narrow it down into 7 factors.

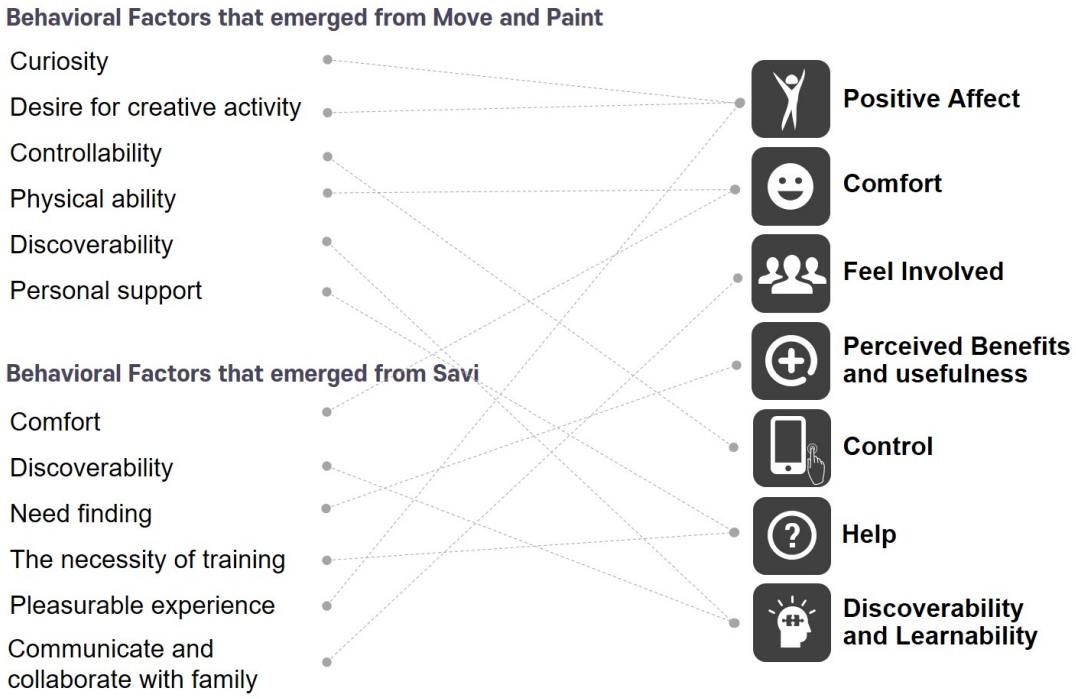


Figure 5.11: Factors influencing older adults' behavior and engagement towards interactive technology.

5.4 Factors Influencing Older Adults' Technology Usage and Behavior that Emerged from the Move and Paint and Savi Studies

We designed two systems to understand older adults in the context of public and personal technology usage. This section describes the key factors affecting technology usage for older adults based on technology related behaviors of older adults through focus group discussions and in-depth interviews. The findings were categorized based on seven factors which emerged from our thematic analysis with the Move and Paint and Savi systems: Positive Affect, Comfort, Feel involved, Perceived benefits and usefulness, Control, Help, Discoverability and Learnability. Based on these factors, we have proposed a new way to categorize older adults as users of technology. Active and Passive are two categories for older adults.

5.4.1 Passive and active seniors

A new way of categorizing older adults emerged from the preliminary study (Section 5.3). Active and passive are two categories for older adults. We identified two groups of older adults. We defined passive seniors as older adults that showed no interest in using technology, had to be encouraged to use basic features of digital devices, and often expressed concerns about the benefits of technology in their lives. Active seniors were the ones who were comfortable with the current systems and computing technology, used it regularly, and were interested when new technology was presented to them. Most of the previous studies on older adults' interactions defined an elderly person on the criteria of age or inability. When designing an interactive system for older adults, it is necessary to understand their behavioral characteristics. A wide range of physical, cognitive, social, creative and emotional experiences affect older adults' behaviors. On the basis of such behavioral characteristics exhibited when they use the Move and Paint and Savi system, older adults can be categorized into the passive-active spectrum. The passive and active groups have independent and opposite characteristics. Older adults are not easily transferred from passive to active and are rarely distributed on the middle range of the spectrum. The number of passive older adults is higher than the active older adults. The behavior and engagement factors we have presented in the following sections emerged from the qualitative studies, which merged the Move and Paint study and Savi study (Section 5.3, See Figure 5.11).

5.4.2 Positive affect

The passive seniors will be motivated to be engaged and become active when the negative emotions they have on technology are changed to positive ones. 'Curiosity' and 'pleasurable experience', the factors that emerged from our qualitative studies, are associated with emotions occurring when users interact with the system. These factors

positively affect the interaction. When initially interacting with the system, curiosity is a motivating factor that would help the older adults' desire to use it by evoking their interest. If the first emotion is positive, users would want to continuously use the system. Since the passive senior group already has a strongly negative perception about the technology, it is important to evoke their interest; this can initiate their interactions with the system, resulting in pleasurable experiences as they continuously use it, which could, in turn, encourage them to further engage with it.

- **Passive seniors:** The passive seniors expressed negative feelings while interacting with technology; therefore the initial interest did not develop into positive emotions. The passive group did not show behavioral change related to the use of interactive technology.

- **Active seniors:** The active seniors expressed continuous interest in interactive technology as the initially manifested interest helped them maintain positive feelings toward the system.

5.4.3 Comfort

The design that can physically, cognitively, and emotionally comfort older adults can engage older adults to use the interactive technology. The passive senior group will be engaged and become more active when they overcome any physical and cognitive barriers and feel stable and comfortable while using the system.

- **Passive seniors:** The passive seniors encountered inconvenience since they could understand the interaction techniques or visual elements and they also reported physical, psychological, and emotional inconvenience while using the interactive technology.

- **Active seniors:** The active seniors had a higher understanding of design elements and felt the user environment to be convenient, as they had various user experiences of technology.

5.4.4 Feeling involved

The passive senior group will be engaged and become more active when they feel involved with a specific activity or human relationship by using the system. Technologies can help older adults attain freedom from the loneliness and isolation that can often accompany aging. Providing the feeling of being affiliated with the society and family while using the technology will likely lead to mobile usage among older adults.

- **Passive seniors:** The passive seniors felt that technology did not have an effect on social activities or human relationships.
- **Active seniors:** The active seniors believed that their social activities would be increased through the intervention of technology. They were willing to actively use technology in order to maintain the social network.

5.4.5 Perceived benefits and usefulness

The passive senior group will be engaged and become more active when they feel the quality of their lives is improved or there is an incentive for using interactive technology. The development of interactive technologies for older adults should be considered by focusing on the needs, and preference of older adults. However, this understanding process is challenging, due to the insufficient knowledge or prior experiences of the technology that older adults have. The system should enable older adults to realize the benefits that come from using the system.

- **Passive seniors:** The passive seniors did not have needs or preferences in the usage of interactive technology.
- **Active seniors:** The active seniors had many demands on interactive technology according to their usage patterns.

5.4.6 Control

The passive senior group will be engaged and become more active when they can control the system without any difficulty. We found that older adults lost interest when the system did not behave as they expected. To ensure that older adults do not prematurely lose attention and sustain engagement with the system, it is important to design the system for controllability, such that they have control and feel as though they are in control.

- **Passive seniors:** The passive seniors had insufficient abilities to grasp whether the system was operated according to their intention.
- **Active seniors:** The active seniors had the ability to make various attempts to use the functions of the system and understand whether it was properly operated. They do did have difficulty in using interactive technology as intended.

5.4.7 Help

The passive senior group will be engaged and become more active when they feel they can get proper assistance whenever they need it. Older adults have a lack of ability to figure out how to use the system. Personal support may be required as a supplement to the system as they connect differently with human beings than machines. Personal support may also only be necessary to increase confidence or reduce self-consciousness.

- **Passive seniors:** The passive seniors needed help from others, since their willingness and ability to spontaneously understand difficulties were not adequate.
- **Active seniors:** The active seniors were willing to spontaneously understand and solve any problems while using interactive technology.

5.4.8 Discoverability and learnability

The passive senior group will be engaged and become more active when there is no difficulty in using the system constantly since it is easy to remember and understand functions after using the system. Understanding older adults' cognitive ability is essential. It is necessary to take care of their emotional well-being when they use the system. The system should be designed to help older adults easily discover and perceive its functions. We found that older adults did not automatically know the functions of buttons and did not explore with any gestures on their own unless prompted. This impacts the discoverability of the system for older adults. Using the metaphors that older adults are familiar with can motivate them to use the system and enhance their discoverability and learnability.

- **Passive seniors:** The passive seniors had difficulty in easily discovering and understanding functions of the system due to their lack of intention to explore the system. They required repeated explanations.
- **Active seniors:** The active seniors explored the system through various attempts and had no difficulty in memorizing and using its functions.

5.5 Discussion

The aim of this chapter was to understand older adults' perception and experience with technologies through user studies and identify the behavioral factors that can encourage older adults to engage with technology. From our Move and Paint and Savi studies, we found that creative expression and emotional commitment play an important role in motivating older adults. From the comparative study using the Move and Paint system, our analysis of the data allowed us to explore the difference in engagement in the two communities. The aging community was more dependent on instructions than the college student community. There were significantly fewer

individuals in older adults that engaged with the creative expression as a product of interaction, while the college community included more individuals who were intentional in creative expression. It was difficult to judge whether older adults engaged in the system, based only on their behaviors when they use the system. It is necessary to grasp their engagement by closely analyzing their emotional aspects. Although older adults mentioned that they were interested in the system that they have never experienced, they were unwilling to variously attempt to initiate or explore the system. Behavioral factors designed to draw the interest of older adults rather made them behave passively and revealed that human intervention was required to encourage them to use the system. A thematic analysis helped identify factors affecting the behavior and engagement of older adults in the use of Move and Paint: including "Curiosity", "Desire for creative activity", "Controllability" "Discoverability", "Personal support", and "Physical ability".

We identified "emotional connection to others" as the most important factor to motivate older adults to use mobile devices. Main themes that emerged from the data were: "Communicate and collaborate with family", "Comfort", "Discoverability", "Perceived usefulness and benefits", "The necessity of training", and "Pleasurable experience". In the context of mobile phones, it is difficult to draw initial interest from older adults. Different from public displays, mobile devices are essential factors in daily life and have been used by most older adults. When negative experiences with the devices are ingrained in them, they are unlikely to engage with the system. In this case, families' active interventions constitute an important factor in changing older adults from passive to active seniors. We then proposed a new way of categorizing older adults as passive and active. As noted above, the passive and active groups have independent and opposite characteristics. Older adults are not easily transferred from passive to active and are rarely distributed on the middle range of the spectrum. Behavioral Factors (Positive Affect, Comfort, Feeling involved, Perceived

benefits and usefulness, Control, Help, Discoverability, and Learnability) can be used as a framework to understand older adults' behavioral characteristics in detail and as a way to encourage and change their behavior from passive to active.

CHAPTER 6: FIVE CASE STUDIES THAT EMERGEd FROM EMPIRICAL OBSERVATIONS OF INITIAL ENGAGEMENT WITH TECHNOLOGY

6.1 Summary

This chapter responds to the research question 3 by using data gained from uDraw and the GrandPad system. The methodologies for these two studies were detailed in Chapter 4. In this chapter, we present an ethnographic study that reveals the importance of engagement for older adults and the context in which engagement is most likely to succeed. In Sections 6.2 to 6.6, we present how five case studies with different characteristics respond when they encounter new technology (uDraw and GrandPad) that have never been used before. The participants are classified into five categories: those whe are positive about technology, negative about technology, and those who employ social use of technology, diverse use of technology, and family-oriented use of technology. We present the case studies by considering six factors: family relationships, social contacts, general attitudes towards technology, need for technology, physical and cognitive health, and motivation. In this chapter, we discuss the new initial engagement values that have emerged from these five case studies.

6.2 Positive (Active) about Technology

Bob is a participant in the GrandPad study. He showed a positive attitude towards mobile technology during the three-month study period. Out of the three participants of the GrandPad study, Bob was the only one who had no problems with trying something new or using new functions of mobile technology. He maintained a positive attitude for the entire duration of the study. In the Diary study, Bob faithfully performed the daily tasks given, and overall, he did not report any difficulty or

inconvenience in using the system. The three apps that Bob was most interested in and used the most were the reading, game, and music apps of the GrandPad.

Figure 6.1: Case 1- Representative character to present positive attitude towards technology

When responding to his experience with technology, Bob recalled a good memory

about technology. The following quote is the answer to the interview question: "what do you like best about your cell phone?"

> "I have been using a cellphone for maybe, I would say, at least 25, 27 years, when it first came on the market. I still remember my first cellphone was a Motorola flip phone. I always like the cell phone feature."
>
> "That was a gift from my wife. I don't know how many ... when the first ever phone came, for my birthday, she stood in line for maybe four hours to get the phone for me. That's why I used that phone."

Looking at Bob's response to the above question, Bob first described his emotional attachment to the mobile device. It is interesting to note that his wife got a mobile phone as a birthday present, which reminds him of positive memories of that moment about mobile phones rather than remembering functions related to mobile phones. Bob has maintained a positive attitude toward the phone from the moment he first owned the mobile phone. When asked the question, 'can you explain how you feel when you are using the phone feature?'. Although the interview questions were about the function of technology, Bob connected his experiences and memories of technology with people.

> "A message I got today was from one of my friends, that I have known him for 45 years, who taught me international trade business. He used to do trade business in South Korea, and I used to do the trade business in Japan. I received an email and a message from him today. That makes me happy."

We learned that Bob engages in the use of a cell phone during peer interaction. Bob mentioned that he finds himself far more comfortable when asking for help from friends within the Pakistani immigrant group rather than seeking assistance from their children.

> "I have a friend who uses the phone more than I do, so he's the one that actually taught me how to use the feature to do a video phone call. Yeah. So now, like I said, there are two groups that I'm connected with, actually there are three. So, we can video chat with each other. However, I don't want to bother my son, he is working at the department store. He is really busy."

A significant external factor that caused Bob to be positive about the use of technology was that his peer community was well developed. It also helped make his active attitudes more positive. The initial engaging experience of technology is important for older adults.

6.3 Negative (Passive) about Technology

John was also a participant in the GrandPad study. John had a negative attitude toward using technology. He was not very interested in using the GrandPad during the research period except for the time that he explored mobile technology for his hobbies. Out of the three participants, John's total usage time was the lowest. He only used the GrandPad for 12 days in the first month of the study. Further, he did not complete the daily tasks very well, not because he faced technical difficulties but because he had no interest in the activities. However, the apps he used the most during the study were the magnifier app and the music app.

Figure 6.2: Case 2 - Representative character to present negative attitude towards technology

John was relatively free to use the computer because he learned how to operate it when he was in the military before his retirement. John has a very negative attitude to mobile phones, despite being experienced in using the technology. During

the interview, John reacted very differently when talking about a cell phone, a computer, or a PlayStation. The experience of using the PlayStation is described as a very positive experience. John likes to spend time with his family playing PlayStation. He explained that there are no difficulties using the PlayStation, even though he might have experienced difficulties while using it. However, since he was in a situation where he could get immediate support from family members whenever he finds anything difficult, it seems that he better remembers the joy than the difficulties he encountered using the system. John added in his explanations that a mobile phone is for emergency use only when staying in contact with family members. In other words, the PlayStation remains a positive memory when it is desired and used, while a cell phone used as needed is expressed as a negative memory.

> Cellphone: "It's good for emergencies. In other words, if something happened, if you break down on the road or something, we get in contact with each other real quick, yeah. I get a bunch of junk phone calls, I don't like it. I just hate when my phone rings and I don't answer."
>
> PlayStation: "I used to play the PlayStation a lot. We'd play the PlayStation together. We played racing and fighting, and building. I forget the name of that thing. I didn't feel any difficulties, I just enjoyed it."
>
> Computer: "A little bit familiar how to use a computer, yeah. I've ordered stuff off the computer and I've got a Facebook thing with a bunch of the people I went to school with, when I was younger. And I keep in touch with my relatives."

Comparing these three systems reveals what makes John uncomfortable. The reason why John hates using his cell phone most often points to problems caused by limited physical function. For example, there is a problem in that the mobility of a

finger is deteriorated, so that a button cannot be properly clicked, and a problem in which the characters on the screen are poorly read without glasses due to a decrease in vision. John often loses interests and complains about issues related to physical discomfort.

> "I don't like the touch screen. I like where you've got to match the button, the old type, the flip phone. Because I lose so much on the touch screen, for instance, I'd be talking with somebody, and stuff pop up that I don't want, and stuff like that." Or "Like the keyboard here, I can't see those things. They're too small, without my glasses."

> "I read texts, but I don't text myself. My fingers are too big or something. I can't do that, I'm too slow. So, yeah if I need something real fast, I say to my daughter, "Do it for me."

> "Really I liked it better when we didn't have a telephone everywhere. I really liked the landline because you didn't have it interrupting you all the time. I'd be under my car, telephone ring, I get up, and they hung up by the time I got to it. So, yeah, hey, don't bother me, unless it's an emergency."

In particular, John continues to use negative words like "hate" and "do not like" to express negative views on technology.

> "I hate a phone, even in the military. I hated telephones. I busted a few phones in the military, I'd get angry." "I'll be trying to use it, and I can't get what I want, I get frustrated." "I hate texting, I do not text" "I felt like throwing it away. I told my wife, "Give me my old phone back." I can pull nothing up that I wanted."

When pointing out the problems of a mobile phone, he always expresses a negative attitude, except when using a mobile phone for one's hobby, and then he has a very active attitude. John takes out the phone immediately, opens the app, finds and shows how to use it, and explains it in an active manner. John uses the mobile phone almost every day, using it as a magnifier for small-size texts supported by the zoom-in function. Studies on older adults identify ways in which existing functions can be applicable ideally to them, as the studies identify a wealth of knowledge regarding their experiences.

> "Like for instance, let's see, let's go to my pictures here. My cars here, my electrical. Like right here you got electrical, my clubhouse, I can take a look and see how the wires go and what wires go where, so I can hook it up better. I used it for that type of thing. Yeah, so I can read it. And it helps me when I'm working."

The younger generation does not always need the zooming function on a photo which can be used as a magnifier because the eyesight of younger people is not bad enough to require zooming in. John was not tech-savvy but despite this, he learned to use certain features that were well suited to his needs. We cannot fully understand his discomfort and needs until we grow old ourselves. Therefore, while exploring the use of technology by older adults, there is a need to discover how existing functions can be used in new ways to suit their needs. Older adults are reluctant to explore the features of mobile technology for a variety of reasons, including fears of it breaking down or ruining the interface by using it incorrectly. It is important to explore how to use the existing functions as senior-familiar functions from the viewpoint of older adults, taking into consideration their abilities and experiences. In order to give older adults a variety of experiences, efforts must be made to create a context where they can freely explore the functions of interactive technology.

6.4 Family-Oriented Use of Technology

Dorothy was the oldest of the participants in the GrandPad study. She could barely use the GrandPad on her own and constantly needed her family's help. With the support of her family, however, Dorothy made great strides in using the technology's features during the study period. Dorothy is a participant of the GrandPad study and an example case that shows how negative attitudes towards technology can be changed in a positive direction with an effort of family members.

Figure 6.3: Case 3 - Representative character to present family-oriented use of technology

Dorothy does not like to use the mobile phone, so usability was not the primary issue. When I asked about 'What do you like best about your cell phone?', Dorothy

could not answer for a long time. Her daughter, Angela, encouraged her to answer.

> Dorothy:"I don't really know how to answer you, if you want to know the truth." Angela: "You like the numbers that you have saved in it? Don't you have some numbers saved where you just press one button to call me, and one button to call my son."
>
> Dorothy:"Yeah, I like that."
>
> Dorothy:"I mean, I can answer the telephone if it rings or what have you. Sometimes, it's a little frightening to me because it is so modern, and I'm so unmodern."
>
> Angela:"When we first got the cellphones, it was basically for just emergency purposes. If she was out of the house. Because at that time, we had a telephone inside the house. Sometimes when it rings, I don't think she can remember exactly if she is supposed to put it to her ear and listen, to hear who's on the other end."

There are few things she can do through her cell phone: First, remembering the number stored by the family on the mobile phone, second, remembering the number assigned to the person who wants to call, and dialing the number. To prepare for an emergency, remembering to always carry the mobile phone. For Dorothy who only makes use of minimal functionality, we are questioning will be improving usability help her make better use of her cell phone? She continued by telling us that mobile technology has no importance and necessity in her life. Generally, frustration is one of the factors that have led to reduced use of technology [111, 207]. The aspect of frustration when using technology leads to demotivation and a lack of self-esteem [156]. According to Dorothy, low literacy in the technological field and total unfamiliarity with technology, along with physical challenges, were found to be some of the issues

that made the adoption of technology a problematic task. These two bring about frustration to the aging population and therefore act as barriers to the adoption of new technology.

> "I don't really like using the phone or telephone. Uncomfortable."

> "Back again to being old fashioned, I'm not modern. There are some things that I don't understand. I put up with it, with help. Yeah, with help. I've had to rely on my son to guide me. And I don't know if I'll ever be much different from what I am now. I am very happy that I have educated children, so they can guide me."

> "Because like I am, I wish I was different, but I'm me."

We had an interview with her daughter, Angela, since it was difficult to interview Dorothy due to her memory issues.

> Dorothy:"I am 81, I remembered. I have three children. Manuel, son, and my daughter, Angela. I had a son who passed away not too long ago, so that's it, that's enough children, isn't it?"

> Angela:"May I mention to you, that my mother has a diagnosis, and part of it is she suffers from antisocial behavior." And "So, I believe that we might be dealing with just a little bit of dementia. And I was just reading last week there are certain things that might be a little Alzheimer's coming. You've heard of Alzheimer's? Well, there maybe just a little bit of that mixed in too, so we've got all that working together."

We delivered the GrandPad to Dorothy and analyzed her usage through a diary study. When she received the GrandPad for the first time, the only thing she did

was turn on the GrandPad and watch the photos posted by her children and granddaughter. All Dorothy needed to do was to touch the screen with her finger. This is because the pictures saved by the family are continuously displayed as a Saver screen. Dorothy's children registered the Companion App to continue sending photos. Dorothy and her son lived four hours away, but her son's efforts enabled her to appreciate the daily life of her grandchildren. The following quotes are the feedback of a diary study from her family members.

> "Mom is still warming up to it. She looked at picture today."

> "She just tried to send a video of her breakfast, but it was blank. I think the GrandPad is experiencing some technical difficulties."

The first step she took was to familiarize herself with the GrandPad. When she wants to see the photos of her family, she can click on the touch screen on her own without anyone having to show her. However, she needed help on how to use all the features except the ability to turn off the screen by herself. Five days after using GrandPad, she was able to send a text and picture through GrandPad with the help of Angela.

> "Mom sent her brother a text/email this morning thanking him for the pictures that he sent her. Even though it was just 1 sentence, it overwhelmed her, but we will get her there."

> "Mom just sent me a picture of her dinner. I think she is getting the hang of it."

> "Mother accepted Uncle Harold's thanksgiving holiday dinner invitation."

Angela reported she has some difficulties to understand the GrandPad for the first two weeks after starting usage.

> "To play a Hangman game, she seems to be a confused, so I played it with her."

> "Mom could not find a dictionary icon on the Grandpad so we looked up the word in a dictionary. Cacophony means harsh, disagreeable, sound."

Sixteen days later (Nov, 28), we could see that Dorothy has finally figured out how to send a photo by herself. Then one day after (Nov, 29), we could get a response that she actually enjoys the GrandPad.

> "Mom did a good job posting a photo of the Thanksgiving dinner that my sister is preparing."

> "Mom looked at the picture today and sent me a voice message. She seems to be enjoying GrandPad."

Dorothy, who has no interest in using technology and feels that it's not a necessity in her life, realizes that it is possible to listen to any song she wants through technology a few days after using GrandPad. GrandPad inspired Dorothy to want to listen to music. The fact that Dorothy sought help in making a choice with the type of music she wants to listen to shows that desirability should be given priority over designing technology rather than usability.

> "Mom just sent me an email informing me that Choo Choo Ch' boogie by Louis Jordan is the song that she listened to today."

> "Mom just added Christmas music from Kenny g, chuck berry, Michael Buble and Mariah Carey to her favorites collection."

She also made another attempt three days later. She succeeded in reading an article using GrandPad's Article App. Of course, she couldn't use the app for a long

time because she easily gets tired, but she was delighted to learn new features. She also tried to play Games with the help of Angela. However, Angela called Dorothy's attention to see her family's photos through the GrandPad and also made a change to listen to music.

> "Mom wasn't feeling well over the last couple of days, thus she got behind. She just won a Bingo game and the GrandPad did not record it. Mom also read the joke of the day about the slotted leopard, and she laughed."

> "Mom sent me a voicemail message informing me that she engaged in the word search game. She completed 5 word search puzzles."

> "Yesterday mother enjoyed playing the slot game. She sent me the following email afterwards: "The slots game is fun. I Love you too."

> "The AARP website inspired mom to start waking to the end of the driveway daily."

Usability and desirability are both important elements that are indispensable for designing technology. Both elements are used to provide better user experience through design. Desirability is not intrinsic to the design, such as the aesthetic qualities, but instead is the connection that the technology has to their enjoyment and relationships with other people in their lives. Dorothy was inspired to listen to music and therefore was able to focus on the usability of the technology. This encouraged her to learn to use other features like games and puzzles. Initially, Dorothy was not interested in using the mobile phone so usability was not even a consideration and she did not try to learn to use it. A major consideration is how to transfer technology to older adults through the context in which the technology is used, how it enables connections and is supported by relationships with people in their life. These factors have an influence on determining desirability and can lead to an interest in usability.

6.5 Social Use of Technology

Gloria is described as a representative of the social use of technology, but two more participants named Peggie and Eva are also important in this section. All three were participants of the uDraw study. They participated in all five focus group discussions during the research period. They did the initial training and participated in an interview and focus group discussions. Gloria visited the researcher at the designated time and additionally used the uDraw system twice. The other two participants did not use the system except during the focus group discussions and an initial training session. All three participants were not willing to use the system on their own, and the researcher's support was always required. They expressed difficulty when using the uDraw tablet but followed the researcher's instructions well. However, their speed of usage was very slow. They could not figure out how to use the system for the given tasks during focus group discussions and training sessions. When comparing the use of the uDraw tablet and Wii remote control, all the participants found it more difficult to operate the remote controller. Moreover, they were not confident in drawing. When asked to draw a fixed shape such as a circle or square for testing the system operation and practicing drawing before playing the Pictionary game, their reaction speed was very fast, but as creativity was required during the game, their drawing speed significantly slowed down.

Figure 6.4: Case 4 - Representative character to present social use of technology

Gloria lives in an affordable rental community center designed for the aged members of the population. These areas promote older adults' wellbeing, aggregation for services, and various dignity enhancing activities. The community centers also promote independence and encourage the involvement of every person in community activities. Given the imminent risk of social isolation, the senior programs are critical

as they provide older adults with chances to engage in social activities and forge new friendships [213]. Additionally, Gloria stays occupied with the attendance of various activities at the community center.

> "I like being involved in things. I like to get out, talking, and volunteering. I was lonely before I moved here. However, I have since met some wonderful people."

Older adults show a preference for emotionally meaningful and positive relationships. Investing time and effort is important to maintain, enhance, and establish relationships with others in the senior community [214, 215]. Gloria enjoys investing in personal effort in keeping up her social relationships. We were able to see how socially active older individuals are changing the community. Gloria is a central part of social activities in the community. She constantly invites and encourages other residents to participate in activities provided by the community center. For example, on the day of a specific activity, she travels around the homes of close friends to convey information and remind them. We observe that her role greatly influenced the spread of interest in certain activities among older adults in the community center. Even older people who were not interested in a particular activity showed a changing attitude when Gloria was actively invited. Gloria was the first research participant who decided to participate in the focus group discussion. She initially showed interest in the uDraw system and hoped to use it actively. She is a participant who has been trained first and has used the uDraw system initially, as well as introduced it to her friends. Looking at how Peggie and Eva participated in the focus group discussion, Gloria's prior experience had a positive impact on their persuasion and eventually played together. Playing games together is a meaningful social activity for them. This social relationship and social context play an important role in determining the use of technology by Peggie and Eva.

Initially, Peggie often reveals physical discomfort during the interview. She is able to walk on her own but is assisted with a walker. Peggie's social activities are heavily influenced by Gloria. Gloria always takes care of Peggie, who is not interested, and tries to socialize together. Peggie had a very negative attitude towards the uDraw system at the beginning, but we were able to see her gradually growing through Gloria and gradually enjoying using the uDraw system. The motivation factor for Peggie is Gloria.

> "I am so tired, you know that this is my nap time. Can I go back and take a nap?"
>
> "I went to hospital yesterday" "You don't get me, I am not like you."

We explored the motivational factors when using the uDraw system. Findings showed that intentions for participating in this research depended on benefits associated with the shaping of social contexts. Older adults typically learn from their relationships about new products and activities, which may influence the perceived benefit of new technology. For Peggie and Eva, Gloria was a major source of potential support when using the uDraw system. Peggie frequently mentions how positively her best friend Gloria affects her life during an interview.

> "I like to spend time with my girl (Gloria), If I'm feeling down and out, I just come here and meet my best friend Gloria who's going to make me smile, or laugh, or whatever. I bet we'd make each other happy. Yeah, we communicate really well."

Gloria shares information with her friends, however, in the process of obtaining and communicating information, she exchanges information in a face-to-face manner rather than using technology. We found that she is reluctant to change her old habits to pursue convenience by using technology. For example, Eva, Peggie, and Gloria

use flip phones. When reminding about the upcoming focus group discussions, due to the cognitive characteristics of older adults, the date of the upcoming focus group discussion is frequently reminded. The following quote is how they respond.

> "Ok, can you write the day and time on the paper for me? I will mark it on the calendar when I go home."

From Eva's quotation, we can see that she does not use technology unconditionally because convenience is enhanced by using technology. Eva has mentioned once that she recognizes that using a calendar app can effectively manage schedules, but it is her old habit to write appointment dates on physical calendars. The findings in our research are that existing habits influence the use of technology rather than convenience for older adults. Helping older people to have positive feelings about technology through one-time interests can also be effective in promoting the engagement of older adults in the use of interactive technologies. When asked, "How important is a cellphone in your life?"

> "No, it's not. It really is not. It's just a tool that I use for different situations in my life when I play a game. But as far as people sitting all day and want to play all day, no. No, because when I leave here, I'm doing something else, I'll put the phone down. But while I'm sitting here waiting to do my laundry, I'll play a game."

> "It's a relief valve if I'm frustrated or having a problem that I can't really deal with at that time and I need something to occupy my mind, if I don't read, I'll go play a game."

Participants mentioned that the uDraw system is not a system to be used continuously because our participants are not interested in drawing. The following is a quotation showing their view of the uDraw system.

> "It's an okay game. We thought a lot of people before they got our age they could probably do this well. But you don't just do this overnight you come in here and ask us to do something the next day when we haven't studied upon it, we haven't played any games before."

> "So it's something not going to use for a long time, it is just going to be for one time for fun."

Participants respond in the third focus group discussion that they are not motivated to continue the drawing activity but are satisfied with using the uDraw system to enjoy time with friends.

> "It's just something that relaxes us, that we just enjoy doing together. That's all."

> "We don't know how to draw. We have never drawn, never going to draw. It's just a get together. It's just something fun. It would be something that I would be interested in coming down and doing. Not just because I want to learn how to do it, but it's like a social outing. We can get together and have fun."

Mostly, older people do not use technology on their initiative but are compelled to use it by the influence of their families or communities they belong to. The paths and methods in which technologies are first introduced to older adults have a great impact on their general perception of the technology. When introducing new technologies to older adults, human intervention is essential to determine the repeated use of technology. It would be vital to deploy personal help or to prevent any feelings of isolation and reduce the stress levels of aging when using technology [216]. Community service programs can also be used to drive towards this goal. The role of grandkids in the use of technology by older adults is important in promoting user engagement with

interactive technology by older adults. Older people often mention that they want to use the uDraw system with grandkids. It is important to consider how to increase the intergenerational connection and how to increase the involvement of grandkids.

> "I'd actually like to bring my grandkids, one of them. To see what it would be like to have them and we all try to draw. You can leave some messages to your grandkids?"

This section shows that older adults attempt to use technology to maintain social relationships in a community center because they have a strong desire to engage and sustain others' interests. In the case of the Affordable Community, there is a lot of interest in technology and activities that older adults can use and accept. This section also shows that Gloria was willing to use technology to participate in activities to better maintain social relationships without significantly investing her effort in learning how to use technology. To increase engagement in the use of technology for older adults, we should consider how the social context to increase accessibility to technology for older adults should be structured. Contextual resources can be successfully used when they match with the heterogeneous needs and capacities of older adults. The benefits of engaging in using technology do not only include the learning of technology but also the engagement into a small group class, which can become an integral part of the social contexts of participants.

6.6 Diverse Use of Technology

Michael was another participant in the uDraw study. He was the participant with the highest initial interest in the uDraw system. As in the case of Gloria, Peggie, and Eva, he also participated in five focus group discussions. In the beginning, he expressed high interest and engagement but could not sustain his engagement for three months. In the first month, he used the system by himself nine times. Of the four participants, Michael was the only one who used the system without any

difficulty. He skillfully used the functions he had learned and experienced with the researcher, but he did not try new functions. Therefore, the range of functions that could be used was limited.

Figure 6.5: Case 5 - Representative character to present diverse use of technology

Researchers visited the community center almost every day as scheduled on the community calendar for the first month to help older adults get used to using the uDraw system during the study period, but there were no older adults who asked for additional help after training, except for Gloria. However, during the focus group discussion, the researchers recognized that they had complaints about the lack of training. For example, Michael went through the general training course mentioned above in Section 3.3.1. We explained to Michael where the gallery was located and which button to click through which route to enter the gallery during the training process. Training also includes browsing through the gallery for drawing that has been saved by others. The information that we could not pass to Michael through training is that if clicking the saved drawing, there is an edit button, and if clicking the edit button, it is possible to open the saved drawing again and edit the saved picture. Michael failed to do this process himself. We should be aware that through Michael's case, older adults are reluctant to try anything other than the ones he or she has learned. The following is what Michael mentioned in the Focus group discussion. But he never asked additional help to figure out the problems in using the uDraw system. We learned that training for older adults should be prepared to repeat multiple times.

> "But I know how to do that though, so I come down here. But you showed me how to do it at the beginning, and I remembered. But I guess what I'm trying to say is, you haven't shown us the different functions on the thing. I don't even know how to go back and get my saved pictures that I draw."

> "That's like I was explaining to you about the new phones. Now, if I go buy a new phone, it doesn't have directions on how to use the phone. They assume that you're supposed to know how to use this phone, which

> is totally not true. It's not true. How can I know about something if I have never heard of it?"

While conducting individual training for older adults for this study, the researcher learned that it was necessary to first check the expectation of each individual before training. While each individual uses the same system, their desired functions are clearly different. Providing training that satisfies an individual's expectations may increase the usability of technology and improve engagement. Based on training experience through this study, group training unified to older adults is not suitable. In addition, we as younger adults or researchers should not expect that older adults will be able to use advanced features by applying the basic features they have learned. Therefore, older adults should have continuous support throughout the system, but there is no difficulty in using the technological system. We also learned that finding extra help from old peers is needed. If there is an older person who could teach others, enthusiastic, active, this person could attract other residents' interests and be well-connected with their peers.

> "Once you leave with that, I'm not going to think about that anymore. That's it. I'm going to learn this time, and the next time you come back, I'm going to know how to do it then."

Rather than adding new features or updating features to the system for older adults, it is much more effective to increase the engagement of older adults by considering how to use the existing functions in various ways. What we learned from this study is that older people are reluctant to use new features. Rather than providing a variety of functions, it is preferred that one usable function is configured in various ways in an easy way. For example, functions such as changing the brush, changing the background, stamping, and changing the thickness are not used by older adults. Instead, the desired color is very specific. So they are engaged to change the colors.

Rather, when one function is very specific, older adults are more likely to engage. It is more effective to specify one familiar function more than to provide various functions of different kinds to older adults.

> "See? That's what I am talking about. I don't need all of that, I just need a simple, simple thing. I don't need all of these brushes, I don't need all of these options. Please get me a simple palette and canvas, that's it."

> "I need more colors. I would like brown, a darker shade of brown, I'd like an orange and that's like a burnt orange. I like more pictures but you don't have enough colors for me. I wanted more colors like a brighter yellow or a deeper orange. A darker brown, I like colors so they were very basic colors."

Digital technology has become a key platform for societal participation. Without access to technological facilities and adequate training on technology, the aging population becomes partially shut off from societal engagements. In turn, this increases the stress levels and the feeling of isolation for older adults [217]. Michael emphasized the importance of awareness in the in-depth interviews and focus group discussions. He said that he would like to use the system once he fully understood when and how uDraw was available, what features of uDraw he could use, and how he could use the system without difficulty with his abilities and experience. In other words, he was ready to engage in something new and was interested in trying it, but he did not know the options available to him. Older adults thus need to be fully informed in advance before they attempt to use the system.

> "Spades, dominoes, chess, solitaire. I actually play those games myself. So those are the games I'm familiar with. All the other technology and all of them, I would love learning new things, but I have never had the opportunity to actually learn."

We introduced two kinds of Wii games to our research participants. Wii play games require the use of physical ability, and Wii brain games require the use of the mental ability. The Wii Play is a shooting game that is similar to Duck Hunt. In this game, players shoot different objects displayed on a screen, which include balloons and clay disks. These objects descend from a sky illusion, and the player has to use a Wii remote to aim and fire at the items using a trigger button on a controller. The Wii Brain game has a single-player mode where a player is given the task of answering several questions correctly. These questions are grouped into five different categories. The categories are classified into; analysis, memory number chomping, visual recognition, and quick thinking. In order to play Wii Play, older adults need to move fast. For example, while playing a table tennis game, Eva cannot keep up with the speed of the game because his body movement is slow. Also, although it is much more advantageous to stand and play the game than to sit on a chair, she feels a burden on standing for a long time. She has a very difficult time maintaining a normal rally in the table tennis game due to physical limitations. In this case, we can observe that she loses her confidence quickly and is reluctant to try other mini-games. However, when playing the Wii Brain game, we can observe the changed attitude of Eva. If the time limit does not solve the assigned problem, she expresses the desire to challenge again. Besides, after the focus group was over and all discussion sessions were over, Eva remained for 30 minutes to continue playing. We found out participants are more engaged in playing cognitive games. The following is Eva's reaction after playing Wii Play.

> "You have to practice like anything else. You got to practice because if you don't do those things all the time, it's harder to do. But when people play games and stuff like that it's a lot easier for them to do it. We can do it if we practice. it's good, it's interesting, but sorry baby, this game is not for me."

However, Participants in the Focus group responded much more positively to the Wii Brain game. We learned that our participants are more likely to do cognitive activity than physical activity.

> Michael: "I feel it's a challenge. I feel like it's a challenge. It's a mind thing for me. It keeps my mind occupied and working. That's what I basically do it for. Because being a senior citizen, I'm not doing a whole lot out of the house. It's very limited that I can do it in the house as far as technology. I like the challenge, the mind thing. Yeah, that's what I like. I mean it's also fun."
>
> Michael: "It keeps me I guess you could say mentally active."
>
> Interviewer: "So that helps you to be more active?"
>
> Michael: "Mentally. Yeah. Give my brain a workout. We don't mind being challenged because we are challenged to everybody. It's (Wii Brain) a little more exciting than that other one (Wii Play). It's a fun activity, more have fun."

6.7 New Initial Engagement Values Emerging from Our Case Studies

In the previous chapter, we present how five case studies with different characteristics respond when they encounter new technology (uDraw and GrandPad) that have never been used before. In this section, we discuss new initial engagement values that have emerged from the five case studies. Table 6.1 shows what values are associated with each of the case studies. In our findings, we present two comparable values, indicated as new values and existing values in Table 1, about engaging older adults in the use of technology. In Table 6.1, the last column labeled 'Existing values' is widely discussed in existing literature to support older adults' use of technology. We summarized 'Existing values' in section 2.2. 'New values' in Table 6.1 is about the

initial engagement value that was revealed through our study. Initial engagement values that we present here are not completely new, but these values deserve more attention when considering the older adults' user experience of technology. These new initial engagement values should be considered in the early phase of interaction for older adults. The following eight values of initial engagement for older adults are the empirical results that emerged from observing older adults in a particular case, which may lead to a somewhat limiting overall understanding of their use of technology. Hopefully, these findings will be used as discussion points to inspire new research directions for future HCI research.

Table 6.1: Initial engagement values associated with each case study.

Category	**Initial engagement values associated with each case**	**New values**	**Existing values**
Positive about technology	Bob is initially engaged to use technology in the context when he could be positive and active and have positive experiences with technology	Desirability	Usability
	Bob is initially engaged when in the context when he could actively communicate with peers and family and when to get support from peers when occurring technology-related issues	Peer support	Professional support
Negative about technology	John is initially engaged to use technology in the context when to make his hobby easier	Motivation Desirability	Usability

	John is initially engaged to use technology when he realizes that he could be able to use the existing features as he intended	Use of existing features	Develop new features
Family-oriented use of technology	Dorothy is initially engaged to use technology when she is available to support from family, to communicate with the family better, and to involve in the family network	Motivation Desirability	Usability
	Dorothy is initially engaged to use technology when she is not required to do anything to receive family information (photos, events, anniversary, etc)	Lightweight Commitment	Continued benefit
Social use of technology	Gloria is initially engaged to use technology when there is more opportunity to build a social relationship while using interactive technology	Social	Independence
	Gloria is initially engaged to use technology when she has more opportunity to use interactive technology with grandkids	Role of Grandkids	Role of caregiver
	Gloria is initially engaged to use technology when she feels familiar with interactive technology to understand its purpose and intention to use	Familiarity	Convenience
	Gloria is initially engaged to use technology when she could do a lightweight activity to keep life busy with her friends while using interactive technologies	Lightweight Commitment	Continued benefit

Diverse use of technology	Michael is initially engaged to use technology in the context when he could try many different activities by using emerging technology (such as VR, voice-activated speaker)	Desirability	Usability
	Michael is initially engaged to use technology when he has more opportunity to overcome cognitive challenges while using interactive technology	Cognitive Activity	Physical activity
	Michael is initially engaged to use technology when he has easy access to interactive technologies for free and aware of its availability	Awareness	Affordability

6.7.1 Motivation (Desirability) (vs Usability)

*Older adults' **motivation** needs to be considered before **usability** to increase initial engagement for older adults.*

Czaja et al. [90] pointed out that age-related challenges make older adults difficult to use interactive technology. According to Lee and Coughlin [83], usability becomes a central issue when technologies are designed or developed to directly interact with users. Davis [218] identified the ease of use for interactive technology as a significant determinant of the adoption for an individual older adult. However, our study identified desirability should be considered before usability for engaging older adults. Whereas usability influences a user's ability to complete a task [89], desirability means they have a pleasurable and engaging experience while using the system. Initial Engagement will increase when older adults have specific reasons or motivation to use interactive technology for having fun and engaging experiences. We

found that Bob likes being active, John enjoys hobbies, Dorothy likes staying in a family network, Gloria likes to maintain good relationships with friends, and Michael enjoys experiencing diverse activities. This study shows that they are willing to take the initiative with technology if it can be used to meet their desires.

6.7.2 Social (vs Independence)

*Creating the opportunity to build **social** relationships with a technology need to be considered rather than supporting the ability to **being alone** for older adults.*

As people begin to grow older, they go through different phases or stages of life. Older adults become passive to participate in activities that are critical for their wellbeing [219]. For instance, physical frailness makes it challenging for older adults to go out to shopping malls or trim flowers in their gardens. In such situations, interactive technologies such as "aging in place" and "assisted technologies" assist with such activities or support older adults to execute them to promote their independence [127, 123, 220]. Studies have found that aging technologies through convenience, have a positive association with social and emotional functioning [205, 221]. However, it is not yet clear when the potential benefits of technology become convenient for older adults in social contexts. Our study shows that Initial Engagement will increase when there is more opportunity to build a social relationship while using interactive technology. Our study points out that social value is important in encouraging older people to use technology. In section 6.5, we show through the case of Gloria, Peggie, and Eva, how social relationships positively influence their interest in technology. Technology developed to promote the independence of older adults is expected to be used mainly in situations where older adults are alone. However, older adults are more engaged in using technology in contexts where they can cooperate and interact with each other.

6.7.3 Familiarity (vs Convenience)

*Keeping a **familiar** lifestyle for older adults instead of forcing older adults to use technology for **convenience**.*

Besides independence, interactive technologies also promote convenience for ADL's of older adults [109, 216]. Many studies indicated that there are many positive impacts of using technology tools for older adults such as enabling them to live more conveniently at their homes [222]. In this study, we found that older adults are reluctant to change their daily routines or old habits to pursue convenience by using technology. Older people can be engaged more and can adopt technology into their lives when technology is integrated into their lives without interfering with older adults' basic routines. The participants did not feel the need to learn to use technology until they broke the way they'd been using it. Rather than develop innovative technologies to promote older adults' convenience and support their daily activities, we need to consider ways to help older adults become familiar with the technologies that are widely and easily found near their living environments. Among the technological interventions developed for older adults, we can easily find an app or device that sets reminders for taking medication. Eva mentioned during the focus group discussion that she never forgets this because taking medicine is an old habit of hers. She also said that it is rare that she forgets an appointment at the hospital. In this case, Eva will not purchase a smartphone to use the reminder app. She will also not ask someone to download the app or spend time learning how to use it. Rather, it is more important for Eva to develop the ability to explore the technology without fear by familiarizing herself with the existing functions of her current mobile phone so that she can use them to her benefit.

6.7.4 Cognitive activity (vs Physical activity)

*Providing the opportunity for **cognitive activities** with technology rather than **physical activity**.*

Age-related diseases and functional problems pose mobility and cognitive constraints that significantly affect older adults' engagement in the use of technology [90, 223, 224]. Many researches and innovation in technology development for older adults specifically focused on health-related technology. There is a steady improvement in Health-related technology. This improvement is made towards achieving better, creating innovations that help solve the challenges faced by the aging caused by disease, old age, and disability [225]. One of the innovations includes using the telephone to monitor their health, communicate with them, and give frequent reminders [114, 17]. We found that older adults who participated in our study are more proactive when faced with cognitive challenges. Older adults tend to overestimate cognitive capacity over physical capacity. Our participants lose interest when they realize that they won't be able to overcome their physical issues. Through the uDraw study, we learned that we need to pay attention to how the attitudes of the participants change passively in physical activity and actively in cognitive activity. When older adults who lack confidence in their physical abilities use technology to perform activities that require physical abilities, their confidence inevitably decreases. In this situation, it is difficult for older adults to engage with technology. However, when performing cognitive activities, older adults show a willingness to overcome their limitations, and they become interested because of the sense of accomplishment they feel when they complete a task.

6.7.5 Peer support (vs Professional education)

*Providing **peer interaction and in-person training** when introducing new technology to older adults rather than organizing **professional group training**.*

Generally, many studies pointed out that older adults need to attend training or educational sessions to perceive, learn, adapt, and accept interactive technologies. Many researchers believe that some of the difficulties that older adults face while using technology can be resolved to some extent through early training or education [155, 226, 195]. However, older adults need constant help until the interaction is over. To promote user engagement with interactive technology by older adults, here are a few things that we learned from training sessions with older adults on our research site. We found that every older adult who used uDraw was relatively good at using the functions he had learned once, but he was reluctant to use other functions that he had not tried without help while using the system. When training for older adults, the researcher needs a great patient. Older adults easily forget what they learned. We should not assume that older adults will be able to use the system themselves. We should not overlook the fact that older people always need someone to assist them while using the system. Besides, the most useful thing for someone to learn is not technical skills, but the confidence and motivation they need to carry on by themselves. Additionally, most older adults do not trust new technologies. Several studies have concluded that the mistrust is due to the lack of previous experience with technologies [143, 83]. This is an additional burden on older adults. Our participants are likely to commit their effort in learning or using the technologies [109]. In this situation, we found that peer support is needed to deliver the right information about technology to older adults. Peer interaction is a potential way to improve trust by older adults.

6.7.6 Role of Grandkids (vs Role of Adult kids)

Grandkids *are more powerful to encourage older adults to use technology than* ***adult kids****.*

Family and other caregivers influence the technophobia and adoption of aging technologies [227, 15, 228]. According to Courtney et al. [8] the family is the major

determinant of whether an older adult would adopt a technology or not. Therefore, the family, and especially children, must first adopt or support the aging technology to facilitate its utility. Many studies are conducted to reduce the burden on a family caregiver to take care of older adults [159, 160]. Sometimes caregivers recommend the use of high-performance mobile technology for the elderly for their convenience, but this can be a burden for the elderly. Older adults feel sorry for the fact that children should pay a high price for devices, they have to learn new features they are not familiar with, and they have to ask for problem-solving whenever a problem arises. The commercial focus needs to change from caregiver to grandkids. We found that the greatest stimulus for older adults emotionally is the participation of grandkids. In the case of the uDraw tablet, GrandKids are often referred to as the person they want to play with. It is also essential to give grandchildren an important role in the use of various technological devices. In turn, these children will help the older generation adopt the enthusiasm for technology use and eventually help reduce the feeling of isolation or intenseness for the aging population.

6.7.7 Use of Existing features (vs Develop new features)

*Think a way to utilize the **existing features** according to the needs of older adults instead of delivering **new ideas or innovative features**.*

There are innovative technologies developed for older adults to enhance the lives of older adults [229]. For example, The Massachusetts Institute of Technology (MIT) have developed Rendever, a virtual reality technology that alleviates social isolation when caregivers and companions are away. Also, Ding et al. [137] cite that there is a significant need for ICTs integration in the life of older adults. ICTs are fitted with sensors and audio features that assist in the movement and execution of activities, making the living environment safe and suitable for ADL's for older adults. Some make life even exciting, like Jibo, which tells jokes and mimics emotions of older adults, to keep them emotionally active. But we found that instead of creating

innovations, it is better to integrate new features into the technology that is already in existence. Even though there is a certain function of interactive technologies that improve the quality of life of older adults and support their daily activities more smoothly, we should be wary of putting older adults in the digitized context where older adults should learn something new continuously to adopt the technology. Rather than continuing to create new functions, it is necessary to consider in advance how to use the existing embedded functions of mobile phones or computers that are easily accessible to older adults.

6.7.8 Awareness (vs Affordability)

*Make older adults **aware of the opportunity** to use interactive technologies that can be enjoyed free of charge, regardless of **cost**.*

The cost of interactive technologies is not affordable for all older adults. Although technology might be optimized to meet optimal convenience and offer the desired pleasure of independence, most older adults are likely to avoid them based on cost. Studies have found that one of the determinants for an older adult to accept an old age technological assist is its cost [109, 230]. Besides, older adults are less aware of the importance or significance of the technologies, and they are not willing to spend money on something they do not understand [82]. Affordability is indeed an important factor in deciding the use of technology for older adults, but our study shows that it is more important to make older adults available more frequently to various technologies. The aging population is generally not aware of the new technologies and their utility. Therefore, there is a critical need for older adults to be enlightened about the new technologies that are potentially useful for their ADLs, since lack of awareness is a barrier to adoption. Older people think technology is expensive, so they are reluctant to try technology because they are afraid to pay for what they use. The more they do, the older they lose the chance to experience technology. Government programs should increase the chances of older adults accessing new innovative technologies for

free in a community or senior centers. This process raises older adults' interest and pleasurable experience in technology and becomes an opportunity to reduce the initial barrier to technology.

6.7.9 Lightweight Commitment (vs Continued benefit)

*Focus on **one time for fun** instead of providing **continued benefit** to use interactive technologies.*

Many studies focused on older adults have also identified usefulness as a key factor [231, 82, 232]. Older adults are likely to use the technologies they desire or are aware of. Studies have shown that older adults are attracted to technologies that provide utilities that are clear and are deemed to improve their current wellbeing [233, 83]. Generally, researchers believe that regardless of the novelty of a technology or its popularity, older adults are more likely to adopt that which they perceive to have a potential benefit or might help them attain their desired convenience [229, 83]. When designing technology for older adults, designers and developers consider sustaining the use of technology for older adults. But our study shows that older adults have identified lightweight usefulness or benefit as an important value. In the use of the uDraw system during the research period, our participants appreciate the opportunity to have time for fun, relieve stress, and connect to other residents. They do not want to use the system for a long period of time.

6.8 Discussion

This chapter presents 5 case studies and 9 initial engagement values that emerged based on the researcher's experience of interacting with older adults over six months. These values cannot be generalized, but it is significant as a starting point for future research on engagement for older adults in the use of technology. Many studies in the field of HCI still focus on the deterioration of the cognitive and physical abilities of older adults and tend to focus on evaluating the usability of older adults in a lab

setting [14]. Suppose older adults encounter and get more experience using new technology gradually and increase their engagement with new technology, it is expected that their negative feelings about technology will decrease progressively. Our findings can be used as a discussion point to overcoming the initial barriers of new technology for older adults.

- Motivation (Desirability): Initial engagement for older adults is facilitated when they have specific reasons to use interactive technology for having fun and engaging experiences

- Social: Initial engagement for older adults is facilitated when technology is used for the purpose of enjoying leisure time with members of society to which older adults belong

- Familiarity: Initial engagement for older adults is facilitated when older adults can enjoy the use of technology within the range that does not interfere with the lifestyle and patterns familiar to older adults

- Cognitive Activity: Initial engagement for older adults is facilitated when an opportunity is provided to do activities that can entertain and stimulate the brain for older adults

- Peer interaction: Initial engagement for older adults is facilitated when an opportunity to learn technology from peers in similar age is given, when technology is introduced by older adults with the same abilities and literacy than a younger generation with different values or ideas

- Role of Grandkids: Initial engagement for older adults is facilitated when there is an opportunity to interact with grandkids through technology rather than just being introduced to technology from grandkids

- Use of Existing Features: Initial engagement for older adults is facilitated when older adults realize that they can try technology easily and happily by using the functions they are already familiar with, freeing from the burden of learning new things to use the technology
- Lightweight Commitment: Initial engagement for older adults is facilitated when older adults use technology for a purpose that they enjoy once, free from the burden of continuing to use technology
- Awareness: Initial engagement for older adults is facilitated when they have easy access to interactive technologies for free and are aware of its availability

CHAPTER 7: FUTURE WORK AND CONCLUSION

7.1 Summary

This chapter summarizes the findings and contributions of this dissertation to research and practice, as well as the limitations, directions for future research, and conclusions. These research trajectories are organized around the three main thrusts of this work, namely building a new model of engagement for older adults towards technology, categorizing older adults in the spectrum of passive and active in the use of the Move and Paint and Savi systems, and identifying factors of initial engagement for encouraging older adults initial usage of interactive technology. This dissertation presents directions for future research such as developing a framework to measure older adults' initial engagement, and generalizability of older adults' initial engagement in different application domains.

7.2 Contributions

The major contributions of this research are as follows: first, re-conceptualization of the engagement that goes beyond need and usability to address the gap in studying older adults' initial engagement with interactive technology in Chapter 3; second, analysis of the active-passive spectrum of older adults' behaviors toward technology in relation to their initial engagement with interactive technology, in Chapter 5; and, finally, identification the factors of initial engagement for older adults in the use of interactive technology in Chapter 6. Each of these contributions is summarized in the following sections.

7.2.1 New model of engagement of older adults with interactive technology

Building on the idea of engagement for older adults, this dissertation presents a new engagement model with a specific process and distinct stages: before engagement, initial engagement and after engagement. Until now, the existing composition of engagement has not been well established to understand older adults' engagement towards technology. There are many studies of age related characteristics that influence the before and after engagement stages of older adults through their behavioral and psychological characteristics as revealed in existing literature review, but there are insufficient studies to understand the concept of initial engagement for older adults. Through a synthesis of past research, and a mixed method studies with four technological interventions, this dissertation provides a base for understanding older adults' initial engagement. The discussions around the new engagement model and initial engagement factors presented in this dissertation expands the existing understanding of older adults' affect, behavior, and cognition. A new model of engagement for older adults can be examined in various related academic disciplines outside the domain of technology as well, such as studies on policy implications, caregiving structures, and social communities.

7.2.2 active-passive spectrum of the behaviors of older adults towards interactive technology

The active-passive spectrum provides a categorization of older adults in terms of the attitudes towards interactive technology: active older adults are comfortable with current interactive technology and show a high level of interest and positive attitudes when new technology is presented to them. Passive older adults show no interest in using interactive technology, and often express negative emotions about the benefits of technology in their lives. In Section 5.4, we discussed seven behavioral factors (Positive affect, Comfort, Feel involved, Perceived usefulness and benefit, Control,

Help, and Learnability) which are distinctly useful to describe a passive and active categorization of older adults toward new technologies. For accessing the usage and attitude of older adults regarding, these factors can be used as an evaluating framework and can be used to undertake future studies and create design principles that take into consideration the needs of the aging population. These factors should be considered in all design stages of planning, ideation, and evaluation when developing engaging technology for older adults.

7.2.3 Identification of the key factors that influence the initial engagement of older adults

Another contribution of this dissertation is the identification of the key factors that influence the initial engagement of older adults: Desirability, Social, Familiarity, Cognitive activity, Peer support, Role of grandkids, Use of existing features, Awareness, and lightweight commitment. In terms of the research methodology, we presented a base for a more comprehensive understanding of older adults when they face a new technology in the real context rather than conducting experiments and analyzing results based on a limited assessment focused on physical and cognitive characteristics. Initial engagement values that we identified in Chapter 6 could be developed further as principles for designing engaging technology for older adults. These values could be further used as contextual requirements to enable older adults to adopt interactive technology. This dissertation addressed aspects of initial engagement that had not been deeply investigated in prior works. These initial engagement factors can be expected to contribute to both researchers and practitioners working on the topic of older adults' engagement, adoption and use of technology, as well as those investigating ways to design and develop engaging technology for improving quality of life at old age.

7.3 Limitations

To increase the initial engagement of older adults, research is needed to understand the context of aging in a digitized world. However, there are a number of limitations to the present research. First, the data we analyzed was limited to a small number of participants. We might have seen different responses or different initial engagement values if we analyzed a larger sample of other older adults. Research related to older adults' use of technology tends to rely on self-reporting methods such as surveys or interviews at a single point of time, and studies to evaluate the behavior of older adults in the long-term period are extremely rare. However, our study presents a longitudinal study and an in-depth understanding of each individual who participated in this study to identify new research perspectives on the engagement of older adults in the use of technology. Second, in terms of generalization, our initial engagement values reflect the attitudes of our research participants in both public and private settings in the given systems (uDraw and Grandpad). Nonetheless, we think initial engagement values that emerged from our empirical observations could be extended or generalized further to older adults with different backgrounds and capabilities; however, more research is needed to confirm that. We cannot be sure that the values mentioned in this paper can engage older adults in general in the use of interactive technologies. However, the initial engagement values generated in this paper were revealed through empirical observations and can be used as basic data to explore ways to stimulate older adults' initial engagement. We do not confirm the effects of initial engagement values in this paper. We do not know whether older adults' initial engagement increases or not if a certain initial engagement value is applied to the interactive system. Although there are limitations, this research has identified a new model for initial engagement that can be the basis of future research.

7.4 Future research directions

A conceptual foundation for initial engagement for older adults is not in place and we have constructed factors that influence older adults' behaviors and engagement with four given systems as discussed in this dissertation. There are two distinct avenues for future research that will be discussed in this section, which are as follows:

7.4.1 Developing a framework to measure older adults' initial engagement and design engaging user experiences for older adults

The work performed in this dissertation provides generalizable insights about evaluating older adults' behavioral characteristics in the context of technology usage. In particular, the active-passive categorization of behavior and engagement for older adults that we presented in Chapter 5 provides valuable knowledge about how to understand older adults' technology usage. Whether older adults spend more time using technology or which features of technology they use more should not be the criteria for evaluating older adults' use of technology and engagement. When we understand the behavioral characteristics of older adults in the process before they engage technology, and through the overall process of gradually experiencing technology, we can improve their engagement with and help them enjoy the benefits of technology. In this dissertation, we have presented the initial engagement factors that might change older adults' behavior toward technology from passive to active. We grounded the notion on the belief that initial engagement has a huge influence on their mindset when they encounter new technology. Initial engagement is a phase that is measured by time or by cognitive changes. Normally, the user engagement phase is measured by time. Another research direction considers it a cognitive maker that older adults undergo certain behavior and cognitive changes when initial engagement changes to long term engagement. We can measure their behavior, which signals a transition from initial engagement to long-term engagement. Currently, there is no indication

in the data to support our claim and determine whether some of our participants were in the initial engagement phase or the after engagement phase (the same as the long-term engagement). As there isn't enough data to establish, determine, and evaluate older adults' behavior and understand how the engagement process changes from one phase to the next phase, we will use the new engagement model as a starting point to discover where a specific older adult is in terms of the engagement phases (before, initial, and after engagement). We can build a useful tool or framework to evaluate engagement with a variety of applications. We will also provide ample evidence of how the engagement process can be further segmented by the cognitive makers of older adults in a future study.

7.4.2 Test the effectiveness of initial engagement to older adults with comparison with other age categories

The factors discussed in this dissertation emerged from the behavior of older adults in the older adults' community, as it interacts with not only older adults but also various stakeholders surrounding them for a long-term period. Measuring engagement for older adults is difficult in that it is difficult to validate or generalize whether each factor has an effect on the majority, because each factor is extracted from different cases. Every case is not a behavioral pattern in which the majority of older adults behave the same. Future research is needed to measure how much of each factor affects the level of engagement in older adults, how different phenomena will occur around aging, and whether these factors cause behavioral changes in older adults with interactive technology. Based on an extensive review of the existing study on age-related characteristics, we designed a study for only older adults to identify the initial engagement factor in the use of interactive technology. We immersed ourselves in the senior community and actively engaged with older adults to identify several factors discussed in Chapter 6. However, the factors of initial engagement that emerged from this dissertation might be valuable for other age categories as well. We will

conduct a study in the future to measure the effectiveness of each factor on different age categories.

7.4.3 Generalizability of older adults' initial engagement in different application domains

The behavioral and engagement factors were generated in the use of gesture based interactive technologies in public settings and mobile technologies in a family setting. Future research would further need to address the possible differences in user perceptions and design practices between technologies of various types and application domains. The findings presented in this dissertation did not distinguish results referring to different types of technologies. One of the application areas of interest for future research is a smart home and smart services for older adults. Due to the pandemic situation, older people spend more time at home. The role of technology is becoming more and more important to keep older adults safe in their living spaces and to give them a sense of psychological stability and enjoyment without being engulfed by depression. Therefore, a smart environment in which various smart technologies can be embedded according to the needs of older adults is a potentially interesting research field. We can establish the design principles for the smart environment that older adults can engage in by taking into account the behavioral and engagement factors discussed earlier in this dissertation. We can measure which factors directly affect older adults and whether older adults increase their level of engagement with technology. For an emotionally pleasurable smart space, we can further study whether the factors discussed in the present study induce positive changes in the behavioral patterns of older adults, the use of technology, and cognitive aspects. We identified various factors in Chapters 5 and 6. A researcher of HCI can take each factor that can be developed as a research topic. They can create a research hypothesis and validate their research hypothesis; for example, desirability will influence older adults' initial engagement greater than usability (Section 6.7.1). Designers working in the

field of HCI can also take each factor as a design principle or design goal for designing engaging technology for older adults. For example, designers might want to consider a tangible interaction to connect generations, such as the role of grandkids (Section 6.7.6).

7.5 Conclusion

Over the past few decades, research into technologies used by older adults began as largely techno-centric; the focus then shifted to government engagement in delivering technological services to older adults and, more recently, to the concept of human engagement and participation in the use of interactive technologies [234]. Due to the COVID-19 pandemic, older adults may be required to use technology to receive care that is related to health and survival, or communicate with a loved one in a remote setting. However, many studies still consider only on the provision of innovative systems and not on how these systems will be initially perceived and engaged by older adults. The digital divide and the increase in inequalities throughout the development of interactive technologies have isolated communities and parts of societies from using innovative technologies. The phenomenon of technology related inequalities will continue unless studies centered on seniors focus on older adults' engagement and adoption. Researchers and designers currently find it difficult to get an in-depth and comprehensive understanding of older adults' attitudes and perceptions towards new interactive technologies.

The overarching goal of the study of aging and technology is to improve the overall quality of life and provide an independent life for older adults. Providing fun or pleasurable, engaging, and hedonic experience to older adults is easily overlooked in technology. The initial engagement values discussed in this study should be considered in providing older adults with a positive experience with technology. For them, technology can be used casually and on a one-off basis to simplify leisure time and have fun with society members to which other older adults belong. Technology does

not need to infiltrate into older adults' lives, and older adults do not have to adopt the technology.

Whether it is for older adults' own needs or not, they still live as members of a social system in which they are exposed to access new technologies. The findings highlighted in this study are not generalized as rules for engagement for older adults. However, in a context in which they are sufficiently considered, older adults can reduce their negative views on technology, arouse the desire to try it for the first time, and increase self-efficacy, resulting in a desire to experience it on their own. This is why self-efficacy in older adults is important in the current COVID-19 pandemic situation, especially in environments where family or acquaintances' help is not well provided. Through gradual experience, people can better prepare for future similar situations by reducing avoidance of the use of technology and increasing familiarity.

Without the exploration of older adults' perspectives in terms of their experiences as affected by using technologies, technology cannot succeed as positive and will be unable to provide positive and engaging experiences to older adults. From a long-term period of study, this dissertation enables research participants to be engaged with technology by providing the opportunity for them to share their needs and opinions regarding the given technology and construct their own perceptions toward new technology. We propose a discussion of the initial engagement of older adults which leads them to decide whether to use technology when they engage with it for the first time. This will enable us to design for the complex phenomenon of aging with technology to enhance older adults' long-term engagement. Through this discussion, we can find, share, and create ideas about the properties of interactive systems that attract and motivate older adults towards technology.

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