Enabling IoT Residential Security Stewardship for the Aging Population

Lorenzo De Carli
Worcester Polytechnic Institute
Worcester, MA 01609, USA
ldecarli@wpi.edu

Indrakshi Ray
Colorado State University
Fort Collins, CO 80523, USA
indrakshi.ray@colostate.edu

Erin Solovey
Worcester Polytechnic Institute
Worcester, MA 01609, USA
esolovey@wpi.edu

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Abstract
Smart home devices (IoT devices, or IoTs) can monitor the health, safety, and security of aging adults, and automate many household tasks, enabling independence far into old age. However, IoT devices have many inherent vulnerabilities, which make them a popular target for cyberattacks. The heterogeneity of IoT devices and their interactions may make them susceptible to new types of attacks, and also make usability difficult for the aging population. Furthermore, the aging population may be particularly vulnerable and diffident to new technologies. Existing network management interfaces are designed for domain experts, and are impracticable for non-technical users. In our work, we are exploring the design of (i) interfaces and guidelines to enable senior users to manage the security posture of IoT devices, and (ii) AI systems that identify such issues and collaborate with the user to resolve them.

Author Keywords
Internet of things; IOT; network security; aging.

CCS Concepts
•Human-centered computing → Human computer interaction (HCI); •Security and privacy → Network security;

Introduction

One of the great promises of smart inter-connected home devices is safe and independent living for the aging population. This promise is, however, hampered by the poor state of IoT device security: these devices tend to be affected by easy-to-exploit security vulnerabilities which make them popular targets for cyberattacks. Highly publicized examples abound (e.g., [7, 2]).

Designing secure devices is inherently difficult due to the wide variety of unforeseen contexts where they may be installed. Also, many vendors tend to have poor security practices, shipping products with vulnerabilities that are easy to discover and exploit. IoT devices, catering to a wide variety of functions, are heterogeneous; this heterogeneity and interaction of devices make them harder to use and also may result in emergent vulnerabilities. This state of things clashes with the vision of a world where older adults depend on them for safe and healthy living.

Our work aims at understanding and overcoming the gap between cybersecurity skills of an aging population and the skills needed to maintain the current generation of IoT devices securely. In order to close this gap, we are working to: (i) build a detailed model of attitudes towards and understanding of cybersecurity in the aging population; and (ii) design new algorithmic tools to assist this demographic in identifying and resolving security issues arising within home IoT networks.

Background

Older Users, IoT, and Cybersecurity

There exists a rich literature on using IoT devices to enable autonomous living for seniors (e.g., [15, 12, 14]), and we expect that IoT devices will perform an important role in assisted living as the population continues to age. These works propose valuable approaches to enable use of IoTs as assistive devices, but they typically do not discuss security implications. Other works discuss seniors' attitudes towards security/privacy issues and cybersecurity tools [1, 6, 8]. They tend to focus either on high-level problems (e.g., the perception of risk related to the use of internet-connected devices), or traditional computing devices (e.g., home firewall configuration). Overall, there has been limited analysis of IoT-specific usable security for older adults.

Securing residential networks

There is a vast literature on detecting and resolving network security breaches, dating back more than 20 years (e.g., [10]). However, much of this literature focuses on enterprise security and/or traditional computing devices such as PCs and laptops. Furthermore, it generally assumes the availability of a human expert (network administrator) to understand and act upon the output of security tools. IoT devices come in various forms and flavors, use different protocols, and interact in subtle ways. This suggests that securing IoT devices requires not only new modes of user interactions, but novel security systems and algorithms.

Understanding the Context

Recent work by Desjardins et al. [3] suggests that most domestic IoT research assumes a detached single family North American home with two parents and children. Although this work does not focus on network security, it highlights the importance of broadening assumptions beyond stereotypical homes. This is particularly important when focusing on an understudied population such as aging users.

Understanding User Motivation and Knowledge

Prior work on user perceptions of smart home IoT privacy [16] suggests that users highly value the convenience of IoT devices, over both privacy and security. Other work [4] provides evidence that people have limited or incorrect understanding about IoT security, and often do not consider it before purchasing. Further, many individuals view security as an “innate, uncontrollable property” and lack knowledge of risks and mitigation strategies, and found it overly burdensome. Grinter et al. [5] showed that home networking setup and maintenance often was nontrivial, even in households with highly technical members. A study in the UK [9] found that individuals tend go to friends, family and coworkers with some technical knowledge for help in keeping their network secure. Taken together, these findings demonstrate an overall cultural problem—lack of perception of security issues as a serious threat. They also demonstrate a gap between the knowledge of average users and the knowledge necessary to properly secure consumer IoT devices.

Enabling IoT Network Stewardship

Our work focuses on the concept of IoT security stewardship: the idea that a residential network of vulnerable IoT devices should be able to gain understanding of basic security issues arising within the network itself, and deploy countermeasures at the network level.

Oftentimes, attackers controlling devices within a network result in anomalous device-generated network traffic. In preliminary work, we designed and tuned classification algorithms for traffic analysis that can (i) fingerprint devices, (ii) fingerprint the actions a user is performing on a device, and (iii) distinguish whether a device is being remotely controlled by the legitimate owner or a hostile user (based on patterns of actions). For example, in preliminary characterization of a Netgear Arlo Q security camera, our algorithm was able to map network traffic to the action being performed (stream video, toggle LED status/speaker/night vision/motion sensitivity, rotate image) with 99.7% accuracy. Likewise, given two different user action profiles (the legitimate owner, and a privacy-invading attacker), our algorithm was able to distinguish them with 96% accuracy.

In a residential network with non-technical users, however, information about traffic and action patterns is of little use as the users may lack the background to interpret this information and put it in context. Our goal is to determine guidelines for the design of network security systems that do not only individuate attacks, but interact and cooperate with such users to resolve them. These interactions should not assume the user has security expertise. In particular, we focus on older users, due to the potentially transformational role that smart devices can have on their lives.

Toward Design Principles for Aging Users

Designing for older users entails numerous domain-specific problems, from visual interface design to the nature of interactions themselves. Elderly populations are often vulnerable; we must make sure that such interactions do not cause alarm. At the same time, provided information must be specific enough to ensure that the user feels in control of the situation. Furthermore, if users come to depend on IoT devices for autonomous living, it is important for a security system to avoid disrupting the functioning of such devices.

The end-goal of our research is to determine design principles for residential network security systems that are usable by—and useful to—senior users. Such systems will consist of algorithms to detect and remediate breaches, and interfaces towards the residential user. Through critical analysis of this domain, as well of the related work, we identified four conceptual areas of focus: *autonomy*, *resilience*, *control*, and *delegation*.

Even expert users may find confronting security issues (e.g. an attacker commandeering a webcam) stressful and technically complex. Furthermore, the current and oncoming generations of seniors are not digital natives (i.e. were not exposed to ubiquitous computing devices and the internet during their formative years), and they may perceive smart devices as difficult or extraneous. It is therefore reasonable to design systems that operate *autonomously* as far as possible. For example, such a system may deploy simple countermeasures automatically, or choose to ignore certain low-risk vulnerabilities.

Further, the systems should be *resilient*, i.e. able to recover from unsophisticated attacks and continue to operate—possibly with reduced functionality. The goal here is to reduce user involvement to the minimum necessary, to avoid creating undue burden. System design must also pay attention to reducing *false positives*—alerts that generate stress to the user but are issued in error.

In order to avoid distrust or alienation towards the system, it is also important to ensure that the user retains *control* of it. The tension between automation and operator control is a classic one in system interface design [11]. Here, we propose to resolve it by letting automated algorithms identify low-level network security problems, while presenting high-level summaries and requests for actions to the user. For example, the user may be informed that unusual activity was detected, and rebooting a wireless router is recommended. Determining the appropriate representation and content of such communications is an open problem, as they must be informative while avoiding generating stress. Indeed, many of the novel problems in this area lie at the intersection of network security, human-AI interaction, and HCI for aging. While threat detection algorithms have been extensively studied, their interaction with non-technical senior users have not.

Finally, we point out that *delegating* control of the system to a service provider—or even to a skilled family member—may also be helpful. There is a well-developed literature on the technical aspects of delegating security management of IoT networks (e.g., [13]). However, not all users may wish to perform such delegation, and not all decisions may be delegated to third parties. Therefore, it is important to illustrate to an elderly user the consequences of delegation and allow an interface that allows delegating some permissions while retaining control over others.

Conclusion

IoT devices have the potential to be immensely useful as assistive devices as the population continue to age. Before seniors can depend on such devices for independent living, significant cybersecurity issues must be resolved. In order to improve the security of IoTs, we investigate new usable security systems that can discover issues and interface with older users in a helpful and informative manner. Design of such systems is based on the principles of *autonomy*, *resilience*, *control*, and *delegation*.

Author Background

Lorenzo De Carli is an Assistant Professor of Computer Science at Worcester Polytechnic Institute. His research interests focus on the security of the internet-of-things, the web, and clouds. He has expertise in network traffic analysis, malware analysis, and high-performance networking.

Indrakshi Ray is a Professor of Computer Science at Colorado State University. Dr. Ray's research interests include security and privacy, database systems, software engineering. Her current research focuses on IoT security, healthcare security, and security of cyber physical systems.

Erin Solovey is an Assistant Professor of Computer Science at Worcester Polytechnic Institute. Her research expertise is in human-computer interaction, with a focus on accessibility and emerging interaction techniques.

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Haptics for Older Adults

Caitlyn Seim
Stanford University
Stanford, CA, USA
seim@stanford.edu

Maarten Lansberg
Stanford University
Stanford, CA, USA
seim@stanford.edu

Allison Okamura
Stanford University
Stanford, CA, USA
seim@stanford.edu

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Abstract
Older adults are a growing population with numerous needs which may be addressed using emerging technologies. However this population is underserved in that the development of new technologies seldom involve the older shareholders. It is well established that for populations such as individuals with disabilities or specialized practitioners, co-design and user-centered design practices with the target population are what truly uncover useful technology. Here we present an excerpt from work on haptics for older adults.

Author Keywords
Haptics; Wearable Computing; Aging; Stimulation; Survey; Vibrotactile; User Study

CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI);** *Haptic devices;* User studies; Please use the 2012 Classifiers and see this link to embed them in the text: https://dl.acm.org/ccs/ccs_flat.cfm

Introduction
This position paper aims to call attention to the need for inclusion of participants who are in an older demographic – in order to find new problems, real solutions and accurate understanding of this group's needs. Here we present an

excerpt from an empirical study which highlights this process and a key reason for design with this group: that these users have different bodies than younger users.

The user-centered design process is key to development of human-facing technologies. Take for example, technology design for differently-abled populations. Including these users in the design process is considered essential to making new devices for them [25]. "User opinion is key to adoption of assistive devices," said Manns et al. in their 2019 paper [29]; while Norman calls attention to users' emotional response to technologies [34].

While older users may overlap with assistive device users, an average older population also has unique features. A brainstorming or observation session with individuals from this group may provide a wealth of new technology ideas. On the other hand, design with the population can expose challenges in the design of technology. This group may use technology differently: preferences may be for buttons over touch screens for example. These users may also have different knowledge: coming from a place with less experience, some may not have the knowledge to transfer gestures or interaction skills to use in *your* new technology. With aging comes body changes to both the sensory, cognitive and motor systems. These users have different sensing capabilities, dexterity and memory. Furthermore, these users have different daily lives, and have seen different sociocultural and sociotechnical events. Their beliefs about what technology can do or should do may be different. These differences present a design challenge, but also a wealth of physical and mental needs which can be serviced by technology.

Haptics for Older Adults
Background and Motivation

Vibrotactile stimulation is especially relevant to applications involving seniors and those with brain injuries. Devices that provide stimulation should be designed with input from the target population. At various stimulation settings some users may perceive input as pain or find the signals intolerable. Users may also have preferences for the stimuli and sensations that they want to encounter. Pleasantness of and affective response to vibrotactile signals are being studied for applications such as wearables for social touch [12], but studies often focus on younger users. Somatosensation changes with age and has been studied in older adults, but these studies do not focus on affective response or user preference.

Vibrotactile stimulation is being used for recovery of movement and sensation in stroke survivors [10, 11, 37] as well as other populations [3, 30]. The method is to apply actuators to the disabled limb and perform stimulation anywhere from 30 minutes to three hours per day. Similarly, vibrotactile stimulation is being applied to enhance motor function during task performance [38], to improve cutaneous sensation [26], and to restore sensation with age [13, 15]. These applications also require extended durations of stimulation. Furthermore, applications such as VR use stimulation to render feedback [27]. Other applications of vibrotactile stimulation include to relieve teething [14], injection pain [39, 33], and chronic pain [40].

Other work has outlined factors associated with pleasantness [12, 35] and affective response [49, 18, 2] to vibrotactile signals in younger participants. We use the same standard metrics used in some of this work to collect the response of our participants. Our first aim is to examine whether any signals are considered noxious or intolerable by our participants. We also aim to assess user preferences in stimulation – to inform the development of more user-conscious systems. We query adults over 40, with and without history of stroke, to reveal end users' beliefs and somatosensation.

Somatosensation in Older Adults

Tactile perception and sensation change with age. Over age 20, individuals gradually lose sensitivity to touch, including pressure and vibratory stimulus [8, 13, 22, 23, 42, 44, 45, 46, 17]. These reductions in perceptive ability have been attributed to both changes in skin and changes in the central nervous system that occur with age. Sensory receptors within the skin change in number and structure as a person ages [4, 41, 42, 32, 43], including the Meissner and Pacinian corpuscles which are most responsive to vibration [19, 36, 48]. Changes in the sensorimotor brain map areas [21], and conditions such as neuralgia or diabetes are also found in older adults to relate to tactile perception [28, 31, 47].

Stroke and Perception

Nearly three-quarters of all strokes occur in people over the age of 65 and the risk of having a stroke more than doubles each decade after the age of 55. Stroke occurs when part of the brain cannot get enough oxygen and leaving a damaged region of the brain often in the sensorimotor area – leading to chronic physical disability [50]. Over 15 million people have a stroke each year, making it one of the leading causes of disability in the United States and worldwide [6, 16, 1]. Stroke survivors may use stimulation for rehabilitation or may encounter it in other contexts, and these individuals also have abnormal sensory function at a rate of 50-80% due to their brain injury [9, 24]. Survivors may have lower cutaneous tactile perception, making them less sensitive to touch and pressure sensations [9]. Some individuals with history of stroke also experience *increased* sensitivity to tactile stimulation such as heat, cold, and pin prick [5, 20, 7] and may experience these non-noxious simulations as pain (allodynia).

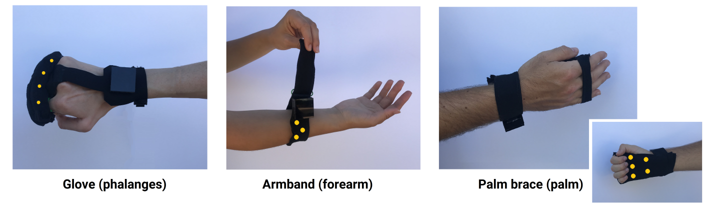

Figure 1: Three stimulation devices used in the study. Each device contains 5 actuators of each type. Locations of the actuators are indicated by yellow dots; not all actuators are visible.

Apparatus

Three wearable devices were designed to apply stimuli for this experiment. Each device stimulates a different area of the upper limb. Actuator sites are depicted in Figure 1. Users try each device during the study to obtain an impression of the signals at different locations: the phalanges, the palm, and the forearm.

Stimuli

We aimed to test user impressions of stimuli at a various settings. We designed 12 vibrotactile signals to provoke a variety of responses from the somatosensory system which may be of use various applications of vibrotactile stimulation. Three dimensions are used to create the 12 signals, including actuator settings (frequency and amplitude), pattern (spatial), activation duration (temporal).

Participants

Two cohorts of participants were recruited through community flyers. The study contained twelve participants: stroke survivors (mean age = 53.5 years) and participants of similar age (mean age = 54.2 years) without history of stroke.

Survey
Participants take a brief survey after every signal. The 12 signals are presented in a random order for each device. Our survey contained three parts. The first part contains likert scales for the user to rate valence and arousal in response to the most recent stimulus. The next part of the survey allows participants to select terms to describe how their hand/arm felt in response to the stimulus. The options are “pain,” “tickle,” “sensitized,” “tingling/pins and needles,” and “numb,” “I can’t feel it” and “annoying.” This list may prime participants, but is a necessary structure. Asking participants to type their feedback is not an accessible solution for either user group. Lastly, participants are asked to give verbal feedback.

Results

Valence and Arousal
Ratings of 1 to 9 were adjusted to -4 to 4 for Figure 2. Most responses were close to the origin in the high-arousal, positive-valence quadrant, which is associated with terms such as “happy” and “excited.” Users with history of stroke showed similar ratings of arousal as users in the age-matched control group in response to all stimuli. A paired two-tailed t-test suggests a small difference between the groups’ arousal ratings for each stimuli ($t(11)=2.75$, $p = 0.02$).

Figure 2 shows that while there is only a small difference in arousal ratings between groups, there is a large difference in valence ratings between groups (paired two-tailed t-test $t(11)=-8.32$, $p<0.00001$). Stroke survivors gave consistently lower ratings of valence.

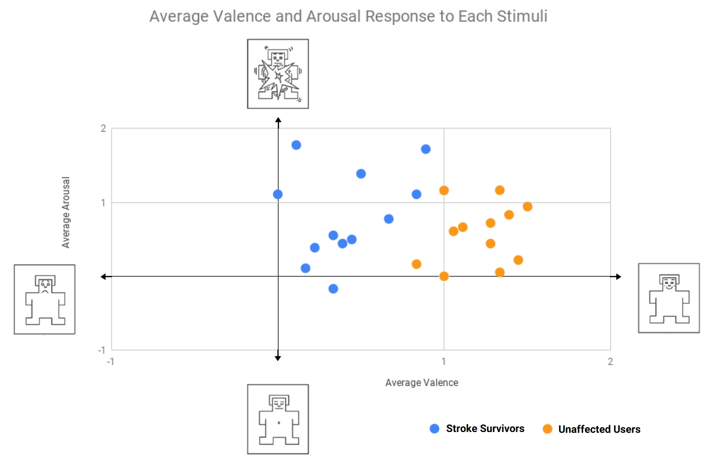

Figure 2: Valence and arousal graph for both user groups. Ratings of 1 to 9 were adjusted to -4 to 4. Each dot represents average ratings for one of the twelve stimuli. Icons are adapted from the Self Assessment Manikin (SAM).

Reported Sensations
Our first aim was to evaluate if any of the vibrotactile signals were perceived as painful or unacceptable by our participants. None of the signals were reported as painful. Reported sensations by stimulus setting and user group are shown in Figure 3.

Conclusion

Design with older adults is key to discover new areas for technology development as well as for creating usable technologies. Older adults may experience stimuli differently, have different levels of technology experience, and have different beliefs and lifestyles.

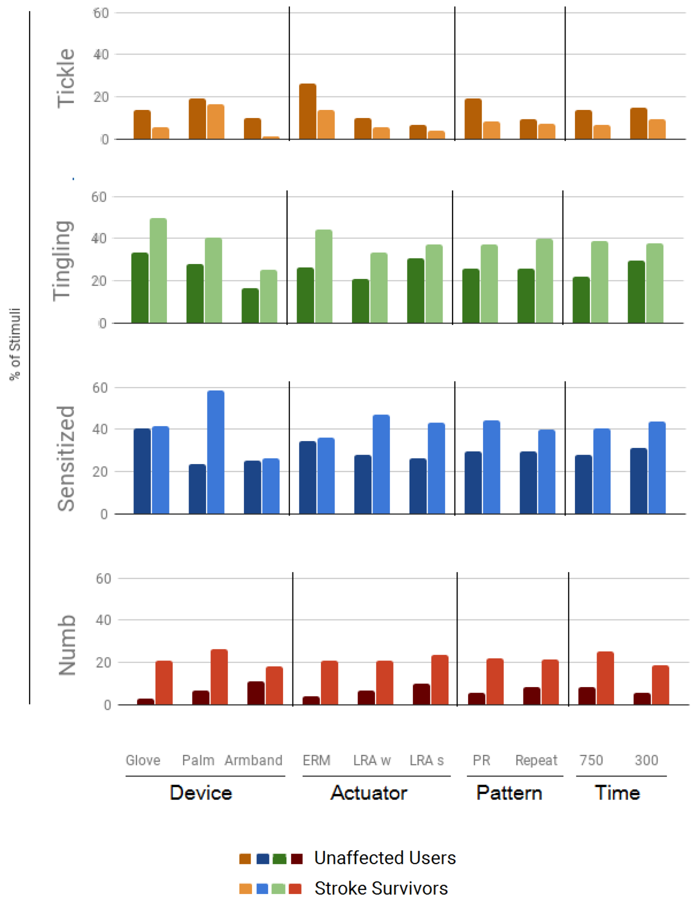

Figure 3: Percent of stimuli in each category that were labeled as giving the hand/arm a tickled, tingling, sensitized or numb sensation.

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Exploring the Concept of Relatedness to understand and design for older people's Needs in Telecare

Isabel Schwaninger
HCI Group, TU Wien
Vienna, Austria
isabel.schwaninger@tuwien.ac.at

Geraldine Fitzpatrick
HCI Group, TU Wien
Vienna, Austria
geraldine.fitzpatrick@tuwien.ac.at

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Abstract
Technology for Active and Assistive Living (AAL), also called telecare, is being developed to solve problems associated with the ageing population. In a long-term study using telecare technologies with older adults, we identified various forms of relatedness running through older people's account. Interpersonal relatedness has been argued crucial in healthcare contexts and may be a predictor of mental health and wellbeing, however, drawing on our own empirical work with older people, we may want to expand the concept of relatedness and explore how it can be a useful concept even beyond the interpersonal. In the workshop, we aim to present previous work on relatedness in Psychology and HCI, along with our own findings. Finally, we aim to discuss how relatedness may be a useful concept to holistically understand and design for older people's feeling of support in telecare.

Author Keywords
Relatedness; Older People; Telecare

CCS Concepts
•**Human-centered computing** → **HCI theory, concepts and models;** *Empirical studies in HCI;*

Introduction

The need for relatedness concerns a feeling of belonging and of being significant or mattering in the eyes of others, of feeling connected and supported by others [14]. Relatedness has been argued as crucial in telecare, and social connectedness can be a predictor of mental health and wellbeing [5]. Mental health among older adults is worth particular attention, as isolation and reduced community involvement is associated with experience of growing older in many societies of the Global North [4]. In previous empirical work with older people using a telecare system (to be discussed later in this paper), we identified relatedness beyond the interpersonal, which may be useful to unpack to holistically understand and design for older people's needs.

In the next section, we introduce relatedness from within Psychology, i.e. Self-Determination Theory (SDT) and across HCI. We then present our own work, where we identified various forms of relatedness around older people using a telecare system over 18 months. We conclude with a discussion, where we also outline our contribution to the workshop. We aim to offer relatedness as a concept for designing technology and technology ecosystems to design for older people's needs and feeling of support.

Related Work

Relatedness in Psychology / SDT

According to Ryan and Deci [14], the need for relatedness concerns a feeling of belonging and of being significant or mattering in the eyes of others, of feeling connected and supported by others. They argue that people's behavior is situated in a social context not only for people to survive and because they require others' concrete care or help, but "[t]here is a basic need to feel responded to, respected, and important to others, and, conversely, to avoid rejection, insignificance, and disconnectedness" [14, p. 96]. The need to feel connected may also explain why people behave in ways that ensure involvement and other people's acceptance, where this need will only be fulfilled when people feel personally acknowledged and affirmed by their actions, and that they are accepted for who they are [14].

Cultural, political and economic systems can also play a role in whether people can experience satisfaction of their basic needs, such as relatedness. According to Ryan and Deci [13], cultural and economic systems set affordances, constraints, and boundaries, which may affect people's pursuit and attainment of need satisfactions. For example, capitalism may promote extrinsic aspirations or life goals that focus on accumulation, personal gains, and recognition, being in opposition to goals for community [13].

Relatedess in HCI

In HCI, there has been an ongoing discussion on how technology could mediate a sense of interpersonal relatedness [3]. For example, previous work has shown how it is crucial for older people's intentions of using technology [6]. In this subsection, we discuss previous work around *belonging* and *connectedness* as key factors of relatedness.

In HCI, belonging has been explored with regards to belonging to computer science, such as in relation to gender [11] or socioeconomic status [10]. Recent research also suggests that culturally responsive computer science programs can facilitate a sense of belonging [2]. Further, there may be individual differences in the need to belong. In a previous study, people with higher need to belong showed greater attachment and trust towards a social robot than people with less need to belong, and they were more satisfied with their relationship with the robot [8].

Technology can mediate connectedness, and it may affect relationships between people. Jeong et al. [7], for example, proposed a robot for activity sharing among people who live alone, and they found increased social interactions in a field study when people used the robot in their homes. Relationships with technology have also been explored with social robots. For example, perceived social bonding and intimacy between a person and a robot was studied by manipulating a robot's affective and social expressions [9].

Forming Relationships in Practice

Method

In a large-scale project on Active and Assisted Living (AAL), over 80 people / households of age 65+ were equipped with technical infrastructure including several apps (including an event calendar and a neighborhood app) and safety watches, and some participants additionally received fall detection sensors which were installed in a room of their choice, while others were given a watch for counting steps and an app for collecting data on blood pressure. To support the uptake of telecare technologies, the project also set up a social infrastructure. The participants were offered monthly meet-ups, run by care facilitators, to exchange and to ask project-specific questions. In the 18-month long evaluation phase, we conducted 20 qualitative interviews with 15 older people, i.e. after 1 year and after 1 year and 5 months. We transcribed the audio recordings of the interviews and analysed them using Thematic Analysis [1]. We gathered insights into older people's long-term experiences in telecare, and our findings point to various different forms of relatedness.

Relatedness in our Project

Drawing on our qualitative data, we identified various forms of relatedness running through people's accounts. We found relatedness among the participants, and among the participants and their peers, institutions, places and technology. We started to explore how participants were in ongoing relationships with other people as carers themselves or as people who receive care. Living in a socio-political context, they also relate to institutions and associated values, for example, as they imbued values with institutions, which had a direct impact on how they understood the project agenda and in the way they trusted technology. We are also interested in people's relationships with themselves (e.g. in the way they approach and treat themselves [12]), as they had different ways of interpreting technology breakdowns (e.g. blaming other people or technology, vs. themselves). Feeling of support by technology per se was also an issue that was discussed by participants. Furthermore, with technology being more and more embedded into people's everyday living spaces, we may want to think of how people relate to these contexts (e.g. in their feeling of belonging). We argue that the complex way in which relatedness plays out in our socio-technical (eco-)system is worth particular attention to better understand and design to support people across different life phases, and as we get older.

Discussion & Contribution to the Workshop

Motivated from our own empirical work with older people, we started to explore the concept of relatedness both in Psychology / SDT and across HCI, as it may support us to create a model of understanding the complex interplay of older people's needs in telecare. In the workshop, we will present a literature overview on the concept of relatedness drawing on Psychology and HCI as a useful resource to understand and design for older people's needs in telecare. Along with the related work, we will present the findings of our empirical work with older people. As relatedness has been argued crucial in care, we aim to discuss in the workshop how social connectedness, feeling of belonging and support may play out between people, as well as between people and institutions, technology and places. We aim to offer relatedness as a concept to explore the ways in which people form meaningful relationships in telecare, and discuss implications for designing complex ecosystems around older people.

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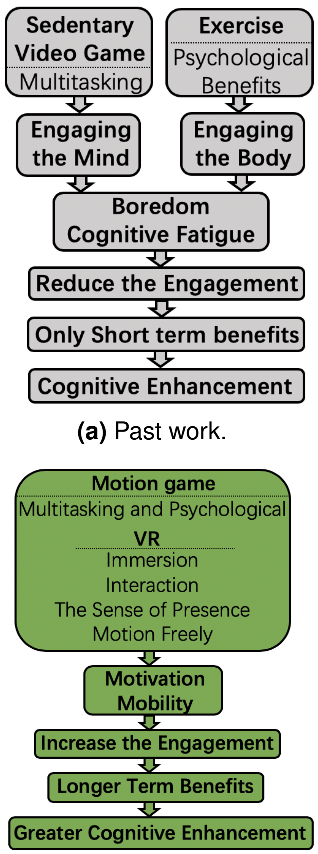
FeedingVR: A Cognitive Training Platform for Older Adults



(a) Past work.

(b) Present work.

Figure 1: Studies on cognitive enhancement.

Xiaoxuan Li
Center for Human-Engaged Computing
Kochi University of Technology
Kochi, Japan
eloisewhirl@gmail.com

Dongdong Weng
School of Optoelectronics
Beijing Institute of Technology
Beijing, China
crgj@bit.edu.cn

Kavous Salehzadeh Niksirat
Center for Human-Engaged Computing
Kochi University of Technology
Kochi, Japan
kavous.salehzadeh@gmail.com

Xiangshi Ren (Contact author)
Center for Human-Engaged Computing
Kochi University of Technology
Kochi, Japan
xsren@acm.org

Shanshan Chen
School of Optoelectronics
Beijing Institute of Technology
Beijing, China
shanchen0923@gmail.com

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Abstract

Aging is often accompanied by cognitive decline. Cognitive diseases such as Alzheimer's lower the quality of elderly people's lives. Recent studies have shown that positive changes in the cognitive capacity of older adults can occur after long-term training with sedentary video games. However, little study has been done on VR motion games which can be more directly beneficial for overall well-being. To this end, we designed a Multitasking VR motion video game for older adult players which aims to (i) train and enhance the cognitive ability of older adults, and (ii) increase physical activity of older adults in terms of both limb movement and walking distance. This paper presents our preliminary results after assessing the cognitive ability of our participants through a four-week study. Our results show the positive effects of our Motion VR game in terms of improvement in cognitive abilities including working memory and attention.

Author Keywords

Motion video games; Cognitive enhancement; Older adults; Multitasking; Virtual reality.

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);** *User studies;*

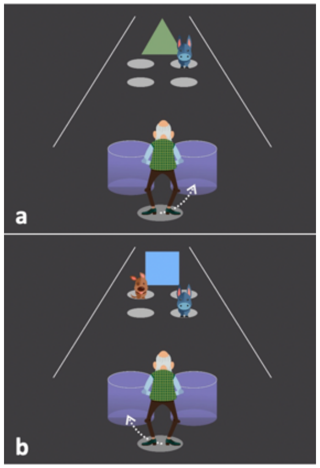

Figure 2: FeedingVR. Integrating multitasking and motion. (a) When the green triangle appears, the player has to step forward to the right. (b) When it is not a green triangle, the player should step forward towards the left.

Introduction

Populations are ever increasingly aging all over the world. Older adults who are physically and/or cognitively impaired are in urgent need of accessible and affordable assistance. The cognitive abilities of older people decline with age and diseases such as Alzheimer's are becoming more prevalent. Suffering and loss due to such diseases extend out from suffering older adults to their families and friends, also increasing the burden on social support systems, institutions and pensions. Due to population aging, national health expenditures of the United States as a percentage of GDP will climb from 15% in 2016 to 19.4% (approximately $6 trillion) by 2027 [18]. Given the many impacts of declining health in the elderly, development of novel health interventions that can prevent, stall or even reverse such decline are in great demand. Thanks to advanced neuroimaging techniques, researchers have shown that the brains of older adults can change and develop new neural pathways in response to various interventions.

A number of recent studies have shown that long-term video game training may lead to positive changes in the cognitive capacity of the older adults [12, 14]. However, most of these studies used commercial off-the-shelf video games that were not exclusively designed for cognitive training or for older adult players (e.g., Super Mario [11]). A recent study [2] investigated the impact of a custom-made video game showing that if a video game can be tailored to a specific cognitive deficit in older adults, it can lead to significant, transferable cognitive enhancement. For example, cognitive training based in 'multitasking' improves general cognitive ability [2]. On the other hand, most video game research for older adults has focused on sedentary video games that can be detrimental to the general health and well-being of older adults by encouraging an inactive lifestyle [8]. Some earlier results showed that a combination of cognitive training and physical training can magnify the effectiveness of interventions [15], and that regular engagement in moderate-intensity physical and cognitive activities can delay functional decline and the onset of chronic disease in older adults [1]. While motion video games are promising, traditional motion game platforms such as Xbox's Kinect, PlayStation's Move, and Nintendo Switch's Ring Fit are limited in terms of their ability to fully detect and integrate the players' physical movements and gestures into the game environment. Furthermore, these games often lack the "pleasant game" environment [3] leaving older adults feeling bored, incapable, discouraged and/or fatigued. This situation decreases the motivation to participate causing many users to abandon training after a short period of time. This obviously reduces the impact, sustainability and value of well-intentioned training programs (Figure 1a).

Compared to existing video games, Virtual Reality (VR) video games deliver better game experiences by allowing users to interact physically and emotionally within a Virtual Engineering environment that is similar to the real world thus creating a strong "sense of presence" through multisensory stimulation [19]. As a consequence, first, the combination of physical, mental and emotional interaction encourages active participation and involvement of the user, and this immersive interaction based on VR can boost player motivation to keep playing the game for longer periods of time and thereby receive greater benefit. Second, advanced VR platforms can perform comprehensive analysis of the player's whole-body motion [6] and provide rich input from the player. Third, a VR environment induces multisensory feedback that can contribute toward greater memory consolidation and retention [19], this might create an efficient platform for cognitive training, where older adult players can fully engage in the cognitive tasks in the game

Figure 3: Screenshots of game: an older adults player who was wearing sensors played our game. The player moved his arms according to the position of the corresponding hole.

which might, in turn, stimulate mechanisms of neuroplasticity. Fourth, given the potential mental and cognitive health benefits of physical activity for older adults, VR can ensure players walk and move their limbs more freely while carrying out cognitive training and thereby receive even greater benefits.

In the light of these observations, we leveraged VR game design to develop a novel motion video game for older adults (Figure 1b). We conducted a preliminary assessment of the participants' cognitive abilities and game experience in a four-week study.

FeedingVR

We designed a VR motion video game called FeedingVR (Figure 2), which aims at (i) training and enhancing the cognitive ability and (ii) increasing the physical activeness of older adults in terms of both limb movement and walking distance. FeedingVR is a low-entry video game that helps older adults to quickly adapt to VR environments based on their respective physical and cognitive characteristics.

The main design element of FeedingVR for cognitive training is multitasking. Multitasking is the ability to perform multiple tasks at the same time and it is an important function of the brain's executive system [9]. However, multitasking gets weaker with age [21]. Multitasking training can be induced when a person performs two tasks concurrently, switching form one task to another, or performing two or more tasks in rapid succession. Thus, to support multitasking, we follow an earlier game design that has exploited multitasking by Anguera et al. [2] and Niksirat et al. [17]. FeedingVR has two tasks: a shape task and an animal task. For the shape task, we integrated a billboard on the left which randomly shows different shapes (e.g., square, triangle) in different colors (e.g., blue, green). If and only if the sign is a green triangle, the player has to step forward towards the right side to enter into a purple area (Figure 2a), but when it is not a green triangle, the player should step forward towards the purple area on the left side (Figure 2b). Animals appear in front of the player if the player successfully follows the instruction implied in the shape task.

FeedingVR uses a farm theme and employs simple, enjoyable, stimulus-response gameplay. It is based on the well-known Whac-A-Mole gameplay, which requires the players to hit the animals when they emerge from their holes. Similarly, in the FeedingVR animal task, when the players see the animals emerge out of their respective holes, they are asked to move the corresponding body parts to feed the animals. In order to help participants learn how to move their bodies, we map their body parts to the position of the corresponding hole (e.g., the upper left hole mapped to the left arm and the lower right hole mapped to the right leg). In order to enhance the sense of immersion in the game, the animal gradually moves toward the player after appearing in the hole (Figure 3). By switching attention between the billboard and the animals, we induced the multitasking paradigm [13] where the number of shapes and colors on the billboard can be tuned as a challenge mechanism.

To promote mastery and a sense of competence, consecutive successful actions are counted and shown to the players (e.g., "Three Combos! ") in real-time. Suitable background music is used in the game design.

Challenge Levels

Five difficulty levels have been designed. Five parameters were used to set difficulty levels. These are, action time (i.e., the maximum time to feed an animal), time interval (i.e., time interval between trials), the number of green triangles (i.e., how many times the green triangle appears in

Figure 4: The player moved his arms and left leg according to the position of the corresponding hole.

Figure 5: The VR platform.

each game), and maximum targets (i.e., number of animals appearing simultaneously), and shape number (i.e., number of types of shape).

Experiment

In order to evaluate the effectiveness of FeedingVR, we conducted a mixed design experiment studying the effect of intervention (between-subjects) and time (within-subjects). We compared the VR game group versus a control group, and we measured the cognitive skills of the participants before and after the intervention. We also measured the participants' balance ability as our secondary research interest.

Participants

Ten participants (five males, five females) aged 65-75 (M=69.5, SD=3.8) were recruited. Five participants (two males) were assigned to the VR game group, and the remaining five participants (three males) were assigned to the control group. None of the participants suffered from any physical or mental impairment. Participants were checked using different screening criteria including the Mini-Mental state examination, the Geriatric Depression Scale, and the Self-rating Depression Scale. All participants met the minimum requirements. Each participant was paid $10 per hour.

Apparatus

FeedingVR was built using Unreal 4.0 by Blueprint and C. With the help of HTC-Vive Pro hardware devices, including Vive Headset, Vive Controller, Base Station and Vive-Tracker. The VR game ran on a 3.40 GHz Intel Core i7-4770 CPU PC with Windows 10. A total of four sensors (Figures 3, 4) were used: participants hold one controller in each hand and one tracker was tied to each of their ankles. All physical data was collected for future research projects including step count, angle of moving arms and legs, the number of moving arms and legs.

Task and Procedure

Each participant signed a letter of consent and was informed about the goal of the study. All participants received exactly the same instruction on how "long-term training with video games will help you to improve your cognitive capabilities". Demographic information including health background and gaming expertise was gathered. Participants were first taught the game rules. Later, they were asked to play the game in the practice mode. After the practice mode, and before they started the real experiment, the game recommended a certain difficulty level according to each participant's performance in the practice mode. Participants were free to select the recommended difficulty level or choose another level, i.e., the difficulty level was decided by the participants themselves.

Participants played three times per week for four weeks. The gameplay was 45 minutes each time including three rounds of 15 minutes with 5 minutes rest between the rounds. Total playing time was nine hours. FeedingVR required players to walk in a $5 \times 5\ \mathrm{m}^2$ area (Figure 5). All participants attended different tests before starting the experiment (i.e., pre-test) and after four weeks of training (i.e., post-test).

Metrics

Overall performance and level of difficulty were logged. Cognitive assessment tools have been used as our primary research interest. Working memory, attention and reasoning were measured using Adaptive N-Back Task (n-back) [7], Attention Network Task (ANT) [10] and Raven's Standard Progressive Matrices (SPM) [16], respectively. As our secondary research interest, we used One-leg Standing Balance Test (OLST) [5] to measure the physical capabilities of the participants. Older adults are prone to fall, and the consequences of falling may be very serious. One-Leg

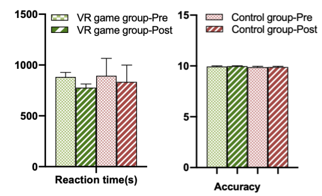

Figure 6: Means of reaction time and accuracy (95% Confidence Interval) for ANT.

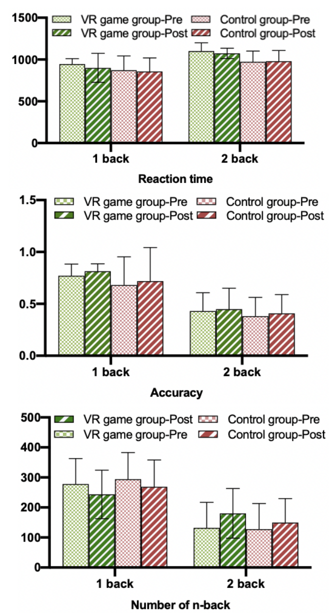

Figure 7: Means of reaction time, accuracy and number of n-back task (95% Confidence Interval) for Adaptive N-back.

Balance is highly related to age [4] and it is an important predictor of injurious falls in older people [20]. OLST included two conditions: eyes-open and eyes-closed. Last, we measured the game experiment. Affect was measured using the Positive and Negative Affect Schedule (PANAS) which was completed by the player of the VR game group before and after. PANAS was rated on a 5-point Likert-scale.

Results

The Wilcoxon Signed-Rank test was used to analyze the time effect (i.e., to compare the pre-test and post-test results). The Mann Whitney U test was used to analyze the intervention effect (i.e., to compare the two groups with regard to improvement).

Attention (ANT)
Figure 6 shows the results for the attention test. We found a significant improvement in the reaction time of the VR group (p=0.043) comparing the post-test (M=776.26, SD=37.35, p= 0.043) and the pre-test (M=881.75, SD=44.58).

Working memory (Adaptive N-Back Task)
Figure 7 shows the results of the n-back task. In the VR game group, there is a significant decrease in the number of trials in the 1-back task (p=0.041), where the participants did less 1-back trials in the post-test (M=243.60, SD=80.80) compared to the pre-test (M=278.25, SD=84.65). In other words, participants after training with the VR game could finish more 2-back trials (i.e., performing more memory demanding tasks). However, the increase in the number of 2-back trials was only marginally significant (p=0.066), improving in the post-test (M=180.40, SD=82.90), compared to the pre-test (M=132.00, SD=85.20).

Reasoning (SPM)
There was no significant difference on reasoning.

One-leg balance (OLST)
Figure 8 shows the results of the balance test. In the eyes-open condition, significant differences were found between the pre-test (M= 53254.20, SD=14587.60) and post-test (M= 87014.40, SD= 6676.00, p= 0.043) in the VR game group, and between the VR game group (M=87014.40, SD=6676.00) and control group (M=40685.20, SD=22741.40, p= 0.017).

Affect (PANAS)
Figure 9 illustrates PANAS subscales. Although no significant difference was found on affect, the players of the VR game experienced a higher positive affect after the game (M=3.12, SD=0.61) than before game (M=2.80, SD=1.05).

Discussion

In this late-breaking work, we present our video game design and the results of a preliminary study to investigate the effect of motion VR game training on the cognitive enhancement of older adults. Our findings indicate that motion VR game training produces positive effects on several cognitive functions including working memory and attention.

We found that the VR game group had quicker reaction in the attention test compared to the control group. These results suggest that VR game training has a positive effect on improving attention. This is consistent with previous studies for multitasking training using video games. This also meets our game design mechanism and research expectations. The multitasking paradigm originates from the cognitive resource theory of attention, which involves divided attention, while the FeedingVR game requires participants to occupy attention resources to perform multiple tasks at the same time. Attention is a basic cognitive process, where some form of attention is involved in virtually all other cognitive domains, including working memory. We also found that

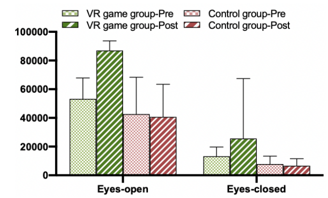

Figure 8: Means of balance time (95% Confidence Interval) for OLST.

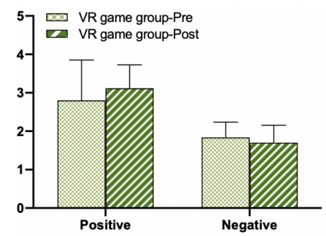

Figure 9: Means (95% Confidence Interval) for PANAS.

compared with the pre-test, the VR game group performed better in the post-test with regard to working memory, they can do more 2-back than 1-back. This also shows that our proposed intervention has potential for the improvement of training-acquired cognitive ability to transfer to other untrained cognitive aspects. Fluid intelligence is most sensitive to the effects of age in the process of cognitive aging, especially working memory and attention and the results also suggest the importance of our research.

We found that VR game training has a positive effect on the balance time on one-leg in older adults. This may be due to the physical movements performed in the FeedingVR game. But this result does not necessarily indicate that improvement in physical balance can be sustained in the long term.

The current study has its own limitations in terms of experimental design, sample size and study duration. In our future work, we will recruit more participants to conduct a randomized controlled trial over a longer training time. We will also add the sedentary VR game group to evaluate the impact of mobility on cognitive enhancement.

Conclusion

Cognitive aging has a detrimental impact on society. Studies have shown that custom-made video games are promising interventions that can enhance the cognitive health of the older adults through the exploitation of brain plasticity. Some studies have shown that the combination of cognitive training and physical training can magnify the effectiveness of interventions. In this work, we specifically used VR in the video game design to study how VR technology can be more beneficial by enhancing older players' engagement and mobility. Our findings show that our VR game that combine motion and multitasking has positive effects on cognitive skills. Future studies will include adding more body movements in VR game training in order to evaluate the effects of cognitive enhancement.

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Interaction Design Guidelines for Wearable Assistive Technologies for Older Adults

First Author
University of Author
Authortown, CA 94022, USA
author1@anotherco.edu

Second Author
VP, Authoring
Authorship Holdings, Ltd.
Awdur SA22 8PP, UK
author2@author.ac.uk

Third Author
Fourth Author
Lēkhaka Interaction Labs
Bengaluru 560 080, India
author3@anotherco.com
author4@hchi.anotherco.com

Fifth Author
YetAuthorCo, Inc.
Authortown, BC V6M 22P
Canada
author5@anotherco.com

Sixth Author
Université de Auteur-Sud
40222 Auteur France
author6@author.fr

Seventh Author
Department of Skrywer
University of Umbhali
Cape Town, South Africa
author7@umbhaliu.ac.za

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Abstract

Wearable assistive technologies (WATs) have the capability to improve the quality of life of older adults. However, to realise their full potential, WATs must be designed properly for reliability, usability, and suitability for everyday use. To date, existing design strategies are not sufficiently comprehensive to ensure that WATs will be usable by older adults. In this regard, we propose 22 generally applicable interaction design guidelines for WATs. These guidelines are consolidated from more than 150 design recommendations and refined through a participatory design workshop with older people. During the workshop, we will present a case study on the development of a WAT that enables older people to utilise Mixed Reality and Internet of Things technologies. We believe the proposed interaction design guidelines can serve as a resource to practitioners working to make WATs more accessible, and to researchers interested in the further development of interaction design guidelines for older adults.

Author Keywords

assistive technologies; mixed reality; internet of things; interaction design guidelines

CCS Concepts

•Human-centered computing → Human computer interaction (HCI); Interaction design; Accessibility;

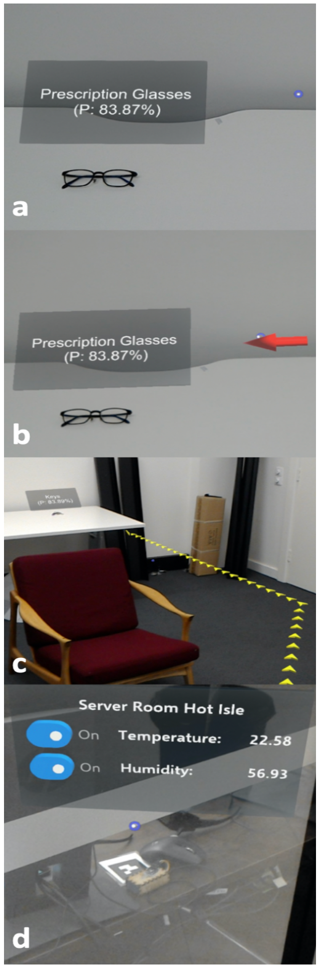

Figure 1: System overview:
a.) Recognised Object (RO),
b.) Directional arrow to RO,
c.) Navigational arrows to RO,
d.) Internet of Things (IoT) system controls

Introduction

The world's ageing population is associated with a growth in demand for health services and residential care costs. As this demographic continues to grow, discussions will need to focus on how older people can safely live at home longer while maintaining their self-independence. Not only that it is socially valuable, but it is also cost-effective to support their independent living [31]. This challenge can be met with Wearable Assistive Technologies (WATs) that not only meet the needs and expectations of older people, but also are reliable, effective, usable, and suitable for everyday use.

Ambient intelligence (AmI) is an environment embedded with Internet of Things (IoT) technologies that are interoperating, sensing, and computing-embedded devices [11]. AmI can support independent living of older people by supplementing their reduced cognitive and physical capabilities in a seamless, unobtrusive, and often invisible way. It can also provide high quality of health care, improve communication [24], and give rehabilitation for older people [17].

Recently, WATs can address a wide range of human needs, such as mental functions [4], personal mobility [3], sensory functions [9], and daily living activities [22]. Specifically, WATs that utilise Mixed Reality (MR) [16] to superimpose and interact with digital content has been increasingly used in a domestic setting. When integrated in AmIs, WATs can assist older people for an improved shopping experience [13], support mental functions, detect potential obstacles, and provide directions for navigation [5].

Despite all this work, we argue that existing interaction design strategies are not comprehensive enough to ensure that WATs which incorporate emerging technologies (i.e. MR and IoT) in an AmI will be usable by older adults. However, it is imperative that WATs are relevant, easy to use, usable, appealing, and beneficial to the everyday lives of older people to increase adoption rates. In such a context, there is a need for a design knowledge in the form of guidelines to support further development in this area.

In this work, we synthesise different interaction design recommendations into a unified set of generally applicable interaction design guidelines for WATs for older people. In addition, we perform a participatory design workshop with older people to further develop and refine a set of more inclusive design guidelines. During the workshop, we will demonstrate the proposed guidelines' utility through a case study on the development of a WAT (shown in Figure 1) that enables older people to utilise MR and IoT technologies.

Related Work

Interaction Design Philosophies for Older People

The academic community has proposed different design philosophies to address usability issues experienced by older people and individual with functional limitations. For example, Mace [15] coined the term Universal Design (UD) as an approach to designing built environments for the needs of people, regardless of their age, diverse range of abilities and limitations, or status in life. This concept can be used interchangeably with the term Design for All [26]. This is commonly known as Inclusive Design [2] in the UK.

In the context of Information and Communication Technologies (ICTs), Universal Usability (UU) [25] follows a UD approach to improve usability, support inclusivity, and provide utility of ICTs. UU is in line with Universal Access (UA) [27] which signifies the right of all citizens to obtain equitable access to, and maintain active and effective interaction with, a variety of ICTs. In general, Design for Ageing (DfA) philosophy [19] can be used to accommodate age-related declines in perceptual, cognitive, and motor control during Human-Computer Interaction (HCI).

Person Guidelines

P1. Provide the same means of use.
P2. Facilitate older people's accuracy and precision.
P3. Provide adaptability to the older adults' pace.
P4. Accommodate a wide range of literacy and language skills.
P5. Provide more natural user interactions.
P6. Use reasonable operating forces and minimise sustained physical effort.
P7. Allow older people to maintain neutral body position and provide adjustable positioning.
P8. Provide memory aids that capitalise on crystallised knowledge to reduce cognitive load.
P9. Provide choice in methods of use to support internal locus of control.

Interaction Design Guidelines for Older People
The academic community has also proposed numerous recommendations for designing effective HCI specifically for older people. For example, Nielsen [20] outlined usability heuristics for user interface design. Zaphiris et al. [32] presented a robust set of guidelines for designing and evaluating age-friendly websites. Different guidelines for a more older-friendly mobile interface design were presented in [12]. A structured overview of the current state of academic literature regarding user interface development for older users over a variety of domains has been provided in [8].

In the context of emerging technologies, most design recommendations generally focus on technological characteristics or primarily address usability issues for younger generations. For example, the design of AmI environments generally focuses on technological aspects, such as context awareness, device integration, networking, and interoperability [21]. Accessibility, safety, and usability issues that older people might experience are given lesser focus during the design process [1], necessitating for more inclusive interaction design guidelines.

In some cases, specific design philosophies have received considerable attention. For example, a large body of work exists and continues to grow around how UD and UA principles can be applied to WATs [10, 30, 29, 28, 5], IoTs [23], and AmIs [7]. Additionally, Motti and Caine [18] incorporated human factors during the design phase of WAT creation process to achieve better wearable solutions. Recently, de Belen et al. [6] explored the inherent opportunities and challenges when designing WATs for older people. In line with this, we aim to provide a set of more inclusive guidelines that consider age-related changes to increase accessibility, usability, and general use of WATs by older adults living in an AmI.

Methodology
The research design followed a two-phase process:

Phase 1: *Consolidating guidelines*
We retrieved more than 150 design recommendations from different sources (see Related Work section) and consolidated them to a set of 22 design guidelines based on the Person-Environment (P-E) Fit Model [14]. The person component (P) is a central part which ensures that accommodation is given to older people. The environment component (E) includes the guidelines that describe the design of the MR interfaces, as well as its context of use in an AmI. In this model, usability is achieved when there is a match between P-E components.

Phase 2: *Participatory Design Workshop*
We conducted a participatory design workshop with 18 older people (M-4, F-14) to further refine and develop a set of more inclusive interaction design guidelines. Our workshops were carried out in a local community centre ('Holdsworth Community') as a part of their discussion sessions which run weekly on Mondays and Tuesdays.

Proposed Interaction Design Guidelines
The proposed design guidelines, labeled as **'Person/Environment Guidelines'**, are outlined on the side bar of this page and the next. Due to the limited space, we cannot discuss each guideline in detail. However, we intend to provide an in-depth discussion about these guidelines during the workshop in order to share our findings to the attendees.

Wearable Assistive Technology for Older Adults: A Case Study
During the workshop, we will also present a case study on the development of a WAT (shown in Figure 1) to illustrate the utility of our proposed interaction design guidelines.

Environment Guidelines
E1. Provide provisions for privacy, security, and safety.
E2. Provide simple UI with reduced complexity.
E3. Be consistent with older adults' expectations and intuition.
E4. Provide informative and effective feedback.
E5. Use different modes for redundant presentation of essential information.
E6. Provide environmental support through context, cues,and organisation.
E7. Provide instruction manual and training program fornovice users.
E8. Guidelines for modes (auditory, haptic, etc.) of presentation of information.
E9. Minimise hazards, provide a simple error handling andpermit easy reversal of actions.
E10. Design dialogs to yield closure.
E11. Provide adequate space for use of different assistive devices.
E12. Promote mobility for older people.
E13. Support proactive communication among devices and users.

System Overview
Our WAT uses four core technologies: Microsoft HoloLens for MR interaction, visualisation, and feedback, IoT technology for environment sensing, Unity 3d for application development, and Azure Custom Vision API for object recognition and scene understanding. It follows the proposed interaction design guidelines and addresses usability by matching the functional ability and expectations of older people and technology requirements.

System Features
Internet of Things (IoT) Control
Older people can control IoT-enabled objects and obtain various sensor readings (i.e. temperature and humidity) from a server using the device (see Figure 1d). They can also query for a sensor's location, obtain the latest sensor reading, and analyse historical information gathered by the sensors.

Object Recognition and Scene Analysis
The system analyses a single photo taken from the device camera, generates 2D bounding boxes for each recognised object, and computes for their projections into the MR environment. Recognition results with more than 75% confidence ratings are called out and spatially anchored near the recognised objects (see Figure 1a). The results persist even after the device has been restarted, allowing users to request for a previously recognised object's location.

Wayfinding and Navigation
Older adults can ask for direction to previously recognised objects. A yellow path that always starts from the user's field of view will be generated if the user is more than 1.5 away from the object (see Figure 1c). Otherwise, a 3D arrow is presented and 3D audio is played to provide directions to the object's location (see Figure 1b).

Conclusion
The increasing need for WATs necessitates that design guidelines must be developed and refined to ensure that WATs are reliable, effective, usable, and accessible for the growing base of older users. By consulting existing recommendations from different sources (i.e. academic literature, industry sources,and technology characteristics) and conducting participatory design workshops with older people, we synthesised a set of more inclusive interaction design guidelines. We distilled the guidelines from over 150 design recommendations into 22 generally applicable interaction design guidelines.

We recognise that our proposed guidelines need further evaluations with heuristic experts. We hope that during the workshop, we could refine our guidelines by asking experts to attempt to determine both adaptations and violations of the proposed guidelines in an existing WAT and to reflect on the guidelines themselves during the evaluation. This would also provide us with feedback about the guidelines' clarity.

As our world population is ageing, we see a significant value in working to further develop and refine design guidelines that accommodate the wide range of perceptual changes that may be present in older adults. Nevertheless, we hope that our proposed set of guidelines, along with the case study on the development of a WAT for older people, will stimulate and inform future research into the development of more inclusive interaction design guidelines.

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Supporting Older Adults with Task Dependent Interface Augmentations

Florian Lang
LMU Munich
Munich, Germany
florian.lang@ifi.lmu.de

Tonja-Katrin Machulla
LMU Munich
Munich, Germany
tonja.machulla@ifi.lmu.de

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Abstract
Older adults face various challenges when interacting with modern technology. These challenges stem from little experience with technology as well as age-related hearing and vision impairments. Accessible interface design and specialized assistive devices, like hearing aids and digital magnifiers, mitigate some of these issues. Here, we propose a system to support older adults with augmented reality to provide a simple method to interact with any public or privately owned device. The support is independent of the ability to understand the interface design or read the labels. Our envisioned system is based on computer vision and machine learning and augments an interface to guide the user to the correct button for their desired task. We collected requirements, use cases, and qualitative feedback from the literature and interviews with older adults with visual impairments.

Author Keywords
Augmented Reality; Accessibility; Visual Impairment; Ageing Population

CCS Concepts
•**Human-centered computing** → *HCI theory, concepts and models; Accessibility technologies;*

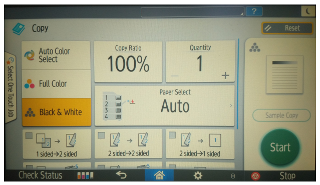

Figure 1: This image shows the touch interface of a printer without tactile feedback. Some components (e.g., the "+" in quantity) have low contrast.

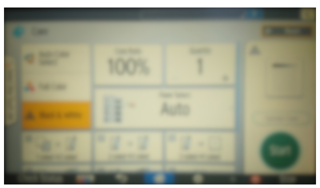

Figure 2: Here, we show the same touch interface from Figure 1 as seen by a person with visual impairment, e.g., cataract. While some elements are still visible, others are impossible to make out.

Introduction

Technology increasingly permeates every aspect of everyday life. Many customer services that have been previously provided by human employees are being replaced with machines or apps. While an app on one's smartphone or computer can often be selected or adjusted such that it will fulfill the specific requirements of the user, this is not possible for many public or even privately owned devices (e.g., ticket machine and microwave, respectively). These interfaces usually display the same layout and interaction logic to all users, and modification options are minimal.

Children and younger adults typically interact with ease with interfaces as they have learned interaction techniques while growing up. In contrast, older adults face significant challenges. Modern technology is often unfamiliar, and interactions have to be learned [7]. Also, they often have physical impairments affecting visual or auditory perception.

Here, we will focus on vision, as most common interfaces are vision-based. Many older adults experience (partial) vision loss. Wong et al. project 288 million cases of age-related macular degeneration (AMD, leading to central vision loss) in 2040 and show that the prevalence increases drastically with age [10]. Roughly one in five adults older than 75 years show symptoms of AMD. Cataract, leading to blurred and dimmed vision (compare Figure 1 and Figure 2), affects nearly every second person above the age of 75 in the USA [3]. Therefore, visual impairments are widespread and a significant problem, especially for older adults.

Current assistive technology often replaces vision with a different modality, e.g., audition [5]. Yet, even legally blind persons often have remaining visual function, ranging from the ability to detect brightness changes to having a smaller blind area in the visual field with otherwise intact vision. Using this remaining vision to display information or give assistance in everyday tasks—e.g., interaction with an otherwise unreadable interface—provides some benefits. It is faster than audio clues, works in loud or crowded places, and private information can be provided confidentially. Most visual assistive devices use magnification and image enhancements.

We propose a system that is precise enough to visually guide users to the interface element for their desired task as can be seen in Figure 3. This system removes the need for the user to read or even understand the interface at hand. We present requirements and challenges for such a system gathered from related literature and interviews with affected persons in detail.

Related Work

When interacting with electronic devices, older adults face multiple challenges. Classic designs for ticket vending machines put older users at a disadvantage, as they lack computer experience [7]. Yet, simple instructional videos can mitigate these differences and a task-based wizard-like design even allows for a "truly universally usable" system [7].

Older adults with low vision need assistance when interacting with an electronic device. Personal devices like a computer or a smartphone can be adjusted to the specific needs using software (e.g., magnifier, voice control) [9]. For analog media or electronic devices not under the control of the user, one has to rely on additional hardware. Using typical handheld electronic magnifiers has some downsides. It displays the impairment to surrounding people and, therefore, might not be used out of fear of stigmatization [6]. Further, it requires a hand to hold the device as well as the ability to place the device in the right distance to the object, which can be difficult for older individuals and makes for cumbersome interactions with interfaces.

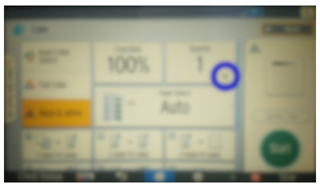

Figure 3: The same touch interface from Figure 2, including an augmentation of the "+" button for quantity, is shown. An older adult with visual impairment can now press the middle of the ring without the need to read or understand the original interface. The user would inform the system about their intention via voice command, and the system uses computer vision to identify the required button.

Head-mounted displays (HMDs) allow for an everyday mobile and hands-free use. Many existing devices target people without remaining vision, resulting in fully auditorial devices like the OrCam [5]. For people with remaining vision, an HMD providing visual feedback can be more appealing as it works with hearing impairments, in loud environments, and protects private information. Some commercial devices like the newly released NuEyes 2 [4] are already available.

Stearns et al. proposed an electronic magnifier using the Microsoft HoloLens and a finger mounted camera [8], which moves the functionality of an electronic magnifier to an AR headset. AR offers more options compared to a magnifier. An assistive function beyond image enhancement is possible, namely augmentation. Zhao et al. presented an AR system using visual clues for visual search during shopping [11]. They augment the desired product by placing an image over the product and adding movement, flicker, or highlighting to guide the user. Guo et al. proposed a system to make interfaces accessible for low vision users, relying on auditorial feedback [1]. They show that a combination of machine learning and crowdsourcing is sufficient to make the assistive device capable of providing a voice-based selection wizard to the user.

System Design Requirements

After collecting requirements from the literature, we interviewed three older adults (67-81y) with visual impairment to collect technical and non-technical specifications for the system.

The device should be portable, non-discernible as an assistive device, comfortable to wear, and hands-free. The contact to the real world has to be maintained, e.g., in case of system failure, the user should not be blindfolded. Therefore, we recommend augmented reality (AR) over virtual reality or video-see-through AR. Further, there should be an accessible input modality, e.g., sound or ergonomic gestures, that are easy to perform for older individuals.

Compared to previous work, we recommend using visual feedback only to provide information fast and unencumbered by noise or hearing impairments. Further, the augmentations have to be precise enough to allow the user the interaction with small and non-tactile interface elements. As visual impression and ability vary widely even for persons with similar diseases, the augmentation should be highly customizable in form, color, brightness, and size.

When shown a suitable AR HMD, the HoloLens [2], two persons complained about the look and size. However, one person commented, "I do not care how I look. If it does help me, I will use it." After wearing the HMD, there were complaints about weight, comfort, and the small field of view. The next iteration HoloLens 2 mitigates some of these problems. Further, we believe that during the next decade, AR devices will improve and allow for easy everyday use. Nevertheless, current devices are powerful enough to build prototypes and evaluate designs and techniques.

Feasibility

One person explained that for their own devices, they either use specialized software, or a black pen to mark often used buttons on other devices (stove, iron). With sufficient size and contrast, they can use many devices without relying on help. All persons confirmed that a system, as shown in Figure 3 and working as explained in this paper, would provide a significant benefit, especially if the system recognizes a wide variety of devices and makes ATMs, ticket machines or home appliances accessible. While they do not encounter many situations where they cannot continue, such a system would remove the need for outside help from partners or strangers and would often make tasks faster and less exhausting for the eyes.

Challenges and Outlook

In the future, there are two significant challenges. First, the system needs to provide intuitive interaction so that older adults can use it without a learning phase. Second, to assist with a wide variety of interfaces, we need to develop a computer vision algorithm that recognizes different kinds of devices and makes them accessible. In the meantime, a crowd-sourcing approach to creating interface templates could be used.

Acknowledgements

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Designing Interactive Systems for and with Older Adults: Discussing and Reflecting Lessons Learned from Interdisciplinary Design Projects

David Unbehaun
University of Siegen
Kohlbettstraße 15; 57072 Siegen, Germany
David.unbehaun@uni-siegen.de

Felix Carros
University of Siegen
Kohlbettstraße 15; 57072 Siegen, Germany
Felix.carros@uni-siegen.de

Abstract
Medical progress, ageing societies, as well as the need of care is increasing rapidly. The use of Information and Communication Technology (ICT) such as fitness applications, exergames or robotic-based technologies may support older adults, people in need of care and relief the health system. In this workshop, the authors provide results from two research projects that focused on designing and evaluating ICT for and with older adults in different care-settings. We will discuss and reflect the presented projects and findings with regard to other current research activities, methodological concepts, and experiences in the field of qualitative work with respect to research and technology design for older adults and people with dementia.

Introduction
Social and demographic change processes such as increasing life expectancy and constantly low birth rates are leading to an increase in the number of older adults in the populations around the world. This results in a higher number of people that are in need of help due to their age and their accommodating health issues. By the year 2050, the number of people over the age of 85 will increase fivefold, according to estimates. ICT-based systems may help older adults to train physical activity, cognitive resources and promote individual and social well-being as well as support caring and professional caregivers. Video game-based prevention and intervention programs like exergames, which are video games that involve different exercises, and integrates exercises as listed above may ease the access for older adults improve their physical and mental capabilities and relieve related stakeholders.

Studies here have suggested that exergames can result in general improvements in people’s fitness, adherence and balance, irrespective of their age [1]. Furthermore, for exergames have been shown to have the potential to improve health and well-being in older adults [2], [3] and in the context of dementia [4], [5].Social robots have been widely deployed in healthcare in recent times because of low availability of healthcare services [6]. Robotic-based systems can be a helpful system to enhance the activity of older adults [7], [8].

In this context, ICT-based such as exergames or robotic-based solutions are a promising approach for older adults and their relatives and caregivers. Developing appropriate ICT-based system older adults requires to identify relevant stakeholder and environmental needs and negotiate them for the design and research process. This field of research and development, concerning the sensitive setting with older adults and their social surrounding, represents a special challenge for the actors in the design and evaluation process. We will therefore use the workshop to discuss and reflect the presented projects and findings with regard to other current research activities, methodological concepts, and experiences in the field of qualitative work, research and technology design for older adults.

The Project

MobiAssist

Within the project MobiAssist, we have developed videogame-based exergames to support daily life activities of people with dementia and their caregivers. The training exercises address physical, creative and cognitive areas. The motion-sensing-based exercise training program is running on a space-saving and quiet mini-computer to reduce the disturbances of using too much technology. Currently, a MS Kinect is used to detect the motions of the participant while interacting with the system, but the open implementation will allow other cameras to be used as well.

Figure 1: Training Session with Grandchildren at home

To simplify the interaction with the overall system, a tablet and a PlayStation 3 Buzzer were used. The tablet shows the current exercise plan, the results of the different games and education material about the disease, while the Buzzer with its big colourful buttons is used as input device during the games. In an eight-month participatory design study, the authors designed a prototype system for the support of daily life activities for people with dementia. In total, 31 semi-structured interviews and 70 moderated group-sessions were conducted.

Preliminary Findings - MobiAssist

Findings indicate that the participants and caregivers benefited in different dimensions.

Benefits for caregivers: In addition to the benefits for people with dementia, the relatives benefited from the use of the system, for instance by supporting the daily routines, gaining more leisure time and decreasing physical and emotional stress resulting from care. Furthermore, informal and professional caregivers recommend the ICT-system as a permanent feature at home and in day-care centers.

Impacts on daily life: The findings also illustrated social impacts induced by using the system. Participants developed a strong sense of advanced social collaborations. By integrating strength training, balance games and creative exergames into the daily routines and activities in their familiar environment, as well as into the day-care facilities of people with dementia, existing family and friend relationships have been strengthened, intergenerational exchange happened and therefore social responsibility was regained, and general social interaction increased.

Well-being and social interaction: Participants showed strong motivation and enthusiasm, initiated learning processes, collaborated and understood the underlying concept of the exergames and its content.

The Project

ARiA

The project was part of the Year of Science 2018 "Working Worlds of the Future" *program and* explored new working worlds in *caregiving by* using participat*ory* and *practive-centred* methods in order to establish innovative solution models for the challenges of demographic change*.* Potentials and barriers for future innovations with robots were made accessible to the *public sphere and* expert audience*s* within the framework of the project. To realize the participatory approach of the project, workshops were held with professional *caregiver*, *care*-students and the *citizen*.

These workshops aimed at developing scenarios for the use of robots in a care context*s*.

Based on the gained experience applications for the robotic system of Pepper have been developed and evaluated in a care facility with 6 participants over a period of 10 weeks.

Figure 2: Group session with Pepper

Preliminary Findings - ARiA

Early findings indicate that the participants and caregivers can benefit in different dimensions.

Caregiver perspective: The robotic system can help caregivers to activate the inhabitants of a care home. First by gaining attention with its appearance and interaction with its surrounding and second by helping caregiver to structure certain activities. The robot can sing, dance, play games or tell stories. Every caregiver can do the same but often not in the variety a robot could do it. Further it helps caregivers to concentrate on individual needs, while the robot keeps on playing his program and distracts the other participants.

Participant perspective: The participants have shown a high level of activity with the robot. The robotic system that showed moving exercises have been accepted by them as trainer for this specific purpose. They saw such systems as an additional entertainment that was bringing joy and training effects. On the question if it could replace caregivers all participants answered in unity that this is not something they could imagine.

Conclusion

Based on our experiences, we argue here that designing technologies based upon a participatory and experience-based research approach offers a significant advantage with regard to uncovering and respecting the social, emotional, ethical and legal concerns, as well as different needs of all stakeholders. In the case of older adults and people with dementia, their relatives and their caregivers, using participatory design methods enabled integration and appropriation into the challenging daily life and allowed the space for a deeper understanding of their individual demands, their interaction behavior and the different impacts of the systems.

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TrePen: A Digital Pen For The Ageing Populations

Nasimuddin Ahmed
TCS Research & Innovation
Kolkata, India
nasim.ahmed@tcs.com

Abstract
One of the debilitating symptoms of ageing is tremor which primarily affects the finger and hand of the patient. This impedes the daily activities of life such as writing, cooking and eating. In this paper, we present a conceptual design of a Pen, "TrePen", to identify the characteristics of tremor and aid the ageing people in writing. Essentially, TrePen is intended to generate the writing signatures by reconstructing the trajectory of Inertial Measurement Unit (IMU) while abating the effect of tremor. The novel signal decomposition algorithm is employed to detect and characterize the tremor. The preliminary result demonstrates the potentiality of the concept and encourages it for further exploration.

Author Keywords
Parkinson, Tremor, Digital Pen, IMU, Accelerometer

CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI);** *Haptic devices;* User studies;

Introduction
With the advancement of medical science, life expectancy has been increased significantly. According to the report of National Institute on Aging [5], in U.S. only, by the year of 2050, the number of citizens over the age of 65 or older will be increased from 48 million to 88 million. However, increased longevity declines the motor function of age-

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ing people which hinders their daily activities. Pathological tremor is the most common motor disorder, manifest in the older population. Tremor is defined as an involuntary, rhythmic muscle movement occurs in various parts of the body. The hand and fingers are greatly affected by the tremor. It can be associated with physiological phenomena(ageing), or with any neurological conditions, such as Parkinson disease. In this paper, we only have considered the Parkinsonian Tremor due to the prevalence of it in ageing populations. Parkinson is a progressive neurological condition of the central nervous system that exhibits motor and non-motor dysfunction. Presently, 10 million people are approximately affected by this disease [6]. To date, the cure for Parkinson is not achieved yet. The medication only imparts the symptomatic relief. Thus it is utmost important to interpret the characteristics and severity of tremor for prescribing suitable medication dose to the patient.

Tremor hampers the daily activities in normal life. The activities include brushing teeth, eating food with a spoon or writing. Although in comparison to other activities writing is not regarded as an essential skill for daily living. However, it is very much desired skill for endowing mental stability. Several reports [3], [2] established the fact that writing plays a significant role in physiological well being. It helps to overcome the emotional inhibition and boost the self-esteem of a patient. This establishes a demand for assistive technology or interactive system which could aid them in writing. Numerous works [4], [1] addressed this and ergonomically designed the pen to improve the grip and reduce the tremor for better handwriting. Even though these devices fairly contribute to the betterment of handwriting, however, it does not possess any programmatic advantage to further reduces the tremor. The major shortcoming of these devices is the absence of a digital footprint. Also, this does not have any capability to asses the tremor characteristics. Acknowledging these issues, we propose the concept of TrePen, an assistive technology for the ageing people severely affected by the tremor. The major contributions of the TrePen are three folds: ***a)*** Distinguish the tremor attributes and utilize as feedback to reconstruct the writing content in digital format. ***b)*** Imparts a mechanical vibration according to the tremor amplitude to reduce the muscle stiffness which augments the better handwriting. ***c)*** Automatic characterization and assessment tremor for effective management of treatment.

The central idea behind this pen is to embed the IMU sensor and captures the trajectory of writing signature along with tremor. Essentially, the TrePen will be endowed with ergonomic design and act like a normal pen for the ageing people. Along with normal writing, it will restore the writing content and saves it like a digital diary for further reading. This pen will be powered through the battery and equipped with a small storage memory where the writing content will be stored primarily. This data will be automatically transferred to the digital devices(tablet, smartphone) through Bluetooth for permanent storage and display. We envisaged that this device will act as an assistive or interactive device for the ageing people. They could write anything on paper using it and also could draw or write anything on air which will be immediately recognized. Potentially, this device would be advantageous in detecting the gesture recognition which will enrich the experience of ageing people in the field of human-computer interaction (HCI).

Fundamental Challenges and Scope of the Paper

The concept of the TrePen bears the similarity to the research problem of IMU-based trajectory construction of human writing. However, the challenge is strenuous due to the inherent noise persist in IMU sensors. The challenge is further elevated by unavoidable noise in terms of tremor. The major fundamental challenges inflicted by the IMU sensor noises are denoted as ***1)*** Gravity Correction ***2)*** Continuos

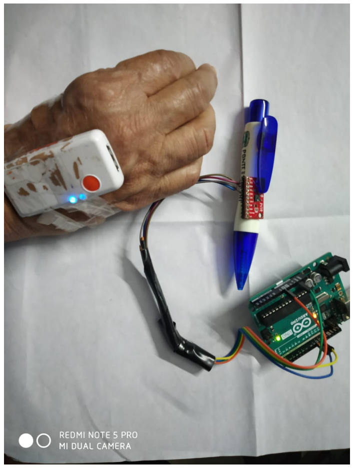

Figure 1: Prototype model of TrePen

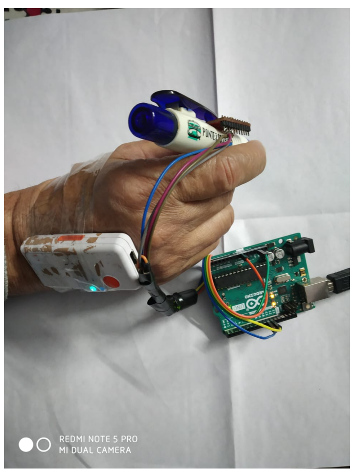

Figure 2: One Parkinson patient using the prototype model of TrePen

Drifting ***3*** **)** Global Coordinate System Estimation. However, in this paper, we position it as a potential research problem and proposed the conceptual idea of the Pen. The hardware and associated algorithms related to the writing restoration are not realized yet. The scope of this paper is restricted, we only addressed the issue of tremor identification from the data obtained from the IMU sensor.

Tremor Identification using SSA

The IMU chip is comprised of accelerometer and gyroscope. However, to asses the tremor signal, only the acceleration signal is considered. While the people with tremor symptom writes, the acceleration signal captures the both writing signature and the tremor signal. Thus recognizing and extracting these signals are considered to be a challenging issue. The writing signature and the tremor signal both are non-stationary, time-varying signal and they are also not correlated. Additionally, the range of the Parkinsonian Tremor remains in the range of 4 to 6 HZ and the frequency of human writing is in the lower range. Considering all the attributes, we have aligned this problem to signal decomposition technique where both tremor and writing signature are denoted as sub-series of the original signal. Singular Spectrum Analysis(SSA) is employed as a signal decomposing technique which decomposes the signal with several constitutive components with meaningful interpretation. We have hypothesized that tremor signal and the writing signature will be aligned in distinct components. The comprehensive details of the algorithm are described below:

Embedding

The primary step of the SSA algorithm is Embedding; where the accelerometer signal is converted into a sequence of lagged vectors. Given a resultant accelerometer signal $ACC_R = \{a_1, a_2, ..., a_N\}$ where N is the number of samples in a particular time window. The signal is converted into L lagged vectors. The L is denoted as the window length. It is worthwhile to mention that, for a meaningful projection, L must be chosen as $L < N/2$. The Trajectory matrix $S \in R^{L\times K}$, where $K = N - L + 1$, is devised as:

$$ACC_R \Longrightarrow S_{i,j} = \begin{bmatrix} a_1 & a_2 & \cdots & a_L \\ a_2 & a_3 & \cdots & a_{L+1} \\ \vdots & \vdots & \ddots & \vdots \\ a_K & a_{K+1} & \cdots & a_N \end{bmatrix}$$

Principal Component Analysis

Principal component analysis (PCA) is a mathematical procedure that transforms the original signal into a meaningful basis that emphasizes the variation. Consider the Trajectory matrix $S \in \mathbb{R}^{L\times K}$, the projected matrix C is defined as $\mathbf{C} = \mathbf{SE}$. Where $E \in \mathbb{R}^{K\times K}$ represents the eigenbasis matrix computed from the covariance matrix. Every column of the projected matrix $C \in \mathbb{R}^{L\times K}$ are denoted as principal components. These principal components are the subseries and associates with the major components of the original signal.

Grouping

In PCA, the eigenbasis is extracted by exploiting the variance of the signal in the form of the covariance matrix. The first few leading eigenvectors are often encompassed the majority of the signal and contribute the considerable amount of energy of the signal. Thus, we have considered the Principal components where 90% of the energy is concentrated. The energy is computed from the eigenvalues and it is defined as:

$$\mathbf{E_{PC}} = \frac{\mathbf{EIV_{PC}}}{\mathbf{sum(EIVDiag)}} \times 100 \qquad (1)$$

Where $\mathbf{EIVDiag} \in \mathbb{R}^{n\times 1}$ is a diagonal vector of Eigen matrix obtained from Eigen decomposition.
Tremor signal contains the higher variance compare to writing information captured by the accelerometer signal; thus the leading principal component is considered as tremor

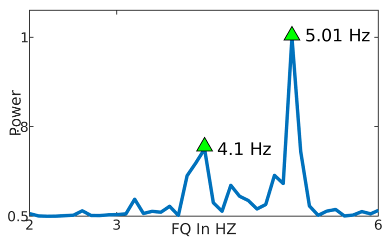

Figure 3: FQ Spectrum Of Noisy Tremor Data

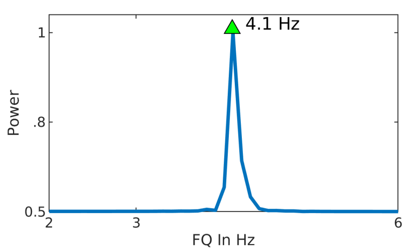

Figure 4: FQ Spectrum Of Reconstructed Tremor Data after SSA

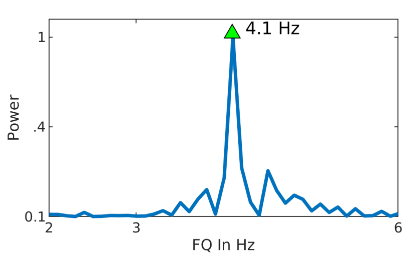

Figure 5: Frequency Spectrum Of Tremor Data From GT Device

signal. Conversely, other principal components are grouped to form the writing signature.

Diagonal Averaging
The final module is Diagonal Averaging which in turn reconstruct the time series of the various groups obtained from the previous method. After Grouping stage, finally two groups are formed: ***1)*** first the tremor group $T \in \mathbb{R}^{L\times 2}$ contains only the leading Principal Components; the number is decided as two and it is obtained empirically. ***2)*** Another group is the writing group $W \in \mathbb{R}^{L\times M}$ contains the other principal components. Where M is the number of Principal Components considered according to the energy distribution. To reconstruct, the time series corresponds to the tremor and writing signature, the projection of the abovementioned groups are inverted based on the corresponding eigenbasis. The anti-diagonal averaging is performed to reconstruct the elements in the time series window. If we consider $T_{RW}(n), n = 1, 2...N$ as the reconstructed time window for tremor, then the diagonal averaging process is defined by the following equation:

$$\mathbf{T_{RW}(n)} = \begin{cases} \frac{1}{n}\sum_{m=1}^{n} T_M(m, n-m+1) \forall 1 \leq n \leq L \\ \\ \frac{1}{L}\sum_{m=1}^{L} T_M(m, n-m+1) \forall L \leq n \leq K \\ \\ \frac{1}{N-n+1}\sum_{m=(N-n+1)}^{L} T_M(m, n-m+1) \\ \forall (K+1) \leq n \leq N \end{cases} \quad (2)$$

The same process is followed to reconstruct the time window for writing signature.

Expriment Design and Data Collection

To validate our hypothesis, the experiment is carefully designed and a basic prototype model of the TrePen is designed to generate the data.

Prototype Model Design
The prototype model is built with a special Pen equipped with a MPU 9150 IMU chip. It is a 9 degree of freedom(DOF) IMU unit that combines accelerometer, gyroscope and magnetometer. The MPU-9150 supports the I2C protocol for data collection. The MPU 9150 sensor is connected to the body of the Pen. The clock, data and the power lines are connected to microcontroller board using the long wires. One Arduino Uno board is used as the microcontroller which is connected to the Laptop through the USB port to collect the data. This prototype model is only devised for the proof of concept. It is intended only to identify and distinguish the tremor from the acquired data.

Data Collection
Since this is a preliminary experiment, the data is collected with a cohort of 6 Parkinson patient in a controlled environment. They are asked to write some letter or word using the TrePen prototype model. Each session of the is restricted to 90 Seconds. A medical-grade device Shimmer [7] is used as a ground truth device to measure the accelerometer signatures of the hand movement during the tremor. Based on the empirical analysis, it is observed that the palm side perceives more vibration compare to wrist or forearm. Therefore, Shimmer device is placed on the backside of the hand palm using a strap, to record the true frequency of tremor vibrations. The Shimmer device and the MPU-9150 is synchronized with system time. The complete Data collection procedure is controlled by an external observer. The prototype model and the process of data collection is depicted in Figure 1 and 2.

Evaluation

Since the tremor signal posses the oscillation nature, we have leveraged the spectrum estimation for evaluation. The signal is segmented into smaller windows and considered as stationary over restricted widow size. The Fast

Fourier Transform (FFT) is applied as the spectrum estimation method on every time window. In our experiment, we have chosen 10 Second window.The dominant frequency of every accelerometer spectrum window acquired from the shimmer device is used as a reference parameter. Subsequently, this dominant freuency is matched with the dominant frequency of reconstructed tremor spectrum window obatained from TrePen. For a particular time window, this process is defined as:

$$\mathbf{FQACCGT_{max}} = \underset{\mathbf{k}}{argmax}\,\mathbf{FQSP_{ACCGT}(k)} \tag{3}$$

$$\mathbf{FQACCR_{max}} = \underset{\mathbf{k}}{argmax}\,\mathbf{FQSP_{ACCR}(k)} \tag{4}$$

$$\mathbf{d_{FQ}} = |\,\mathbf{FQACCGT_{max}} - \mathbf{FQACCR_{max}}\,| \tag{5}$$

Where $\mathbf{FQSP_{ACCGT}}$ is the frequency spectrum of tremor signal obtained from shimmer device and $\mathbf{FQSP_{ACCR}}$ is the reconstructed tremor signal processed after SSA.
If the absolute difference $\mathbf{d_{FQ}}$ is less than the threshold then this window is denoted as a match. The threshold is defined according to the frequency resolution of Fourier Transform and it is selected as .1 Hz. The tremor identification algorithm caters 90% accuracy; among 255 of total windows 230 windows are rightly identified as tremor signal. To have a better perspective, for one particular time window three plots are generated and depicted in Figure 3, 4, and 5. It is evident from Figure 3, that the spectrum of noisy accelerometer signal is cluttered with noise and the original tremor signal (4.1Hz) is buried with noises. Here, the dominant frequency is 5.01Hz which does not match with the ground truth dominant frequency(4.1Hz). On the other hand, when the signal is processed using the algorithm, the reconstructed tremor spectrum in Figure 4 is clean and matches with the ground truth.

Conclusion

In this paper, the concept of TrePen is presented, capable of distinguishing the tremor and assist the people while writing. The notion of this TrePen is based on the IMU trajectory tracking to yield the writing signature. The hardware and the associated algorithms are in the ideation phase, not yet implemented. Currently, we show the feasibility analysis of identification of tremor which will facilitate the assessment and effective reconstruction of writing signature. As future work, we intend to build the real hardware of TrePen for the deployment in the real field.

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Issues with Close Other Proxies using Self-Service Technologies on Behalf of Older Adults

Celine Latulipe
Department of Computer Science
University of Manitoba
Winnipeg, MB, Canada
celine.latulipe@umanitoba.ca

Lisa Engel
Department of Occupational Therapy
University of Manitoba
Winnipeg, MB, Canada
lisa.engel@umanitoba.ca

Mary Shariff
Faculty of Law
University of Manitoba
Winnipeg, MB, Canada
mary.shariff@umanitoba.ca

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Abstract

This workshop paper highlights the support that 'close others' provide to older adults in acting as proxy users of self-service apps in eHealth, eFinance and eGovernerment. Proxy use of such eServices on behalf of older adults is occasionally done formally, when the eService explicitly provides proxy accounts, but is most often done informally by older adults sharing login credentials with close others. This sharing of passwords brings privacy and security risks, but also can cause problems for service providers. We provide a description of these issues as well as considerations for the design of eService portals to mitigate information disclosure, fraud and security risks.

Author Keywords

Older adults; Proxy Users; Privacy; Security; Self-Service Technologies; eHeath; eBanking; eGovernment;

CCS Concepts

•**Human-centered computing** $\rightarrow$ *Ubiquitous and mobile computing; Collaborative and social computing theory, concepts and paradigms;*

Introduction

An eService portal is an online service, accessed through a mobile application or web browser, that requires a user to login, and then allows the user access to their data (i.e.,

Helping With Technology
An eighty-something participant in the Cheque Mates study [20] estimated how frequently older adults rely on close others for tech help:

"Forget computers. 20% of the people – you know, my generation - do not have computers. 7% have got no one who can use them for them. An awful lot [are] of an age that have got children, helpers, carers, grandkids, who use the computer on their behalf."

medical record, bank account, pension) and allows the user to engage in domain-specific tasks (i.e., renewing prescriptions, transferring funds, pension planning). Self-service technology is increasingly promoted as companies and governments seek to lower costs by reducing or eliminating brick and mortar service locations. While online access has the potential to allow older adults with mobility issues or in rural areas to access needed services, such services are often not designed with older adult users in mind.

Close Others
Close others are people who have regular contact with older adults and may help them with daily living, including social activities, health and wellness, shopping, banking, and accessing social services. Historically the CHI community has used the term 'caregiver' to describe people who assist older adults. However, 'caregiver' tends to be associated with healthcare assistance. It also fails to acknowledge the reciprocal support and care relationship between older adults and their close others [11, 19]. Thus, following the lead of the occupational therapy community which considers a broader range of activities [4], we choose to use the term 'close others'.

Close others can include many different people an older adult would receive support from, including paid support workers, family, friends or other community members. Many older adults have multiple close others who support the older adult in different ways and have different types of relationships. An older adult may have close others that fit into any of the social circles identified by Wang et al.: predetermined, chosen, interest-based, location-based, and shared-identity circles [21]. Various researchers have shown how important it is to take into account the perspectives of close others or caregivers when designing technology for older adults [5, 7, 3]. Research has also shown that close others can help older adults learn to use new technologies [15].

Close Others as Proxies
Close others often act as proxies and access eService portals on behalf of the older adults they help. While this is generally helpful to the older adult, proxy usage of eService portals can create a wide variety of serious security and privacy problems, especially when the older adult also experiences social conditions or health impairments that increase vulnerability [13, 12, 8]. Proxy access to such eService portals often happens by older adults sharing usernames and passwords with the close other, or by the close other creating the account in the older adult's name, and setting up the login credentials themselves. We call this *informal proxy usage*, and whether this occurs via mobile device or using a computer, it can create a wide variety of serious security and privacy problems, and can also be problematic for providers interacting at the other end of these systems (such as government workers, healthcare providers, bank officers, etc.). The alternative to informal proxy usage is the provision of proxy accounts that explicitly acknowledge the role of a close other as a technology helper or proxy. eService portals should support close others' use on behalf of older adults through the provision of proxy accounts. This could allow the older adults to limit the information and functionality accessible to their close others, and help the older adults protect information they wouldn't want disclosed to the close others. However, few eService portals explicitly support proxy accounts, and little is known about how to structure such accounts.

In this workshop paper we will describe the issues that arise from the lack of explicit proxy accounts for self-service technologies, and we will provide an initial set of considerations that companies and government services should be aware of when designing self-service technologies that may be used by the close others of their older adult clients.

Legal Formalities come Later in eBanking

While most jurisdictions require legal power of attorney or court appointment as a substitute decision maker before a bank is allowed to grant financial account access to someone other than the account holder, most older adults do not use these mechanisms until they face serious incapacitation. Even when such processes are followed, bureaucratic hoops can delay these processes.

Our informal observations in Canada and the US indicate that informal sharing of passwords for eBanking assistance happens long before an older adult is at the point where a power of attorney or substitute decision maker comes into play. Thus, it is likely that many instances of proxy banking fall under the informal category.

Issues Around Close Others' Proxy Use

The lack of proxy accounts for close others leads to a serious problem: older adults commonly share their login credentials for eService portals so that their close others can engage with eService portals on their behalf. From a security standpoint, sharing passwords is a bad idea because people often use the same or similar passwords across multiple systems [6], and so giving a password from one eService portal (such as a hospital patient portal) to a close other might also give that person access to the older adults' other eService portals (such as online banking), opening up the opportunity for elder fraud [18].

Older adults often have various different close others who help with different tasks, and the information sharing between the older adult and each close other is highly contextual [14, 2]. Privacy is critical and even within one eService portal, there may be limits to the amount of information an older adult wants to share with a particular close other. For example, an older adult may want a close other to help with reviewing test results in an online health portal, but by giving them the password to that system, the close other could also get access to the older adult's full medical history, including diagnoses of stigmatized illnesses, prior substance abuse issues, or prior reproductive health decisions. The sharing of login credentials means the system can not differentiate between the older adult and the close other, potentially leading to unwanted information disclosures.

Our previous work has shown that older adults often struggle with patient portals and rely on a close other to help them use it, or to use it on their behalf [10]. This research also showed that most older adults are unaware how much information is visible to their close others on patient portals, and expressed concern about certain types of information being shared (billing information and stigmatized illness diagnoses) [10]. These participants relied on their close others to help with the patient portals because of discomfort with technology [9], and/or lower eHealth literacy [1]. We also conducted interviews with healthcare providers [16], who are on the provider side of the eService portal. They may struggle to know with whom they are communicating when older adults' proxies are using the portals. In the patient portal example, doctors might communicate quite differently if they are messaging with the patient vs. the patient's adult child, neighbour or friend.

Pecina et al. studied proxy messaging with healthcare providers [17]. Of all messages sent to providers through an adult patient portal, fewer than 1% of the messages came from a proxy account. Additionally, at least 7% of messages sent through the adult patients' accounts were sent by someone other than the patient, demonstrating barriers to adoption and use of proxy accounts, even when they exist.

Similar issues exist across other domains such as banking and government services. Anecdotal evidence suggests that many older adults rely on adult children or other close others to do online banking for them, and much of this is done informally through password sharing.

Design Considerations

Providing proxy access to eServices involves the creation of a different type of account and some way for older adults to indicate what types of information and functionality a close other proxy should have access to. It is important to make the setup and configuration of proxy accounts as simple as possible so that the older adult user is not overwhelmed.
If they are relying on a close other to use the eService on

their behalf, it is likely that they are not feeling comfortable using the technology, and so it may be important to allow this setup to happen via paper forms that are mailed to the eService provider. Proxy accounts may benefit from:

Expiry Dates: Relationships can change and so use of expiry dates can ensure the older adult still wants a particular close other to have proxy access.

Checks & Balances: When critical assets are at play (pensions, financial assets, etc.) require multiple proxies, as a check against elder fraud [18].

Transparency: Proxy actions should be logged and sent to the older adult via email, phone notification or on paper through the mail.

Limits: Certain actions should be off limits to proxy users. For example, if paper statements are mailed to the older adult, the proxy should not be allowed to change the older adult's mailing address.

Blocks: Older adults should have a mechanism (via a simple phone call) to immediately block access of a close other whom they have given proxy access.

Mobile Possibilities

For older adults comfortable with mobile phones, eService systems could send alerts and notifications about their close other's activities on the eService account.

Designing a user-friendly app to help older adults manage close others' proxy access to eHealth, eBanking and eGovernment services would also be useful. Ideally, one app that has a consistent interface could be used for proxy account management across multiple services.

Even if proxy accounts are provided, there is evidence to suggest that they may not be used [17], especially if people do not realize that proxy accounts can be created. Even if they are aware, they may not be used due to the setup burden, lack of awareness about the amount of information available [10], lack of awareness of the risks associated with password sharing [6], or a high level of trust between the older adult and the close other [10]. Given these barriers, it seems likely that many older adults will continue to share login credentials with close others. This likely violates the terms of service of most eService portals. eService companies would be wise to acknowledge the practice and build in mechanisms to help address the issues we describe. For example, an eService portal could ask the user upon login if they are a proxy user. If the user indicates that they are a proxy, then features such as the following could be used to protect against fraud and privacy intrusions:

- Log activity conducted by the close other proxy.
- Display warnings before providing access to sensitive information or functionality.
- Ask the proxy to upload a time-stamped picture of themselves with the older adult.
- Send a summary of information viewed and actions taken to the older adult.

Conclusion

The increasing importance of self-service technologies accessed via mobile and desktop devices can leave older adults struggling to access needed services, and has the potential to widen the digital divide. The common practice of close others using these services on behalf of the older adults they support can help bridge that divide, but if that access is informal (through sharing of login credentials), there are significant privacy and security risks. eService providers can better support older adult participation by explicitly acknowledging the existence of close other proxy users, by providing proxy accounts, and by designing their systems with the knowledge that informal proxy usage is also likely to continue, even if proxy accounts are provided. Much more research is needed on how to best structure such accounts and how to design systems with informal proxy usage in mind.

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Conversations On Multimodal Input Design With Older Adults

Adam S. Williams
Colorado State University
Fort Collins, CO 80525, USA
AdamWil@colostate.edu

Sarah Coler
Columbine Health
Fort Collins, CO 80525, USA
Sarah.Coler@columbinehealth.com

Francisco Ortega
Colorado State University
Fort Collins, CO 80525, USA
fortega@colostate.edu

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Abstract

Multimodal input systems can help bridge the wide range of physical abilities found in older generations. After conducting a survey/interview session with a group of older adults at an assisted living community we believe that gesture and speech should be the main inputs for that input system. Additionally, collaborative design of new systems was found to be useful for facilitating conversations around input design with this demographic.

Author Keywords

Human Computer Interaction; Older Adults; Interaction Design; Inputs

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);** *Interaction design;* Accessibility;

Introduction

Input technologies can help enable seniors to maintain their independence into later years by offloading some of the needs of daily activities, or by reducing the cognitive load needed for those activities [8]. There are however differences in how older adults and younger adults interact with and perceive controls [2]. Some of these differences include perception limitations or inexperience with new technologies.

Scale	Response
0	Never
1	Once
2	Yearly
3	Monthly
4	Weekly
5	Daily

Table 1: Response scale for device usage frequency

Scale	Response
0	Very Poor
1	Poor
2	Fair
3	Good
4	Excellent

Table 2: Response scale for self assessment ratings

Sadly, when interactions with a system are poor older adults often assign personal blame instead of considering that they interface may not be properly designed for them [2]. It is important to reduce these feelings of inadequacy. When input technologies are not accessible it promotes feelings of exclusion and loss of control which can contribute negatively on one's life [8].

Gestures have shown promise as an appropriate interaction technique for older adults, showing no significant difference in accuracy between older and younger adults [9]. Speech has also been seen as a preferred input for older adults [1].

Multimodal interfaces show promise in improving accessibility for older adults by providing a more natural and efficient interaction space [3]. Multimodal inputs are associated with higher user satisfaction, particularly with speech and gestural interfaces (touch) [4]. The benefits of this combined modality extend beyond user satisfaction. These input streams often contain non-redundant information which can lead to better recognizer systems development [6].

Survey

To evaluate the feasibility of multimodal gesture and speech based inputs we conducted a survey/interview session at an assisted living home. This pilot study is aimed at guiding our ideas about the future direction of input devices for this generation. This survey included questions about device usage frequency and comfort with using devices. The scales for responses to these questions are shown in tables 1 and 2. There were 11 participants (age M= 86.1, SD = 10.89). The range of ages spanned from 66 to 100 (8 male, 2 female). Previous careers ranged from homemaker to pilot.

Results

Due to small sample sizes we are treating the responses to the survey as a framing for the discussion. Thus, in-depth statistical analysis was not performed on the survey results. The results are very clearly impacted by age. People over 86 (group 2) selected never use for all of the device usage frequency questions. People 86 and under (group 1) answered more of the usage questions. Most participants in group 1 report using a smartphone daily 3/4 (group 2 1/7). All phone usage questions were rated as daily or never. Only 2 participants reported using a mouse/keyboard daily, both in group 1.

Group 1 rated their eyesight as good (M=3.25), group 2 rated their eyesight as fair (M=2.83, SD=1.35). Dexterity follows the same trend with group 1 rating their dexterity as good (M=4, SD=0) and group 2 rating it as poor (M=1.88, SD=1.5). These results are shown in figure 1. Group 1 rated their comfort with touchscreens as good (M=3, SD=.7). The mouse/keyboard and speech controls were rated as fairly comfortable both with (M=2, SD=1.41). For all device comfort questions group 2 rated their comfort as very poor.

People said that they wanted to see more inputs that mirror what they currently use. Those being touchscreens. Some people felt that technologies are moving too fast. Indicating a preference for keeping inputs consistent in emerging technologies. When asked if they would like speech based inputs people unanimously said no. When asked if they thought using speech as commands for a system most people said it would be beneficial. The responses to these similar questions flipped based on the framing of the question.

After having difficulties getting input preferences for general new technologies we framed the questions around a virtual reality bingo game (VRBG). The participants helped design

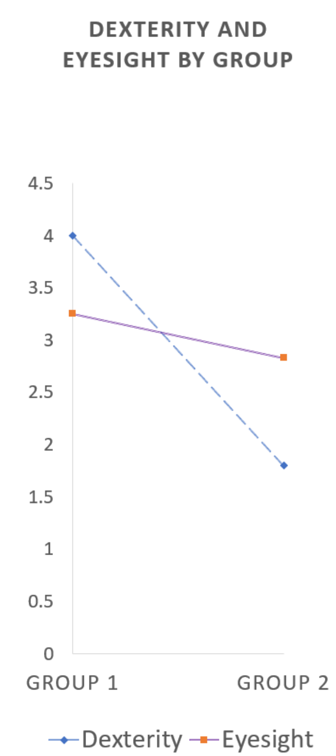

Figure 1: Participants self reported eyesight and manual dexterity by group

what this game would do. Having helped with design, participants were more involved in conversations around inputs for it. Participants wanted to touch the virtual bingo card to place their chips. A few people wanted speech based inputs in combination with touch, but not as a stand alone input. Participants said they wanted few controls in this system. One participant said “simple is safe” which was then repeated by other residents over the course of the conversation.

Outside of the scope of inputs, people wanted to be able to scale bingo cards to work around eyesight or dexterity limitations.

There was apprehension around participation in the conversation. Prior to the VRBG segment of the conversation the thought of technology seemed to be off putting to some participants. This was more pronounced in the participants above 86. Some participants, though eager to fill out the questionnaires and talkative during the initial session, become very quite during the discussion about inputs. There was some level of guilt reported by several participants saying that they “didn’t want to ruin the results” indicating that their self perceived lack of experience with technology would be harmful to the survey. One participant went so far as to say they did not want to participant at all because they were “computer illiterate” and did not want to ruin the results. That participant later joined into the conversation. This looks similar to the self blame found by Cui et al. [2]. Some other quotes from participants are found in table 3.

Discussion

The results from the survey and the interviews are anecdotal. That said they provide some direction for future input design. The interviews around input design also give insights on conducting meaningful conversations with this demographic. It was difficult to frame what we were asking when talking about what inputs they would like to see in future devices. There was a large disconnect between computers, phones, headsets, or any other type of technology. Different framings of the same question yielded drastically different answers.

When considering hand-based inputs, gestures or otherwise, its import to consider the level of mobility and hand usage older adults have. All of our participants reported having some level of manual dexterity decrease, with 4/11 indicating it was severe. This decrease in manual dexterity has been linked to decreased selection task performance [5]. The addition of speech based inputs would make for a more flexible system, able to better cater to individual needs than touch or gesture alone.

Going into a conversation with specific questions was difficult. There is high potential for the participants to not contribute. Establishing a dialog around a common notion was helpful. The common notion in this instance was the VRBG. Having a member of the actives staff involved was impactful, the familiar face helped ease some of the anxieties in the room. That staff member was also able to help re-frame questions in a way that participants were more open to or more able to answer.

We recommend conducting interviews with this population across multiple time periods. Establishing a rapport would help with participant involvement in the conversation. Most residents mentioned guilt about “ruining results.” We believe that having multiple sessions will help lessen this guilt which will help get at more meaningful conversations.

Future Work

This lab plans on developing the VRBG as a tool to get engagement in conversations about input device design from this population. With that, we plan to have reoccurring meetings to help enable participatory design of the system. While the end result may not be hugely impactful to this audience. The effect of having a stream of suggestions and iterative design based on the needs of this population will be.

"you don't want me to participate, I'm computer illiterate"
"simple is safe"
"technology moves too fast"

Table 3: Quotes from participants

Conclusion

Touchscreens and more intuitive Natural User Interfaces can enable older adults to join the digital world [7]. It is important that inputs are designed so that current older adults, and generations set to enter that space can remain in the virtual world.

Gesture and speech based inputs are the best future direction for interaction design with older adults. Touch based inputs were favored by most participants. We believe that gestures will begin to replace touchscreen interactions and can utilize many of the same features as touch. While there was some hesitation around speech inputs, we believe that as technology improves speech will become more accepted. When considering the next generation of older adults, the pervasive use of speech based home assistants might change this preference from touch. Multimodal systems that can utilize multiple input streams, in particular gestures and speech, can provide a robust interaction space. One capable of overcoming the individual level difficulties incurred while ageing by providing alternative input options. With the wide range of abilities found in older generations, this flexibility is critical to wide spread accessibility.

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Insights from elderly women who live alone: An interview study.

Nana Kesewaa Dankwa
University of Kassel
Kassel, 34128, Germany
nkdankwa@uni-kassel.de

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Abstract
This paper describes one part of a user study with elderly women who live alone in Germany. The user study comprised of an exploratory getting-to know participants, an experience of use and interview studies. This user study is a part of a research project dedicated to innovating smart home technologies with and for elderly women. This paper highlights insights from semi-structured interviews with 7 elderly women who live alone. It also draws attention to the need for

research on ageing populations to consider aspects of gender and sex in research.

Author Keywords
Ageing users; elderly women; interview-study; gender; smart home.

CSS Concepts

• **Human-centered computing~Human computer interaction (HCI)**; *Haptic devices*; User studies;

Introduction

Research in ageing populations in HCI though minimal needs further considerations into the complex identities and contexts of older persons. Identity factors such as gender, race, culture, socio-economic status should determine how technologies are designed with and for persons[1]. This research paper draws attention to the role of gender in working with older persons to design technologies. Gender is a key determinant of the quality of life of older persons [18]. Generally, gender and sex in research presents perspectives often overlooked[13]. However in older persons, gender influences their participation, health, financial status etc. as they actively age[18]. This paper presents qualitative research work conducted with 7 elderly white women (65+) who live alone in Kassel in Germany. It highlights insights from the lives of the elderly women.

Background

Gender and Ageing

As a result of the gender gap in life expectancy, elderly women (65+) spend a greater part of their elderly lives alone[12]. In the EU, elderly women represent the largest proportion of women living alone [12]. Elderly women living alone are more likely to suffer from poverty, illness and disability [12,19,8]. Elderly women may also deal longer with advances in Information Technology innovations, often designed with and for young adults. Though HCI research over the past decade in Gender and Ageing populations has increased tremendously, research with and for elderly women remains minimal. Our research seeks to contribute to research in HCI on Ageing populations and draw attention to the need to consider the complexities of identity such as gender and living status in designing specifically for older generations. The ultimate aim of this research project is to seek opportunities for designing smart home technology for elderly women.

Gender and Smart Homes

Smart homes for ageing persons has been identified as vital to supporting ageing-in-place[3]. Smart home functions often largely cater for supporting independent living and responding to health needs such as dementia, disabilities etc. [5,6].The functions of smart homes should largely extend to manifest the diverse needs and contexts (gender, race etc) of persons ageing[10]. The home remains one of the gendered spheres of society in most cultures with what most people do at home being determined by gender[11,15]. Additionally, the living behaviors and contexts of older persons living alone are different from older persons living in shared homes or health facilities[8,9,12]. The consideration of the gender aspects in smart home research allows a new outlook on the different preferences and needs of gender in a home. The home has different connotations to each gender-construct and thus a consideration of potential (e.g. behavioural) sex-gender differences in innovation avoids the delivery of stereotype-driven products.

Methodology

This research is a part of an ongoing larger research project that seeks to design smart home technologies with and for elderly women living alone in Germany.

The project is structured into four phases, with a preliminary study, use of experience study and interviews already undertaken. Future work will engage the elderly women in collaborative creative sessions to design smart home devices that fits to their needs and use. A brief report of the other phases are highlighted in this article. The interviews were to gain rich knowledge and understand the experiences of the elderly women. It was also to gain insights into their past and current lives, values, living situations and activities to identify the opportunities for technological interventions in their homes. Therefore face-to-face semi-structured interviews were conducted in the homes of the elderly women. This paper highlights aspects of the themes reported from the interviews.

PARTICIPANTS

Seven elderly women were recruited for the interview study. They lived in a suburb in Kassel, a city in Germany. They lived alone and perfectly (mentally and physically) fit to take part in the interviews. All women but two lived in their own houses. One of the other two lived in their apartment and the other in a rented apartment. The women were between the ages of 75-83 years. The contact to the women was more of a snowballing sampling. The first contact was gained through the author's neighbour. The women were told the interviews were to get to know their lives better as first contact had already been made through the pre-liminary study.

No.	**Age**	**Years living in the home**	**Years living Alone**	**Education/Training**	**Years worked**
S1	81	51	10	Pharmacy	-
S2	83	50	7.5	Nursing (Pediatric)	6/7
S3	82	50	3	Sales + Cosmetology	10
S4	80	38	3	Home Economics	24
S5	79	45	11	Tax Office	30+
S6	75	19	19	Bachelor (Education)	30+
S7	79	55	1.5	Wholesales	45

Table 1. Demographics of the women.

PROCEDURE AND METHODS

Semi-structured interviews are key in gaining in-depth insights into the ageing experiences of older persons[2,4]. The semi-structured interviews were conducted face-to-face with open ended questions. The interviews lasted between 30-70 minutes. All interviews were conducted in the homes of the women. The interview questions were structured into four main categories. The first set of questions were personal information about the participants, the second set were to gain insights into their past years and activities, the third set of questions were about their current lives and activities and the fourth set about their ownership and use of technology. There were specific questions about their daily routines, social activities, relationships and skills. The interviews were conducted in German and recorded with a smart phone, labelled and transcribed for analysis. The interviews were analysed using conventional content analysis [7]. The transcribed interviews were read through for codes and then categories and a section of themes that rose out of the categories are presented here.

Insights

The insights presented here from the interviews are highlights of the themes arising from the interviews. The themes presented reflect on societal structures: the contributing factors that determine the quality of life of elderly women, alone but not lonely; the subjective evaluation of satisfaction of living alone. Additionally, the insights reflect on the women's keen role in sustaining community and their use and ownership of technology.

SOCIETAL STRUCTURES

It is an undeniable factor the contributing role of societal structures to ones quality of life at old age. The traditional roles of women though changed over time have substantial influences on the financial, social etc. state at old age. All women were born just before or during WWII which influenced their roles and lives as children, teenagers and women. The roles of women were more traditional, especially in West Germany, established childcare for children below 3 years were non-existent. Childcare for children from 3 years to pre-school (5) were very competitive. Thus mothers could not effectively work as men did. All women interviewed had been married at very early ages (average 22 years). All women but two had children. Two had been full time housewives (S1,S2) and had raised 4 and 3 children respectively. These women depend on their husband's pension benefits. Though in Germany the laws are now favorable towards women who had childcare roles, they should have however worked for at least 3 years. S7 and S6 had no children thus benefited working fulltime. S5 had to engage the assistance of childcare from Greece so she could work in their family business. The women with children who worked mentioned factors such as "office" in the home and additional childcare as enablers.

ALONE BUT NOT LONELY

De Jong Gierveld describes loneliness as a subjective evaluation of the quality of relationships one has which is dependent on factors such as age, financial situation and health[8]. The interviews did not measure the states of loneliness of the women. The insights given here are reflections the women made about how they feel about living alone. All women described their lives as not lonely but rather appreciated the stage they found themselves in: "*I do well living alone. I enjoy it as well*"**(S2)"**. The social circles they had and the activities they undertook were key factors that kept them actively engaged as persons living alone: "*When you keep busy, you do not fall into a hole. You keep a balance and have a feeling of self-worth"***(S1).** Their preference to live alone at home was due to their values of independency:"*As long as I am independent and can still take care of everything by myself, I do not wish to live in a home***(S4)"**, freedom:"*I want my freedom to do what I want to do when and how I want to do"***(S2).** All women were not keen on moving even to their children due to their social circles, friends etc.: " *because I could never imagine myself making new connections with 82 years"(***S3)**. These reflections contradict popular labelling of elderly women who live alone as lonely. Similar experiences of freedom, satisfaction etc. by elderly men living alone in the US also contradict these negative notions of older people[17].

COMMUNITY, WHAT HOLDS IT ALL TOGETHER.
The interviews with the women made clear the importance of the immediate community. Though all women enjoyed the time spent with their children or siblings when possible. They valued much more the community that surrounded them. Each woman was part of a club of a sort. These clubs organized regular meetings for example to play games, embark on trips, have dinner or visit each other. Additionally some took courses from the Adult Education Center for English (S5) or novel reading (S2,S3,S7) to meet others and keep the mind active. The use of communication technology such as telephones, mobile phones, emails and even letters was nothing over the top in keeping their relationships nurtured. However the commitment to ensuring that they nurtured their relationships and assisted each other when the need arose was what stood out and mentioned as priority. This has been confirmed as a unique trait of women in guaranteeing the ongoing contact of kin and non-kin relationships[9].

TECHNOLOGY USE AND OWNERSHIP
There has been extensive work with Ageing populations and their use of technology. This theme however brought out interesting insights on how the women purchase new technology: on a need basis. And additionally, the role their families played in their use and ownership of smart devices which is reiterated by Sri Kurniawan in their study of elderly women and their use of mobile phones[16]. All but two women had smart mobile phones. Three women (S2, S3, S7) had computers they regularly used. The purposes were for searching for information, reading mails, online banking and house administration tasks. All women but two had internet in their homes. Interestingly, all but one woman had had or used computers. S4, S5, S6 and S7 due to their professions use computers. Interestingly, S4 and S6 used them only because they had to at work and preferred not to use them at home.

Conclusion
The insights from the interviews were beneficial in understanding the values, experiences and activities of the women. Though this paper only highlights aspects of the interviews, the interviews bring attention to how challenging it will be to find one smart device that fits into the varying needs and perspectives of these women. On one hand, perhaps leaning towards a smart home device that builds and supports their existing communities might be helpful. Additionally, a further study might be required to consider the interactions with tangible artefacts in their homes[14]. The interviews were helpful in knowing the skills and interests which are fundamental in planning the co-creation sessions. It is necessary to avoid materials and methods that are incoherent with their values, skills and interests and important to consider their existing structures of social networking and interactions.

Future Work
This research will conduct collaborative creation sessions with the elderly women aimed at designing smart home devices that will fit into the lives of the women and most importantly needed. These sessions will involve creative sessions that will work towards designing prototypes that suit in the home.

Acknowledgements
The authors express gratitude to the women who gave up their time and willingly shared stories of their lives with us. This research is carried under the auspices of

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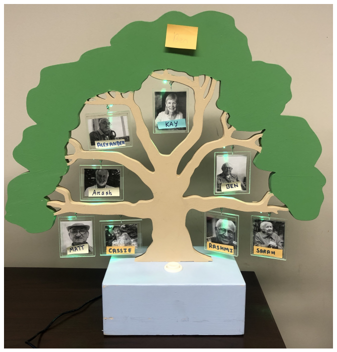

Figure 1: Check-in Tree

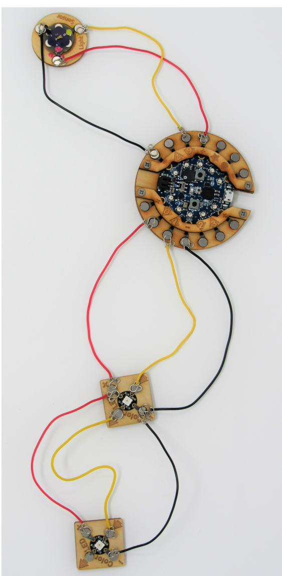

Figure 2: Check-in Toolkit

Design and Evaluation of Electronic Check-In Systems for Older Adults

Pallabi Bhowmick
Indiana University
Bloomington, IN 47403, USA
pbhowmic@iu.edu

Novia Nurain
Indiana University
Bloomington, IN 47403, USA
nnurain@iu.edu

Kay H. Connelly
Indiana University
Bloomington, IN 47403, USA
ksiek@indiana.edu

Katie A. Siek
Indiana University
Bloomington, IN 47403, USA
connelly@indiana.edu

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Abstract
In this paper, we describe two Check-in systems and propose a within-subjects study with rural older adults to evaluate if older adults prefer to customize their systems. The Check-in systems provide older adults the ability to check-in on their neighbors and peers, however one system is ready made and with the other system, the older adults build into their chosen enclosures with customizable outputs. Such Check-in systems can help older adults age-in-place and empower them to take care of one another, thereby, fostering a more independent life.

Author Keywords
Aging in Place; Electronic toolkits; older adults; Making

CCS Concepts
•**Human-centered computing** → *User interface toolkits;*

Introduction
Most older adults would prefer to age in place, however some older adults report concerns about feeling socially isolated [3]. Researchers have investigated how to help older adults connect with each other to reduce social isolation by providing electronic systems to check-in with loved ones by one-way [4] and two-way communication [1]. These electronic Check-in systems were publicly facing physical objects (e.g., a frame or tree) that were envisioned to be on display in one's home.

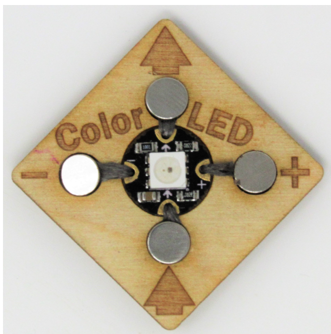

Figure 3: A NeoPixel showing hardware connections

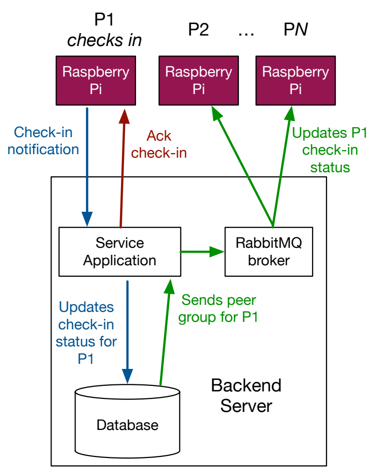

Figure 4: Backend Architecture updating check-in status for Participant 1 (P1) for both Check-in systems

In this paper, we propose a within-subjects study with rural older adults where we will compare two electronic Check-in systems where multiple users can check-in with each other via two-way communication. The first system is a peer-based, Check-in tree [1] shown in Figure 1. The second system is a peer-based Check-in toolkit that provides older adults with the ability to customize the physical enclosure [2] shown in Figure 2.

System Overview

We will describe the two systems, the Check-in Tree [1] and Check-in Toolkit, which is an extended version of Craftec [2].

Check-in Tree

The Check-in Tree [1] is a peer-based Check-in system tailored to the check-in needs of older adults. Older adults in rural areas typically use some common real-life Check-in systems (e.g., turning on/off the porch light) to indicate with neighbors that they have woken up. For example, neighbors will call if a friend has not indicated they woke up. This idea of morning check-in is replicated through the Check-in tree prototype. The tree design and specific features were fine-tuned to make it look more aesthetically pleasing based on feedback from three older adult consultants.

Ideally, each older adult in a neighborhood peer-group would have their own Check-in tree. Each Check-in tree would have a picture of everyone in their peer-group along with their own picture at the top, as shown in Figure 1. When an older adult gets up in the morning, he presses the button on the Check-in tree and the LED near his picture goes from gently pulsating to steady. The older adult's status (steady LED light) appears on the Check-in trees of all of their peers. In case the LED does not change, then a neighborhood peer could check on their neighbor.

The Check-in tree is made up of a custom enclosure routed out of wood with a Raspberry Pi 3 stored in the tree base. Each picture is lit up by an LED that is connected to the Raspberry Pi via internal wiring through a breadboard. The Raspberry Pi connects to a central server via a researcher provided internet connection from the older adult's home, as shown in Figure 1.

Check-in Toolkit

The Check-in Toolkit is also a peer-based Check-in system that simulates the functionality of the Check-in Tree, and also extends the functionality of Craftec [2]. Craftec empowers older adults to explore electronic interactions that inform future interactive systems by abstracting inputs and outputs on a Circuit Playground Express and associated input and output components. We extended Craftec by utilizing a Circuit Playground Bluefruit so that it can wirelessly communicate with the technical architecture. We also added in NeoPixel components so that we can communicate older adult availability based on colored lights similar to the Check-in tree. Older adults can use the Check-in Toolkit to enhance household items to communicate about check-ins or create an artifact that will blend right into their surroundings.

Included in this toolkit is an Adafruit Circuit Playground Bluefruit, a Raspberry Pi, a LilyPad light sensor, and Flora RGB Smart NeoPixels. The Circuit Playground Bluefruit is connected with a Raspberry Pi via the built-in Bluetooth for wireless communication. The light sensor acts as an input to indicate a check-in action, and the strings of RGB NeoPixels work as LED outputs. Each NeoPixel indicates one participant.

The Circuit Playground Bluefruit connects to the light sensor and LEDs through magnetic connections built into the laser cut balsa wood bases. Each component's base is engraved with the component name. Each pin on the electronic component is hand sewn with conductive thread to holes in the balsa wood bases that contain magnets. Figure 3 shows the connections for a NeoPixel. Insulated wires with jewelry clips attached to the ends touch the embedded magnets to allow connections to be easily made between the components.

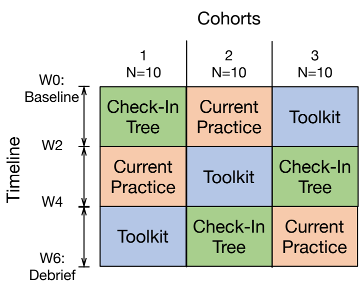

Figure 5: Study Plan

Technical Architecture
Each electronic Check-in system's Raspberry Pi connects to a backend server via a researcher-provided internet connection as shown in Figure 4. When an older adult checks in for the day, the Raspberry Pi sends the message to the backend server where the service application collects the peer-group data from the database and then forwards it to the RabbitMQ broker to notify all the members in the participant's peer-group about their check-in. The RabbitMQ broker utilizes a publish-subscribe protocol where all participants in a peer-group subscribe to the broker. RabbitMQ publishes received notifications from one participant to all subscribed participants in the peer-group simultaneously.

Study Plan

The study aims to identify how older adults would like to check in with each other. We will compare older adults' use and preferences utilizing three systems - (1) the ready-made Check-in tree; (2) a self-built Check-in toolkit system; and (3) their own current practices - via a within-subjects study over 6 weeks with 30 older adult participants.

We are most interested in finding:

- RQ1: With whom are older adults checking-in?
- RQ2: How often are older adults checking-in with each other?
- RQ3: How often do older adults follow-up on each other after checking-in?
- RQ4: What are the reasons behind older adults' preference of using a certain system prototype?
- RQ5: What challenges are faced by older adults while checking-in?

Study Design
We will conduct a within-subjects study design for a duration of 6 weeks where participants will use a specific system in a 2 week phase. The Check-in systems are randomized among participants divided into 3 cohorts as shown in Figure 5. For example, in the first phase ten older adults in cohort 1 get the Check-in Tree, another ten older adults in cohort 2 utilizes their current check-in processes (if any) and the remaining ten older adults in cohort 3 will have a workshop to build their own Check-in system with the toolkit. The randomization will help reduce recency and anchoring bias. Each cohort will have ten participants where they need to have a peer group of at least one other person to check-in with.

After ethics board approval, we will work with the Indiana University Center for Rural Engagement to identify rural community centers to recruit cohorts of older adults. Once enrolled, we will conduct semi-structured baseline interviews with older adults to assess current check-in behavior. We will investigate with whom older adults check-in with and how they usually do so. We will check-in with participants each week and conduct a longer interview at the end of each two-week phase.

For the *current practice* phase, participants will utilize their current practices for checking-in to gather baseline data so that we can compare between the two check-in systems and their interview data. Participants will use a diary to log specific data, such as a list of people they checked-in with, the medium they used, when they checked in, and any follow-up they may have done. Alternatively, we could have participants review call logs and do a recall interview to discuss who they called and why.

For the *two Check-in systems* phases, the data will be automatically collected and stored in a secure remote server. The backend database will record quantitative information such as, peer-group network data, check-in timestamp, and check-in status. The timestamp information will provide us with the frequency of check-in and help us understand how often older adults check-in on their peers.

At the end of each phase, we will debrief participants on that system via semi-structured interviews to understand older adults' acceptance of such Check-in systems and the challenges faced while checking-in with each systems thereby, providing potential design directions to overcome those challenges.

Discussion

The proposed study aims to explore not only the utility of a Check-in system in helping older adults connect socially, but also the impact of making the systems customizable from the user end. We are particularly looking forward to feedback from experienced researchers at the workshop on the study design and data collection methods and in general, key aspects that should be taken into consideration while working with rural older adults.

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Why Don't Elders Adopt Two-Factor Authentication?
Because They Are Excluded By Design

Sanchari Das
Andrew Kim
Ben Jelen
Joshua Streiff
L. Jean Camp
Luddy School of Informatics,
Computing, and Engineering
Indiana University Bloomington
Bloomington, IN 47408, USA
sancdas@iu.edu anykim@iu.edu
bcjelen@iu.edu jostre@iu.edu
ljcamp@iu.edu

Lesa Huber
School of Public Health
Indiana University Bloomington
Bloomington, IN 47405, USA
lehuber@indiana.edu

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Abstract
Two-Factor Authentication (2FA) provides effective protection for online accounts by providing efficient and highly robust access control. Adoption and usability, however, remain challenges for such technologies. Most research on 2FA focuses on students or employees in the tech sector. As older adults increasingly use everyday digital technologies, providing convenient means for them to protect their online data has become extremely crucial. To aid with this, we investigated the user experience of 2FA security tokens with ten older adults (> 60 years) using surveys, semi-structured interviews, and a think-aloud protocol. Their lack of adoption of the devices stemmed from its shortfall of inclusive design. Most available security tokens which were compliant with tablets have very small form factors; nearly invisible in a purse, and easy to slip through a pocket. The larger security keys are device and browser (Google Chrome) dependent. Hence, we propose design modifications and effective risk communication techniques to encourage 2FA adoption among organizations that are most invested in protecting older adults - such as retirement management funds, banking institutions, and health care organizations.

Author Keywords
Authentication, Older Adults, Security by Design

CCS Concepts

•Security and privacy → Human and societal aspects of security and privacy; Usability in security and privacy; Please use the 2012 Classifiers and see this link to embed them in the text: https://dl.acm.org/ccs/ccs_flat.cfm

Introduction

Passwords are one of the most prolific methods of online authentication. However, in the wake of common cybersecurity attacks, such as phishing [9], online identity theft [2], and improvements in password cracking techniques [10], passwords have become increasingly vulnerable to both human and technical exploits. In order to reduce the risk of account breaches, two-factor authentication (2FA) is a security measure that can be added to provide an additional layer of identity verification. Despite the additional security benefits of 2FA, it remains relatively underutilized for personal usage [4, 13, 5].

Technological advancements have led to increased use of the Internet and digital devices by older adults [1]. Previous research has shown differences in risk perception between older adults and other populations [3, 8, 15]. Financial scams in particular are estimated to cause as much as $36 billion loss [11] for older adults each year. For this reason, we investigated the usability of hardware security tokens for a more diverse and representative population of older adults (> 60 years). To understand the challenges older adults encounter with 2FA tools, we analyzed the end user experience of registering and using the FIDO U2F Security Key (Figure 2) by implementing a think-aloud protocol, surveys, and semi-structured interviews.

Methods

We conducted a qualitative usability study of FIDO U2F Yubico Security Keys (Figure 2) to understand how older adults interact with 2FA security tools. We tested the usage behavior and risk perception of older adults by replicating and extending the study methodology of Das et al.'s work [5]. In that study, we tested the usability of hardware security tokens with university students by conducting surveys and a think-aloud procedure.

Figure 1: Security Key by Yubico that supports U2F and FIDO2

Study Design

We recruited participants through snowball sampling by advertising through flyers and word-of-mouth. The subjects were required to (i) be at least 60 years old, and (ii) have a personal mobile phone/tablet/laptop. Once selected, they filled out an online pre-survey, where they were asked questions about their computer and security expertise in order to identify differences in the technology proficiency of the subject pool. After the pre-survey, an in-person think-aloud protocol was conducted, where a participant was provided with the YubiKey and asked to register the key with their personal Gmail or social media account. During the think-aloud protocol, the participants described their actions while offering real-time explanations about their choices and reasoning.

Four participants did not have a Gmail account or did not want to set up 2FA with it, so they were asked to set up the YubiKey with their Facebook account instead. Facebook requires their users to associate their phone number to add security based or app based 2FA. One participant was unwilling to share their phone number with Facebook, so they set up the YubiKey with their Twitter account. Another participant was unable to access their personal Gmail or could not verify their identity from their phone number; thus, they used their work account, which supports security tokens. All participants were given set up instructions available on the Yubico website [1]. Specific instructions for Google/Facebook/Twitter integration were provided in the application list by Yubico.

All of our participants experienced challenges during the installation procedure and required the assistance of the researcher to move forward. After the setup was completed, the researcher asked the participants a series of open-ended questions about the Yubico Security Key, as outlined by Das et al. [5]. The 2FA security keys were given to the participants as a token of appreciation for their participation. We audio-recorded the interviews and the setup think-aloud process. All of the recordings were transcribed by researchers and stored in secure locations. Using these transcripts, further qualitative analysis was performed. The study was approved by the institution's ethical review board.

Findings and Discussions

We analyzed the qualitative data we collected to understand the detailed reasons for non-adoption or negative perception of 2FA usage in everyday life. For our qualitative analysis, we adopted the methodology of Das et al.'s work [6]. Our pre-screening survey evaluated the computer and security expertise among participants based on Rajivan et al. [12]. Majority of the participants had no experience with computer security, which was why many participants had security scores of 0. All of our participants experienced difficulty with registering the keys and took an average of 52 minutes to complete the study. Nearly all participants (nine out of ten) acknowledged that registering the keys was a complicated process, as most of the participants noted,"...I would have given up long ago if I was not registering it with you (the associated researcher)...""

[1] https://www.yubico.com/

Device Compatibility and Form Factor

Most of the participants in our subject pool only had a tablet or a personal desktop; they did not use a laptop for their online browsing. The YubiKey that we tested does not work with tablets or smartphones. We provided information about other Yubikeys such as near-field communication (NFC)-enabled YubiKeys, as well as security tokens that are compatible with USB-C ports. Our participants mentioned that the USB-C port key has an extremely small form factor, which would make it difficult for them to use daily.

Facebook 2FA Issues

When registering their keys, four participants added 2FA to their Facebook accounts. Facebook recently made it compulsory for users to add their phone number to enable a second factor of authentication. One of the participants refused to provide their phone number to Facebook due to privacy concerns. Another participant tried to receive their verification code, but did not receive anything after repeated attempts due to a Facebook server error. They said:"... I would have given up in the third attempt and returned the key to the seller. I might not be able to login to my own account if Facebook does not allow me to add the key in the first place..."

Browser Incompatibility

Yubico U2F protocol-enabled keys only work with Google Chrome version 38 or later or Opera version 40 or later. Five out of the ten participants tried to use other browsers, such as Safari, Mozilla Firefox, and Internet Explorer, where these keys would not work. Thus, they believed that the key was not functioning properly, and the researcher had to guide them to the correct browser. Browser requirements were only mentioned later in the instructions, which confused the participants.

Hidden and Unclear Instructions
Nine out of ten participants expressed frustration with finding the instructions on how to register the keys. Four of the participants watched the videos on the Yubico website and noted that the keys are useless if they cannot even register them. The instructions seemed verbose to the participants, who wanted a simpler interface where they do not need to go back and forth between instructions and account settings to register the keys.

Implications
Our study found that the FIDO key technology, as implemented with the Yubikey, was a poor match for older adults. It did not cater to their existing technology, and it failed to address their needs and risk perceptions. We encourage confirming registration and clearly communicating the risks of not using 2FA to improve older adults' online security.

Confirmation of Registration
Adding a page that confirms the registration is a simple design change, but it can be effective in enhancing the user experience. After completing the registration, the participants were not sure whether the registration procedure was complete or not. Due to the key's form factor, they expected that they could use the *Safely Remove Drive* option as they usually do for the USB flash memory sticks.

Communicating the Risks
Risk perception is based on our instincts and the information provided to us; it has a strong role in our decision making process [14]. Thus, for computer security threats, we need to communicate the benefits of 2FA adoption and the risk trade-offs of non-adoption to older adult users. If users cannot perceive the severity of their inaction, they will not be aware of any potential adverse consequences [7].

Limitations and Future Work
Studying a representative sample of diverse older adults, rather than a convenience sample of younger adults, is critical to designing effective and acceptable solutions. Our work addresses the lack of studies focusing on the online security of older adults, particularly regarding their authentication strategies. We explored their 2FA usage and adoption issues and provide actionable recommendations to improve it. We acknowledge that individuals can have different experiences with different types of accounts, such as email and social media, which cannot be generalized. However, a comparison of different accounts provides us with problem points that can be addressed at the application level to improve security for all. As a future extension, we intend to conduct a timeline-based analysis of users' continuous usage/non-usage of the security tokens. We also plan to apply different types of risk communication strategies (graphical and/or textual) to gauge their effectiveness on elderly users' risk perceptions. In future research direction we will subdivide the subject pool by age to provide more granular analysis.

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Why the use of technology by older adults is an engagement issue (not a usability issue)

Lina Lee
UNC Charlotte
Charlotte, NC 28223 USA
llee52@uncc.edu

Mary Lou Maher
UNC Charlotte
Charlotte, NC 28223 USA
m.maher@uncc.edu

Abstract
Older adults face significant loss and limitations in terms of mobility, cognitive ability, and socialization. By using interactive technologies they have the potential to overcome such loss and limitations, and to improve their quality of life. Many studies focus on usability to address their challenges when using interactive technologies. The issues in designing technology for

older adults should include engagement and positive affect. In this study, 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.

Author Keywords
Engagement, Aging and Technology, Design

ACM Classification Keywords

Introduction

Aging is one of the most significant social transformations of the twenty-first century. Applying technology to the aging process has the ability to help people "age well" and stay active [2, 12]. Despite the increasing amount of studies in the field of aging and technologies [3, 6], it still lacks design theories specific to older adults [14]. In this study, we focus more on understanding how to motivate older adults and increase their interest in technology from a cognitive perspective. We aim to make a theoretical contribution to this issue, asking: 1) How can we model the context of aging in the digitized world? 2) What are the factors that engage the older population in the use of technology to adapt and live well in the digitized world? To answer these questions, we investigated major theories related to aging. We conducted a variety of studies on older adults by using 4 technological interventions which promote creative expression and emotional connectedness. We have accumulated data on older adults' behaviors, experiences and opinions about the technology through various research methods such as focus group discussion, in-depth interviews, observations, and in-the-wild user studies. Based on this experience with older adults, we present some factors to start the discussion on moving beyond usability when designing for older adults.

Why Engagement?

As the population increases and we experience better nutrition and healthcare, we are seeing that the number of older adults is increasing. Older adults will inevitably be surrounded by interactive services and technologies in their living environment, regardless of their wishes in this regard. Numerous studies have shown positive correlations between technology use and subjective wellbeing [16], pointing to the fact that engagement in new technologies might be of importance for successful and active aging. However, designing new technology for older adults is challenging [11]. When people grow older, they inevitably experience a significant decrease in their physical, cognitive, and sensory capabilities, which lead them to develop negative attitudes towards technology [3, 17]. In reality, studies on diverse technological interventions tend to focus on utilitarian factors, such as usability, monitoring physical experiences [5], and rarely mention engagement and social positive affect [10]. Many studies overlook the fact that the positive mindset of older people has a positive impact on their physical and mental health. When designing interactive technology for older adults, considering the factors that engage older adults in the use of technology should precede designing of interactions or consideration of usability issues.

Aging in Digitized World

Aging has many dimensions that have been explained by multiple theoretical perspectives [8]. Efforts are needed to understand the context of aging in the digitized world. The earliest theories on aging came from the psychosocial disciplines, including activity, disengagement, subculture, continuity, age stratification, person-environment-fit, and gerotranscendence theories [1]. These theories focus on attitudinal, environmental, and institutional changes in their later life [7]. Living arrangements are dynamic because of changes associated with life events, such as widowhood, retirement, and changes in living environment. Aging is a lifelong process characterized by transitions. Psychological theories (human needs, individualism, stages of personality, life span, and selective optimization theories) show how mental processes, emotions, attitudes, motivation, and personality influence adaptation to physical and social demands [15]. These theories help us to understand how cultural, spiritual, regional, socioeconomic, educational, and environmental factors as well as health status impact older adults' perceptions and choices about their technology needs. Collectively, these theories reveal that aging is a complex phenomenon there is a need for research in the field of aging and technologies. HCI researchers can use this knowledge and implement ways to understand how older adults adopt and accept new technologies to their life.

Technological Interventions We Used

In this study, we use four technological interventions to identify the factors to increase older adults' interest and engagement in interactive technology. Initially, our design concept emerged from needfinding interviews with older adults. We found that many older adults enjoy being creative, playing games, and being social. *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 [9]. With these four technological interventions, we conducted 10 focus group discussions with a total of 35 older adults (Move and Paint: 2 times with 16 participants, uDraw: 5 times with 4 participants, Savi: 3 times with 15 participants). In-depth interviews were conducted with a total of 38 older adults (Move and Paint:15 participants, uDraw: 4 participants, Savi: 16 participants GrandPad: 3 participants). We performed in-the-wild user studies to investigate the engagement and behavior patterns of older adults with a total of 47 older adults. We conducted a longitudinal study as an intervention with a diary study, self-report, pre and post in-depth interview with a total of 7 older adults.

Designing Engaging Technology for Older Adults

We analyzed the data using various qualitative methods using thematic analysis, behavior classifications, and framework analysis. Below we summarize our findings related to the design and context of technology for older adults that have the potential to lead to successful design and adoption of engaging technology for older adults. We identified three design goals for designing engaging technology to explain why older adults should engage in the use of technology. Then, we identified two contexts as requirements to enable older adults to adopt interactive technology.

Design Goal 1: Refocus from designing what older adults need to what older adults want

Older adults would be more encouraged to use 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 focus merely on finding the needs of older adults, the interactive systems for older adults are mainly inclined towards the devices to compensate for their physical and mental shortages. Efforts are needed to perform a 'want-finding' process when designing interactive technologies for older adults in order to lead to fun and satisfactory experiences. Older adults might prefer using VR games just for fun instead of wearing a wearable device to monitor their health and track fitness.

Design Goal 2: Socialization a key motivator for older adults to engage with technology
Interactive technologies should be presented as tools for promoting socialization. Many research disciplines point out that active participation and engagement in social activities are critical for maintaining a good quality of life for older adults [13]. Changes in the role as members of society caused by aging have a great effect on the use of technology by older adults. Sustaining enhanced connections is an important motivator in relation to the acceptance of technology [4].

Design Goal 3: Designing technology that is focussed on engaging experiences (UX) in more important than usability for older adults
When introducing new technology to older people, it is necessary to consider how to help older adults engage with technology while providing positive experience to them, beyond mere usability. The initial interest of older adults is important and they will accept the technology when they are comfortable with the environment in which the technology is introduced. When this design principle is applied, it is possible to reduce fear, difficulty, and stress that they feel while they use new technology. To have older adults adapt to interactive technology, they should not be required to engage in a complicated process for using that technology.

Contextual Requirement 1: Focus on the barriers older adults have when introduced to new technology (not on usability but on installation)
Older people tend to decide on the use of technology on the basis of time and mental efforts they expend, rather than benefits they get from technology. For example, although Move and Paint is specially designed for older adults, subsidiary problems, such as issues regarding setup and software updates, still make them dependent. They will be reluctant to use the system because of such inconvenience, instead of preferring to use it for the benefits they would gain. It is necessary to consider how the installation process can be simplified so that older adults can use it by themselves.

Contextual Requirement 2: Personal intervention is necessary for engagement
Mostly, older people do not use technology on their own 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. Personal help or community services are important to preclude any sense of isolation and reduce their stress while interacting with the system.

Discussion
The overarching goal of the interactive technology developed for older adults is to assist them in tackling problems they encounter, and to design easy-to-use systems. Many papers present the importance of understanding the characteristics and attitudes of older adults in order to improve the usability of technology for this population. To understand key factors that

influence their acceptance of interactive technologies, researchers must strive to develop a theoretical framework or principles that can be commonly applied to understand the emotional needs and engagement of older adults. We propose a discussion of the characteristics of older adults which lead them to decide whether or not to use technology. This will enable us to design for the complex phenomenon of aging with technology. 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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Designing Voice User Interfaces for Older Adults: Challenges and Opportunities

Alisha Pradhan, Amanda Lazar
College of Information Studies
University of Maryland, College Park, USA
{alishapr, lazar}@umd.edu

Abstract
Voice interaction supported by commercially available voice assistants are increasingly used by older adults. In particular, voice assistants embodied in smart speakers (e.g., Amazon Echo, Google Home) enable non-visual interaction that does not require extensive expertise with traditional mobile or desktop computers, thus offering new possibilities of access to digital technology. However, emerging research indicates that this new interaction modality has its own challenges. In this position paper, we discuss our findings from a field study to highlight the challenges and opportunities for designing voice technologies for older adults.

Author Keywords
Older adults; voice assistants, voice user interfaces

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Introduction and Background
Voice user interfaces (VUIs) supported by conversational voice assistants such as Alexa, Google Assistant or Siri, are having an increasing presence in many older individuals' daily lives [8]. The voice assistants embodied in smart speakers such as Amazon Echo and Google Home offer conversational voice-only interaction, thus presenting new affordances as compared to traditional computers or touchscreen mobile devices.

Past work on older adults' use of voice interaction paired with graphical interfaces sheds light on how individuals deem it as easy to use [3] and prefer the speed of voice interaction over typing [12]. Research also suggests that voice-based interaction can increase the overall confidence of using technology for some older individuals [9]. These findings are also corroborated in emerging research on commercially available VUIs. Preliminary research in this space indicates how older adults are overall positive about using voice interaction supported by smart speakers, primarily due to its ease and convenience of use and enabling of easy access to digital technology [4].

While the benefits of using voice interaction for older adults is evident in past and emerging works, there is also research indicating how this modality of interaction might have its own unique challenges. Some of these challenges can arise with voice interaction due to hearing loss, noisy environments and concerns around privacy [3]. Specifically, in context of commercially available voice technologies, recent works have noted similar challenges in older individuals hearing the voice agent due to high pitched female voices [1]. Identifying these challenges is essential as there is a growing impetus to better understand and design voice interactions specifically catered to the unique needs of older individuals [10]. In this work, we describe findings from our fieldwork to highlight challenges experienced by older adults when using VUIs.

Study Description and Findings

Methods. We deployed smart speaker devices (Amazon Echo Dot and a paired tablet) in the homes of seven retired older adults (aged 65 or above). Participants had no prior experience using voice assistants, and none used a smartphone or computer daily. Devices were set up in participants' homes by the research team. Participants were given initial training to use the basic device features such as setting alarms, reminders, timers, playing music, asking questions etc. We conducted four in-person, semi-structured interviews: following device setup on first week, at the end of the first and second week, and an exit interview at the end of the study. The interviews covered perceptions of voice-based technology, actual usage of the device and desired use of this technology.

All in-person interviews and diary entries via phone call were analyzed using a thematic coding approach [2]. The results of the field study are described in detail in two papers [6,7]. In this extended abstract, we synthesize and expand upon some of the specific challenges that participants described when using the smart speaker-based voice interface, as well issues with designing voice-based interaction for searching online information.

Timing out of the device. Participants reported problems with the device timing out after using the wake word due to a delay in speaking their complete command. For example, P6 described how she "*might wanna say, "Alexa, could you tell me..." and then I'm thinking. So then it cuts off, then I think of what I wanna ask and then ask."* Some participants described how frustrating this was: P5 explained that she had to go back and *"do the whole thing over, and then you're worried and you're trying to do it really fast that it is gonna shut off again."* These findings are consistent with research that indicates that with age individuals might take longer to realize intentions [11], which can lead to slower speech rates. Voice interfaces may base timeout lengths on younger users, and many of these voice interfaces do not support customizable listening time of the voice agent for user input.

***Remembering specific voice commands*.**
Participants, at times, experienced difficulty with remembering specific keywords that were required to use some skills and/or device features (e.g., reminders). Issues arose either in invoking the feature/app itself or while navigating within the feature/app to achieve specific goals. For example, P2 was unable to independently use a third-party app (Bible skill), which she had activated in presence of the researcher during the introduction of the Alexa skills.

Compounding the problem of remembering keywords, applications that used navigational commands (e.g., “more information” or “next”) were challenging. These commands are inconsistent across built-in device features and third-party apps. For example, P7, who learned to use a voice navigation command for one app (“more information” in the Allrecipes skill) tried applying it to other tasks and was unsuccessful (e.g., “more information m. and t. bank”). These inconsistencies in using voice commands affects the overall experience of using voice interfaces for many users. Ongoing research on compiling heuristics for designing voice interaction could consider keyword consistency as an important heuristic.

Customizing the voice feedback. Some participants described how they wanted to customize Alexa’s voice output, particularly when using memory support features such as alarms or timers. For example, P3 described her preference for having an alarm that speaks *“when you ask it for the alarm, it just gives you that beep...that noise. And I think it would be better if it would just say..."It is now such-and-such a time. Time to get up." I understood… better speaking-wise than the beep, the sound”* [P3]. P2 similarly desired for a personalized voice feedback for the alarm: “*I would want the alarm clock to call my name…and say "[P2’s name], get up now."*

Challenges in designing voice-only interfaces for health information seeking. In addition to the above challenges and customizations described by participants, we observed that all participants used Alexa to find health information by voice, which in itself raises open questions on how to ascertain credibility of information in voice-based interaction. As voice-based interfaces become widespread, it is important to consider differences that exist between non-visual voice interfaces and traditional computer-based searches for older adults. Voice interfaces do not provide multiple information sources or contextual data (including page layouts, advertisements, etc.) associated with a webpage, which are essential elements for discerning trustworthiness of information on a website. Even though some voice assistants currently reveal the source of information (e.g., Mayo Clinic), these sources might go unlooked or unheard (as in the case of VUIs), particularly by older users [5], and hence might not be enough to address the issue of information credibility, warranting further research in this space.

Conclusion and Future work

In our three week long field study with older individuals who used computing devices infrequently, we observed some challenges while using VUIs including difficulty in remembering specific keywords and the device timing out before the user could complete the command. Opportunities to provide unique end-user customizations and ensuring credibility of information accessed through VUIs open up new avenues for future research. While our findings are with respect to older adults residing in United States, it is possible that much of these challenges might become manifold as this technology is being adopted globally—with non-native English speaker users, users from diverse socio-economic, and literacy groups. Future work should further investigate these concerns at global scale.

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At Home with the Amazon Alexa: A New Lens for Designing for Older Persons with Cognitive Impairment

Galina Madjaroff Reitz
University of Maryland
College of Information Studies
College Park, MD
gmreitz@umd.edu

Helena Mentis
University of Maryland Baltimore County
Information Systems
Baltimore, MD
mentis@umbc.edu

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Abstract

Technology solutions for older adults who want to remain in their home have focused on the burdens of caring for someone with cognitive impairment and characterizing their caregiver as carrying a burden. The solution for home-based technology interventions has thus been focused on the biomedical, declinist, and disease narrative driven view especially with those of

cognitive decline. Following a deployment of the Amazon Echo with intelligent agent "Alexa", we conducted interviews, home visits, and collected dialogue history data where we identified that daily care activities for the couples were complex interactions that emerged from the using the technology and supported the partners' interpersonal, creative and symbolic needs. These results provide a new lens for the design of interactive systems in the home by maintaining autonomy for both caregiver and care recipient to live in line with their own values and identity.

Author Keywords

Authors' choice; of terms; separated; by semicolons; include commas, within terms only; required.

CSS Concepts

• **Human-centered computing~Human computer interaction (HCI)**; *Haptic devices*; User studies; Please use the 2012 Classifiers and see this link to embed them in the text: https://dl.acm.org/ccs/ccs_flat.cfm

Introduction

The design of technologies for older adults, specifically those with dementias, has often been focused on the model of supporting the perceived decline. In other words, designs are based on paternalistic, illness narratives that reinforce the notion that older adults need are to be assisted with taking medication or tracking their location [14,16]. It also laments the burden on the caregiver in providing the support needed.

But there is a different way to look at how to help/treat people. In the Aging Studies literature, the concept of person-centered living and care builds upon the strengths of a person and honors their values, choices and preferences [21]. A person-centered model of care reorients the medical disease-dominated model that can be solely focused on the individual's activities of daily living (ADL's), to one that is holistic. Madjaroff et.al [16], discuss a person-centered model of care that supports remaining abilities and caring relationships. BASICS is a hierarchical model that explores the individual needs of the older person and each letter of BASICS represents a level in the hierarchy of needs; one must satisfy each level in order to move onto the next. For example, biological needs, followed by Activities of Daily Living and so on until one's need for expression of beliefs, hopes, and dreams are fulfilled. We have adopted this model to reflect evaluation of technologies for dementia.

Likewise, disability studies in HCI have begun to frame the design narrative as identifying the functional needs of the person with disability and matching those to a technological opportunity. Frauenberger [8] and Mankoff [17] discuss the idea of the dichotomy between the medical and social constructs in approaching disability design studies, particularly in the way they motivate the design and evaluation of technology. They both argue that the medical model may be useful, yet "deeply oppressive" and "if the medical model prevails, a person with an impairment might, justifiably, be asked to forgo his/her autonomy forever…"[17]. The social model on the other hand shifts the narrative from "cure to care" with a focus on the person's strenghts and their lived experience.

Madjaroff and Mentis [16] explored the potential of a new model of design of home-based technology for those with a progressive cognitive impairment and their familial caregivers. They postured that technology that elevates one's personhood and provides a realm where technology improves the narratives of care in the home leads to a better quality of life for both caregiver and care recipient. Finally, Lazar et. al [14] argued that the *critical dementia* perspective in design for those specifically with dementia-related impairments recognized people with cognitive impairment as making meaning in a contextualized and social manner.

To illustrate how such a technology can be designed, we took the approach of first deploying a technology that was not designed with the aging or cognitively impaired population in mind, and yet is supportive of all five of the six levels of the BASICS model: the Amazon Echo. Several of the Echo features are particularly valuable to this population, including those with aphasia, apraxia and agnosia, common symptoms of those suffering with MCI. Because this technology was not designed from the medical model we postulated that it would support both the caregiver and their partner in the home without sacrificing autonomy.

We deployed the Amazon Echo with its digital agent Alexa in the home of six couples, caregiver and care recipient partners for a period of four months. What we uncovered through interviews, home visits, and dialogue history data was that an interactive technology not built from a medical model is adopted to support more than just the management of the disease. We found that participants had a high number of interactions with the intelligent agent device during the study period and the technology supported not just Activities of Daily Living but a higher level of need, including interpersonal, creative and symbolic. The daily care activities of the CPs that were seemingly fundamental were actually complex care activities that emerged from using the technology that support the care partners on multiple levels in satisfying multiple needs. From these findings we make suggestions on what the future of design for those with various levels of dementia could look like.

Mild Cognitive Impairment

Mild cognitive impairment (MCI) is considered a transitional stage between normal aging and dementia and is typically diagnosed once there is presence of cognitive decline without significant functional impairment [13]. Cognitive decline refers to impairments that involve issues with memory, language, thinking and decision making that are greater than just age-related changes. Older adults who have experienced these symptoms, and their family and friends, are often aware of these changes, but they usually do not interfere with daily life and activity [19]. Mild cognitive impairment is characterized by a noticeable decrease in cognitive functioning that goes beyond normal changes seen in aging (Peterson, 2001), but is not clinically diagnosed as dementia yet.

Design for dementia

Typically, in gerontology and geriatrics research, the main focus of technology deployment is investigating how to improve the patient's memory and cognition prevent the patient's falls [1] [10] or alleviate caregiver's distress by enhancing access to online support services [9]. Likewise, technology solutions have focused on the burdens of caring for someone with cognitive impairment [2,14,23]. The design of technology for dementia interventions has thus been focused on the biomedical, declinist, and disease narrative driven view of cognitive decline [22]. In other words, the care receiver is seen as deficient and in need or help while the caregiver as a result is seen as shouldering a burden and needing relief.

Due to the rising prevalence and incidence rates of dementia, and this newly and identification of MCI for older people acknowledged state of early dementia, of varying degrees there has been a considerable focus on the deployment of technology that supports the needs of older adults with cognitive impairment reference . There are several important challenges when addressing the needs of older adults with cognitive disability and their caregivers, including (1) diminishing emotional well-being [20], (2) social isolation [15] and (3) loss of autonomy and sense of security [18]. These all lead to a lower overall quality of life for both caregiver and care-recipient [21]. In order to design and disseminate technology that enhances the lives of older adults with dementia and related disorders and their care partners, it is important to broaden our consideration of the many elements that make up their lives, needs, preferences, and experiences with technologies in their home. The emphasis should be less on what needs to be 'fixed' from the perspective of those on the outside and instead focus on a life that is fulfilling and self-affirming as defined by the care partners [16]. Understanding the needs and values of key stakeholders in the family system, involving the individual with MCI and their own care, their caregiver and any other actors that contribute to their well-being, is an important basis for developing and designing technologies that support the person and their familial caregivers. Family systems and subsystems are affected by the presence of cognitive impairment of one of its members with varying impact on physical function and psychosocial well-being of each member [21].

New models for design

The predominant models of design for the aging cognitively impaired population have been to alleviate the burdens of caring for someone with cognitive impairment [2,14,23]. This includes characterizing the care recipient exclusively as vulnerable and dependent [4,14] and they should be cared for predominantly by using close monitoring via sensors [5,24] assistive technologies [11,12,25] by their caregiver whose role is seen primarily as a burden and mitigating risk. In this stream of research, the person affected with cognitive impairment is often treated as a separate actor from the caregiver [2,3,6,23,26]. Viewing this interdependence through a negative lens can lead to reducing the care recipient simply to a person with no autonomy who merely needs to be assisted and the caregiver as the one there to provide that assistance. Interdependence is a much richer concept that includes the framework of relational autonomy- supporting the idea that a person's autonomy is affected by those around them, in this case the caregiver and care-recipient. This means that both actors depend on each other for support in gaining more autonomy. This framework for design must be sensitive to the roles of each person in the partnership without bias. As cognitive decline progresses, identity preservation and choice are that much more important for both individuals in the relationship [7]

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Interactive Demo: Training Older Adults to Resist Scams with Fraud Bingo and Scam Detection Challenges

Molly Davies
Vice President of Elder Abuse Prevention
WISE & Healthy Aging
mdavies@wiseandhealthyaging.org

Daniel Marino
Amelia Nash
Kevin A. Roundy
Mahmood Sharif
Acar Tamersoy
NortonLifeLock Research Group
{Daniel.Marino, Amelia.Nash, Kevin.Roundy, Mahmood.Sharif, Acar.Tamersoy}@nortonlifelock.com

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Abstract

Older adults are disproportionately affected by scams, many of which target them specifically. In this interactive demo, we present *Fraud Bingo*, an intervention designed by WISE & Healthy Aging Center in Southern California prior to 2012, that has been played by older adults throughout the United States. We also present the Scam Defender Obstacle Course (SDOC), an interactive web application that tests a user's ability to identify scams, and subsequently teaches them how to recognize the scams. SDOC is patterned after existing phishing-recognition training tools for working professionals. We present the results of running a workshop with 17 senior citizens, where we performed a controlled study that and used SDOC to measure the effectiveness of Fraud Bingo. We outline the difficulties several participants had with completing SDOC, which indicate that tools like SDOC should be tailored to the needs of older adults. We also discuss how to adapt Fraud Bingo and SDOC for international audiences.

Author Keywords

Scams, Fraud, Interventions, Older Adults

CCS Concepts

•Human-centered computing $\rightarrow$ **Human computer interaction (HCI);** User studies;

S	C	A	M
S2 Bank Examiner Scam	C12 Direct Express Text Scam	A17 Grandchild In Distress Scam	M30 Recovery Room Scam
S6 Boiler Room Fraud	C16 Free Airline Ticket Scam	A23 Limit Personal Info on the Internet	M27 Nigerian Letter Scam
S1 "Advance Fee" Loan Scam	C9 Click Bait	A20 Guard Pin Number	M32 TypoSquatting
S8 Check links/urls	C13 Do Not Call List	A18 Guard Bank Accounts	M31 Install Anti-Virus

Figure 1: A Fraud Bingo card (please zoom in for improved readability).

Scam Tips

S1. "Advance Fee" Loan Scam - for an advance fee, you will get the loan you need. But then the paperwork stall begins and the loan never comes.
S2. Bank Examiner Scam - someone posing as law enforcement or bank security calls to tell you that fraudulent activity has been detected on your account. You are asked to participate in catching the "thief" by withdrawing money and giving it to this person as "evidence".
S3. Be Wary of Online Dating Sites - An online love interest who asks for money is almost certainly a scam artist.
S4. Be Cautious of Email Attachments - Opening email attachments from from unknown senders may infect your computer
S5. Block Pre-Screened Credit Offers - www.optoutprescreen.com or (888)567-8688
S6. Boiler Room Fraud - Call center selling questionable investments
S7. Charitable Solicitations - Before you donate over the phone, look up the charitable organization's number online and call them back. Scammers will say they are from the American Cancer Institute when the real organization's name is National Cancer Institute.
S8. Check links/urls - Hover the mouse over a link to a url to see where it's taking you. Destination URL should be displayed in lower left corner in most browsers
C9. Click Bait - Be careful when opening attachments or clicking links on emails that claim to relate to an emotionally charged current event, internet memes, conspiracy theories, etc.
C10. Credit Report - Review annually with all 3 credit bureaus. Freeze credit if you don't need to apply for new credit for a while.
C11. Report Scams to FTC - Federal Trade Commission (877)382-4357
C12. Direct Express Text Scam - Text message from a party claiming to be Direct Express, you are directed to call a number to provide card and pin number
C13. Do Not Call List - (888) 382-1222 or https://www.donotcall.gov/
C14. Dumpster Diving - Remember to shred documents with personal info
C15. Email Phishing - Do not follow links in emails or supply personal information
C16. Free Airline Ticket Scam - Phishing scam to obtain your personal info by claiming to be a reputable airline company & offering a free flight
A17. Grandchild in Distress Scam- Slowdown, talk to someone you trust and do not send money to anyone claiming to be your grandchild
A18. Guard Bank Accounts - Don't provide account information to anyone calling or emailing
A19. Guard Internet Passwords - Use complex password that do not contain identifying info
A20. Guard Pin Number - do not share it with anyone
A21. IRS Money Owed scam - The IRS does not send taxpayers unsolicited e-mails about their tax accounts, tax situations or personal tax issues.
A22. Jury Duty Scam - Scammer calls to say that you missed jury duty and now have a warrant out for your arrest. They ask for your social security number so they can "verify" that you were on the list.
A23. Limit Personal Info on the Internet - Only sign up for trusted websites
A24. Lottery Scam - The scammer claims you have received a prize but you need to pay taxes on the prize before you can receive your winnings.
M25. Mail Theft - Don't leave incoming or outgoing mail in your mailbox overnight or on weekends. Have the post office hold your mail if you're out of town.
M26. Use Caution When Browsing Websites - Always look for the https:// prefix. If you don't see the "s" don't enter any information on that webpage that you want to keep secure
M27. Nigerian Letter Scam - Nigerian Official asks for your help in exchange for a reward, this help is usually asking for money
M28. Online Auction Fraud - Do not purchase underpriced items, they may be counterfeit
M29. Text Phishing - Fake alerts that your accounts have been compromised
M30. Recovery Room Scam - These "recovery rooms" get the names of people who have been defrauded in other scams and then call and claim to be Federal attorneys or agents who will recover your losses for a fee.
M31. Install Anti-Virus - protect your computer from being hacked by installing anti-virus software on your computer and mobile device.
M32. TypoSquatting - Also known as "url hijacking" where bad actors own hostnames that intentionally look like valid domain names with typos such as Gopgle.com

Figure 2: Reverse side of an Fraud Bingo playing card with descriptions of all scams. Participants may take these cards home with them if they so desire.

Introduction

Older adults are disproportionately affected by scams and frauds of various kinds. For example, the United States' Federal Trade Commission reported that romance scams resulted in more reported losses ($143 million) than any other type of scam in 2018 [5]. While the median loss reported per victim was $2,600, it rose to $10,000 for victims 70-year-old or over. Prior work identified factors that are correlated with susceptibility to scams, among which age is often cited as a key factor [7, 8, 6]. Researchers found that older adults experience declining sensitivity to untrustworthy information [1, 3] and a reduced ability to detect lies [1, 10]. Studies also highlighted age-related functional brain changes in response to untrustworthy cues [1].

The lack of intervention tools specifically designed for older adults motivated the WISE & Healthy Aging Institute to develop Fraud Bingo—an activity to educate participants about frauds while playing the popular game Bingo—which has since been recommended by federal and state governments throughout the USA for use at senior centers.

We also developed the Scam Defender Obstacle Course (SDOC), an interactive web application, in similar vein to existing training tools used to educate working professionals about phishing scams [9]. Utilizing Fraud Bingo as a scam training, we explored SDOC's suitability as an evaluation tool during a workshop that involved 17 senior citizens in Santa Monica, California. We found that tools like SDOC that are designed to evaluate and train working professionals to recognize phishing scams are less effective for many older adults. Here, we present Fraud Bingo, SDOC, and lessons learned from running both with groups of older adults.[1]

[1] We will provide interactive demos for SDOC and Fraud Bingo and will discuss the challenges older adults had using SDOC

Fraud Bingo

Fraud Bingo is an educational game that is similar to Bingo, with the main difference that when a participant announces a square they are asked to read a fraud-related advice that is written on the back of their Bingo card. Fraud Bingo was developed and rolled out quietly by WISE and Healthy Aging, who have run dozens of events in Los Angeles County for over eight years to groups of between 30 and 150 participants. The game have spread by word of mouth to other parts of the United States. It has also been translated to languages other than English, including Armenian, Chinese, Korean, and Spanish. Various incarnations of the game exist, some of which cover frauds broadly, while others focus on specific frauds (e.g., investment frauds).

Fraud Bingo's development was motivated by a need to create an engaging educational tool that could attract large audiences, and in which people of all skill levels and cultures could participate. It builds on bingo's popularity, and prizes given out in events help attract audiences.

The majority of advice that we printed on the Fraud Bingo cards were derived from the original WISE & Healthy Aging Institute's game. From this set of advice we eliminated ones that were less relevant to computer security. Moreover, following prior work [4, 8], we added advice related to online romance scams, typo-squatting, and techniques that are typically used by scammers to mislead victims. Additionally, we decided to modify Fraud Bingo from a 5×5 to a 4×4 square since we were concerned that the values in the card cells would not be random enough based on the size of our pool of advice and number of cards we needed to generate.

Scam Defender Obstacle Course

The Scam Defender Obstacle Course (SDOC) is an online evaluation and training tool that we developed to *1)* measure susceptibility to a set of common on-line fraud schemes; and *2)* educate users on scam warning signs.

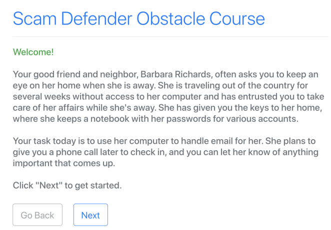

Figure 3: The SDOC instructions challenge ask participants to perform computer tasks and respond to emails on behalf of a friend.

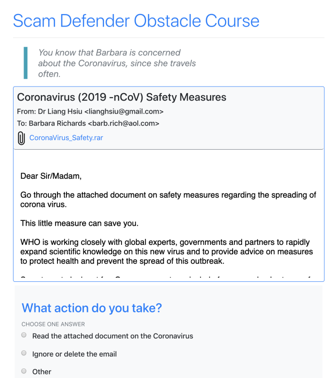

Figure 4: SDOC uses scam examples derived from real scam emails. This scam uses fears about the 2020 Cov-19 virus to entice users into opening a malicious attachment.

SDOC asks the participant to imagine that they are handling the affairs of a good friend who is out of the country and away from her computer for some time (see Fig. 3). The participant is then shown a series of emails and browser windows that they encounter while using their friend's computer to accomplish this task (Fig. 4). Some of the challenges present a legitimate correspondence with an action that should be performed – for instance, the gas company sending a notice that the payment for service was declined and the balance must be paid. Other exercises present emails that are common, real-world scams that include a range of lures that attempt to get users to click a link, open an attachment, or otherwise take an action that could lead to the recipient being defrauded. For each of these challenges, the participant is asked to indicate what action they would take (e.g. "Ignore and delete email", or "Click on link to update billing information"). The participants are also presented a free-form text box and asked to explain why they chose a particular answer.

The SDOC was designed as a dual-purpose tool, to both evaluate and educate. We aim to use it to help measure the effectiveness of educational interventions, such as Fraud Bingo, in helping older adults to avoid falling for scams by comparing the performance of a control group that was not trained with a group that did receive training. However, since the participants are engaged in a hands-on exercise and being exposed to real-world fraud lures, we did not want to miss the opportunity to provide feedback and tips to users to help educate them. In order not to affect the results of the evaluation, we refrained from providing any feedback until all ten challenges were completed. Afterward, users were shown which challenges were legitimate and which were scams, along with an explanation of the indicators that can be used to arrive at the correct conclusion.

Lessons from our Bingo & SDOC Workshop

We ran a two-hour workshop whose intended purpose was to serve a controlled study evaluating the effectiveness of Fraud Bingo as an intervention technique. The event was free and advertised and open to the general public. Participants were informed that they would participate in Fraud Bingo and in a computer training. 17 older adults participated in the workshop, and they were divided into two groups. One group of eight participants began the workshop in a computer lab where they tried their hand at SDOC. Eight additional participants began the workshop in an adjacent room where they played Fraud Bingo. After 50 minutes, the two groups switched rooms, and participated in the opposite activity. One additional senior citizen arrived at this time and participated only in SDOC. Eight of the 17 participants were part of a class hosted by WISE & Healthy Aging for individuals experiencing early-stage memory loss. These participants were split evenly between both groups.

Running this workshop taught us valuable lessons about how to run an improved version of our study in the future. We share those insights below.

Running Fraud Bingo

When asked, participants reported being satisfied with the experience of playing Fraud Bingo, or made no comment. We observed several reasons for which Fraud Bingo works well as an educational tool for older adults. In particular, the actual game of Bingo exists in various incarnations throughout the world and is easily learned. At least three participants had never played Bingo before our event, yet they were able to participate in our workshop without any difficulty. Moreover, the activity was inclusive—even partici-

Figure 5: Fraud Bingo workshop.

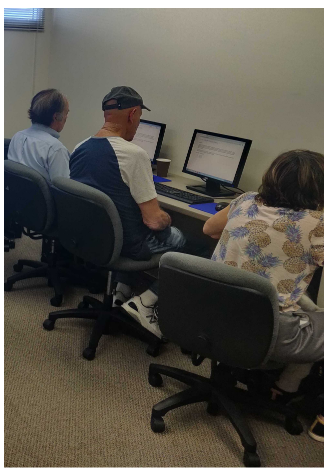

Figure 6: SDOC portion of the workshop.

pants with memory loss and other forms of cognitive decline were able to participate effectively. Last, via interactions throughout the workshop, participants were able to contextualize frauds for one another by relating experiences they have had. Such form of cooperative learning can potentially make the educational activity more effective [13].

Running SDOC

Our workshop represented the first occasion on which senior citizens had tried out the SDOC. The course was successful in certain ways, but the workshop also taught us several lessons in how to improve upon SDOC's design.

On the positive side, participants who were able to complete the SDOC (about half), reported enjoying the activity. Furthermore, SDOC increased participants' confidence in their knowledge, as several reported that it "reinforced what they already knew." This can potentially motivate the participants to adopt secure behavior in the future [11].

At the same time, the workshop highlighted several limitations of SDOC that should be addressed to improve its applicability for educating older adults. To mention some: *1)* The emails may have been long for certain participants, some of whom had difficulties scrolling though and answering the subsequent questions (especially participants with cognitive decline); *2)* Participants were biased to mark emails as scam (potentially because the rate of scam was higher than what would be expected in practice [12]); and *3)* Free-form answers took up time (as certain participants had difficulty typing) and left too much room for interpretation. These limitations may also be relevant for other educational tools in the vein of SDOC (e.g., [9]).

Adaptations for a Global Audience

To serve the needs of international audiences, Scam Bingo and SDOC should be adapted to local needs (e.g., certain frauds are mostly encountered in specific parts of the world [2]). Fraud Bingo has already been translated into several languages, which is a good first step, yet the clues and tips themselves are still tied to scams that prey upon older adults in the United States. Fortunately, existing bingo-card generation software makes it easy for advocates for older adults replace US-specific scams with local equivalents, while preserving tips that are universally applicable.

Similarly to Fraud Bingo, SDOC can be easily adapted to include scams that are relevant to the region and culture of the participants. In general, scams that prey upon similar fears tend to exist across many cultures, yet customization is necessary, as much of the educational value of SDOC lies in its ability to expose participants to scams that they are likely to encounter in practice. Localized patterns of computer or device usage must also be considered. For instance, in countries where older adults are more liked to use mobile devices than computers, scam-detection training should focus on mobile devices.

Conclusion

In conclusion, we found Fraud Bingo to be an effective training tool for older adults that span a wide range of cognitive abilities. While SDOC was appreciated by some older adults, it needs to be adapted to different skill levels, particularly in a workshop setting. In addition to adopting design guidelines for improved usability, we advocate that similar training tools be of flexible duration so that participants can complete as many or as few challenges as they can get to in a set amount of time and still receive feedback on their performance.

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