INSIGHTS ON AN AUTOMATED FALL DETECTION DEVICE DESIGNED FOR OLDER ADULT WHEELCHAIR AND SCOOTER USERS: A QUALITATIVE STUDY

BY

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THESIS

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ABSTRACT

This study examined the desired specifications, perceived ease of use and perceived usefulness of a fall detection device (FDD) among 15 older adults who use wheelchairs and scooters through remote semi-structured interviews. Participants (mean age: 67.5 ± 4.7 years) lived with a variety of disabilities including multiple sclerosis, cerebral palsy, spinal cord injury, stroke, osteoarthritis and spina bifida. Participants were asked about certain design features of a potential FDD. The interview examined features such as charging specifications, device use, who will be notified when a fall occurs (notification settings), functionality of the sensor, and what instructions are provided on how to use the FDD. Participants were also asked to provide feedback on the form of the device, such as a watch, necklace (pendant), pin or other form of their preference. Additionally, researchers examined the challenges participants had with their current technology (such as difficulty don/doffing wearable technology, charging the device, etc.). Participant responses were analyzed through a thematic analysis and reported upon categories of device features, perceived ease of use and perceived usefulness. Results indicated that participants prefer a wireless charger, watch model, and the option to toggle between which contacts are notified in the events of a fall. Participants identified challenges in charging devices due to limited fine motor skills and the difficulties of plugging in a wired charger. Participants preferred a watch model as it may not draw attention and go unnoticed as an FDD. Participants wanted to be able to change who is notified in the event of a fall, depending on the availability of the contact. Overall, participants believed an automated FDD would be useful and easy to use. Participants' insights will inform the design of an FDD to increase usability and prevent technology abandonment. Future research should focus on user system usability to determine the effectiveness and benefits of an automated FDD.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

This chapter, co-written with Laura Rice, Wendy Rogers, Mikaela Frechette, Libak Abou, Peter Presti, Rachel Brokenshire, Harshal Mahajan, and Jacob Sosnoff is currently under review for publication in a journal. The co-authors gave permission for this publication in this thesis.

1.1 FALL STATISITICS

Falls are a health concern for individuals living with a variety of disabilities, especially older adults who use a wheelchair or a scooter on a full-time basis. As of 2014, there are approximately 5.5 million wheelchair and scooter users in the United States [1]. It is estimated that approximately 30-75% of wheelchair and scooters users experience at least 1 fall annually [2, 3]. Although the literature specific to older adults wheelchair and scooter users is limited, due to a decline in processing speed, working memory, executive functions and motor skills, older adults are likely to have similar or higher fall frequency rates [4]. Falls can have a significant impact on an individual's day to day life, leading to an assortment of injuries and the development of a fear of falling.

1.1.1 Physical and psychological consequences of falls

The injurious nature of falls can lead to a range of injuries from abrasions or bruises to concussions or fractures [5]. Serious, non-fatal injuries like fractures, concussion, dislocations and head injuries may require hospitalization [2]. Moreover, falls can also result in death. Approximately 68% of fatal wheelchair accidents are the results of falls [3]. In addition to physical injuries, wheelchair and scooter users may develop a fear of falling (FoF). FoF has a variety of consequences including loss of confidence and independence, lower rates of community participation, and deficits in mental health [6, 7]. The disuse-disability cycle suggested that a reduction in physical activity and deconditioning results in an increase in dependency and fall risk [6, 8]. Lower self-rated mental health was associated with activity curtailment further supporting the idea of the disuse-disability cycle suggested by Tinetti and Powel [6, 8]. Furthermore in 2007, Peterson, et al. stated that a fear of falling has greater consequences on activity curtailment among ambulatory individuals living with multiple sclerosis than the frequency of falls itself [6, 7]. Wheelchair users also had an increased risk of falling due to functional limitation, thus a fear of falling and increased risk of falls may result in increased activity curtailment [7].

1.2 FALL RECOVERY

After experiencing a fall, wheelchair and scooter users frequently need assistance to get up or recover. In 2019, Rice, et al. found that 78% of power wheelchair users and 80% of manual wheelchair users needed assistance to recover from a fall [9, 10]. The inability to recover independently may result in a long lie time. A long lie time is defined as an individual being on the floor or ground for over 1 hour [11]. A long lie time has the potential to lead to a variety of conditions and injuries including but not limited to: social isolation, fear of falling, muscle strains, pneumonia, pressure sores, dehydration and hypothermia [11-15]. Rice, et al. reported 20% of power wheelchair users experienced a lie time of over 10 minutes and 50% of manual wheelchair users experienced a lie time of over 5 minutes after the occurrence of their worst fall in the past 12 months [9, 10].

A long lie time can be detrimental to both short term and long-term health. Approximately half of ambulatory older adults die within 6 months after experiencing a long lie time [16]. It is reported that approximately 20% of older adults who were hospitalized because of a fall experienced a long lie time [11, 17]. Furthermore, a long lie time can be predictive for future injurious falls, and lead to an increase in hospitalizations [18]. In addition, due to physical injury and limited sensation, even a short period of time on the floor or ground may be detrimental for wheelchair and scooter users. A delayed initial recovery could potentially lead to fear of falling, activity curtailment and social isolation [9, 10]. As a result, the inability to recovery independently may result in significant injuries and an increase in fear of falling.

1.2.1 Need for a Fall Detection Device

The inability to recover independently and the potential for an extended lie pose a significant risk to full time wheelchair and scooter users. As a result, a need exists to develop an automated fall detection device that can accurately detect that a fall has occurred and automatically summon assistance. Unfortunately, no fall alert devices currently on the market have been validated among wheelchair and scooter users to automatically summon assistance in the event of a fall [19]. Preliminary data collected by our research team has shown that there are significant differences between fall patterns of ambulatory individuals and wheelchair users. In addition, commercially available fall detection devices are unable to reliably detect the occurrence of falls among wheelchair users. Among 25 able-bodied individuals who fell out of a wheelchair in a controlled laboratory setting, a commercially available fall detection device was only able to detect 4.67% of the falls that occurred (paper in review at Assistive Technology).

Due to the limitations associated with the commercially available fall detection devices (FDD) currently on the market, a need exists to develop an automated fall detection device specifically designed for wheelchair and scooter users who are aging with long-term disabilities. This assistive technology will be able to automatically alert emergency services and/or caregivers when a fall occurs to help the individual summon assistance to quickly recover from the fall and prevent a long lie period from occurring. Automated alerts have the potential to decrease lie time, hospitalizations, and potential physical and psychological consequences of a fall. Previous research has shown that an automatic alert system plays an important role in fall recovery as an individual may not be able to trigger the device manually after a fall has occurred due to: the device being out of reach, limited fine motor skills or the person experiencing a loss of consciousness during the fall [12, 20]. Further, previous research has shown that older adults are at times reluctant to manually trigger a manual fall detection device even when they have the ability to do so due to being perceived as a burden to their families [12, 21]. Moreover, one current automated FDD, Speedy, has an overall fall detection accuracy of 65% [22]. There are weaknesses with the speedy FDD in detecting backwards and sideways falls in ambulatory older adults, where the success rate is 58% and 45%, respectively [22]. Another FDD is a video monitoring-based fall detector. However, this form of FDD is only viable in an individual's residence, which would limit the FDD's ability to summon assistance if a fall occurred outside of the scope of the video surveillance. Further, a video monitoring-based fall detector may lead to increases in social isolation and activity curtailment, and decreases in community participation due to individuals fearing to leave their residence. A video monitoring-based fall detector would need to cover all areas inside and outside of a person's home, which may lead to discomfort and rejection of use. This is a limitation in fall recovery as wheelchair users experience falls outside and inside of their residence. Due to the limitations of the current devices on the market, a need exists to develop a specific automated fall detection device for wheelchair and scooter users.

1.2.2 Technology Acceptance Model

Before developing a piece of assistive technology, it is important to understand the needs of the target population. The device must be designed around the intended user to influence the acceptance and use of the device. If designers do not understand the needs of the target population, the device may not be useful or used by individuals. Therefore, the acceptance of an FDD is crucial to the long-term success of the device and actual use by older adult wheelchair users. A device that is not easy to use or has no advantageous use will likely be abandoned. The theoretical foundation of this research is based on the Technology Acceptance Model (TAM) developed by Davis, et al. [23]. The TAM provides a framework for understanding factors associated with the acceptance of new technology. The model is focused around perceived ease of use, perceived usefulness and behavioral intention to use [23]. Additionally, the TAM was chosen over other technology acceptance models, such as the Senior Technology Acceptance and Adoption Model (STAM), because of the simplicity and reliability of the model. The TAM is widely recognized and has been used to design a variety of technology centered around older adults and ageing in place. The TAM will provide a framework to guide our understanding of preferred features of an FDD.

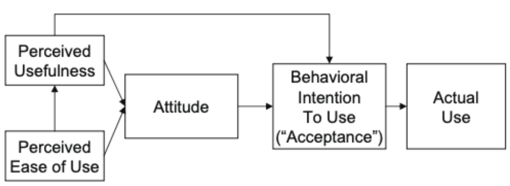

Figure 1: The Technology Acceptance Model. [24].

1.2.3 Designing for older adults

There is not a one size fits all approach when designing for older adults or individuals living with disabilities. There are numerous differences between individuals and it is important to take into account the wide variety of differences when designing a new technology. Age-related declines do occur, such as deficits in vision, hearing, executive functioning and processing speed [4]. Therefore, it is important to design a device with those age-related differences in mind. However, there are individual differences in rate and amount of decline at different ages in one's life, so it is important to not have a one size fits all approach and to accommodate for age related differences.

1.3 IMPORTANCE OF THE STUDY

Before developing such a device, there is a need to gather feedback from wheelchair and scooter users in the target populations about the characteristics and specifications of the proposed FDD. This feedback will be used to inform the development of the device. A user-centered design process will drive the development of the device to ensure that it meets the specifications and needs of the target population. Additionally, this study may influence the design of future wearable technology for older adult wheelchair or scooter users.

1.4 PURPOSE OF THE STUDY

The purpose of this study is to gather an in-depth understanding of the desired specifications, perceived ease of use and perceived usefulness of an automated FDD tailored to older adult wheelchair and scooter users. Insights gained during the interviews will allow researchers to hone in on potential downfalls of the device, which might have gone unnoticed. The interviews will also result in detailed understandings of user opinions, concerns, and wants of the device. Interviews provide designers and researchers with features or concerns that are often overlooked in surveys or proposed design ideas. Further, interviews were conducted with older adult wheelchair or scooter users as this is the targeted population for the device. However, these considerations will also assist in making the device accessible for a wider range of potential wheelchair and scooter users.

1.5 OBJECTIVE OF THE STUDY

The specific aims of this study were to gather insights from older adult wheelchair and scooter users about an automated FDD to inform the development of future FDD. Specifically, we examined the preferred form of the device (watch, necklace, pin, or other), how/how often the device should be charged, when, where and how often the device will be used, placement of the device on the individual’s body, the desired look of the device, notification protocols and settings, preferences on manual or automated detection, and what instructions are required on how to use the device.

CHAPTER 2: LITERATURE REVIEW

2.1 FALL HISTORY AND FALL RESEARCH

Falls among aging adults who use a wheelchair or a scooter on a full-time basis pose a significant risk to the health and independence of the individual. In 2020, Nie, et al. reported that over 50% of community-dwelling older wheelchair users reported falling annually [25]. Falls may lead to hospitalization and/or loss of independence, and as a result may lead to premature admissions into assistive or supportive living facilities [26]. Although there are limited studies on the risk factors and frequency of falls among older adults who utilize a wheelchair or scooter for their primary means of mobility, falls are still considered an adverse health risk [27].

2.1.1 Fall circumstances

The circumstances surrounds falls are often complex, resulting in multiple factors influencing the occurrence of a fall. While no studies have examined circumstances of falls among older adults who use wheelchair and scooters full time, it is likely that the multifactorial nature of falls is also experienced by older adults who use wheelchairs and scooters full time.

Rice, et al. conducted semi-structured interviews among individuals with a variety of health conditions who use wheelchairs full time to examine the circumstances associated with falls [9, 10]. Rice, et al. categorized contributing factors to falls as: time of day, location, action-related fall contributors, and intrinsic and extrinsic factors [9, 10].

Rice, et al. noted that the majority of falls occur during daytime when wheelchair users are most active [9, 10]. Among falls that occurred in the evenings reported by manual wheelchair users, many were associated with poor lighting [9]. Additionally, Rice, et al. reported that among power wheelchair users who experienced a fall in the evening, many were associated with moving quickly after waking and the urgency to use the restroom [10]. The sense of urgency may cause individuals to take fewer precautions resulting in a fall.

Regarding location, outdoor falls often occurred when individuals were propelling in undesirable environmental conditions such as uneven, unstable or debris ridden surfaces [9, 10]. Paraphrased from Rice, et al. wheelchair users must have high-quality wheelchair skills to avoid environmental obstacles to ensure safe maneuvering outdoors [9, 10]. Additionally, falls occurring indoors often occurred in the bathroom due to a sense of urgency or due to a wet and slippery floor [10]. It is important that wheelchair users develop strategies to reduce the risk of falls in a bathroom setting. The use of non-slip floormats and grab bars may be beneficial in improving the stability of transfers in a bathroom setting.

Falls may be attributed by action-related fall contributors, such as propelling the wheelchair, transferring, ambulation, reaching, and sitting [9, 10]. Many falls happened during wheelchair maneuvering due to environment and disability-related impairments [9, 10]. Further, falls happened because of a loss of balance during moments of ambulation, transferring and reaching for an object [9, 10]. These actions, although unavoidable, can contribute to fall circumstances.

Moreover, falls happened due to intrinsic and extrinsic factors [9, 10]. Intrinsic factors included fatigue, loss of balance or pushing at high speeds [9, 10]. Additionally, wheelchair users experienced bouts of fatigued which attributed to a fall during wheelchair propulsion or transferring [9, 10]. Extrinsic factors included an unstable environment or wheelchair set up [9, 10]. Examples of an extrinsic factor than contribute to falls are cracks in a sidewalk or steep ramps [9, 10]. A variety of circumstances can result in a fall for wheelchair and scooter users.

2.1.2 Physical injury

Physical injuries as a result of a fall can include but are not limited to: scrapes, bruises, fractures, concussions or muscle strains [5]. Injuries may be divided into two categories: serious and non-serious injuries. A serious injury can result in a fracture, concussion, muscle strain, dislocation, amputation, and head or spinal injury and usually requires hospitalization [2, 3]. Kirby, et al. reported that 45.5% of injurious falls of wheelchair users living with SCI resulted in fractures [28]. Approximately 27% of wheelchair related injuries result in hospitalization [29]. The majority of wheelchair related accidents are non-fatal injuries, however, it is estimated that nearly 37,000 non-fatal wheelchair-related accidents need emergency medical services annually [28].

Non-serious injuries, such as bruises and abrasions, can also cause adverse effects for wheelchair users. Bruises and contusions may lead to pressure sores, resulting in discomfort or infection due to slower healing times [30]. Kirby, et al. reported lacerations (22.3%) and contusions/abrasions (20.1%) were the result of falls that caused injury [28].

2.1.3 Fear of falling

Falls may also result in psychological impairments, such as developing a fear of falling (FoF) and decreased community participation. Tinetti and Powell define fear of falling as the constant concern of falling that hinders an individual's performance of daily activities [8, 31]. Tennstedt, et al. explained that individuals are less likely to describe themselves as "afraid of falling" but as "worried of falling" [32]. FoF was first thought to be a consequence of falling; however, there is evidence that individuals who have not fallen can also develop a fear of falling [33, 34]. This evidence suggested that fear of falling is multifactorial and not only caused by falling. McAuley, et al. suggested fear of falling has cognitive, behavioral, and biological influences [35]. This implication further analyzes that the root of FoF is more than the consequence of the fall itself. Further, McAuley, *el al* established a relationship between increased physical activity and the decrease of fear of falling in ambulatory older adults [35]. Additionally, there is a difference in the prevalence in fear of falling between ambulatory older adults who have fallen and who have not fallen. The prevalence of FoF in older adults who have no history of falling ranges from 12% to 65% [36-41]. In comparison, the prevalence of FoF in older adults with a history of falling is estimated to be 30% to 90% [36, 42].

The prevalence of fear of falling among wheelchair and scooter users is comparable to ambulatory older adults. There is limited research on the specific prevalence of the fear of falling among wheelchair users, however, Rice, et al. discovered that approximately 75% of wheelchair users with multiple sclerosis report a fear of falling [9, 43]. Rice, et al. noted fear in regards to specific circumstances and curtailment from specific activities [9]. As fear of falling may lead to a loss of confidence, loss of independence, decrease in performance of normal societal roles and in increased prevalence of falls [6, 7, 9].

2.1.4 Activity curtailment

The loss of confidence in performing activities of daily living has a detrimental effect on wheelchair and scooter users. A recent study by Sung, et al. examined the relationships between fear of falling, community participation and quality of life among community-dwelling wheelchair and scooters users [7]. Sung, et al. found that wheelchair users who reported FoF also reported significantly lower scores on the community participation indicator (CPI) and World

Health Organization Quality of Life Brief version (WHOQOL-BREF) compared to participants who reported no FOF [7].

The relationship between FoF and activity curtailment is well defined and studied among ambulatory older adults. Howland, et al. revealed that activity curtailment as a result of a fall was independent of injury, age, gender, health status or history of falling [32, 36]. Further, the act of activity curtailment leads to other risk factors associated with falling, such as deconditioning and muscle weakness, restricted activity, decreased postural control and decreased confidence in performing activities of daily living [32, 41, 44-46]. The negative consequences of fear of falling leads to a wide range of physical, mental, and social challenges.

2.1.5 Fall Recovery and Lie Time

There is limited research on the prevalence of wheelchair users who need help recovering after a fall has occurred. Rice, et al. performed in-depth interviews with 20 manual wheelchair users (mean age: 47 ± 13 years) examining circumstances surrounding their worst fall in the past 12 months [9]. Rice, et al. noted that 80% of manual wheelchair users needed assistance to recover after a fall occurred [9]. Half of the 16 participants reported being on the ground for longer than 5 minutes [9]. Additionally, Rice, et al. examined the circumstances surrounding 19 power wheelchair users' (mean age: 41.7 ± 7.6 years) worst fall in the past year [10]. Rice, et al. reported that approximately 78% of the participants who use a power wheelchair needed assistance rising from a fall, with the majority of those participant lying on the ground for 10 minutes or less [10]. Individuals indicated that they could not recover due to their wheelchair moving out of reach or they had trouble positioning the wheelchair in an upright position after the fall event [9, 10]. Then participants, who needed help recovering from a fall, reported that they were assisted by a care partner who assisted in lifting them back into their power or manual wheelchair [9, 10].

Moreover, significant lie times are correlated with adverse health outcomes. Among ambulatory individuals, a significant lie time can result in serious health outcomes, such as pressure sores, gastrointestinal bleeding, urinary tract infections, myocardial infarction, pneumonia or death [47]. It is important that wheelchair and scooter users develop a fall recovery plan if a fall occurs. Fall recovery could be developing floor to chair transfer skills or the use of safety alert system.

It is important for wheelchair and scooter users to develop fall recovery strategies in the event of a fall. There is limited research in fall recovery strategies for wheelchair and scooter users. However, an intervention program in ambulatory older adults focused on floor-rise training [48]. The intervention program detailed improvements in FoF and fall recovery time. Although, that intervention program was catered towards ambulatory adults, a similar floor-to-chair training may be effective in improving fall recovery for wheelchair and scooter users. Wheelchair and scooter users may work with physical or occupational therapists to develop the skills of a floor-to-chair transfer. Additionally, wheelchair and scooter users may not be able to recover independently and require assistance. To summon assistance individuals may use an FDD or a cell phone to alert someone in the event of a fall. It is important for wheelchair and scooter users to have fall recovery strategies in place to increase recovery and decrease lie time.

2.2 FALL RECOVERY TECHNOLOGY AND DESIGN

Fall detection devices can be used as a part of an individual's fall recovery plan. The most common type of FDD is one in which an individually must manually trigger the device after a fall occurs. After a fall occurs, users will press a button on the device that will connect them with a response center. After connecting with a response center, the response center will alert emergency services. Although manual FDDs are cheap to produce, there several limitations. One limitation is that a user may experience a loss of consciousness or a significant injury and would not be able to manually activate the alarm. An individual may also experience pain or cannot reach the device to activate the alarm, which would cause the alarm to never to be triggered [12, 20]. Additionally, previous research indicates that individuals may be reluctant to trigger an FDD because they did not want to inconvenience family members or emergency services [12, 20].

Another type of FDD is an automated device that uses an accelerometer or gyroscope to detect a fall [49]. These devices rely on an algorithm developed through a machine learning process to identify that a fall has occurred. The device recognizes certain data thresholds, which then will determine if a fall has occurred [50]. The algorithm is then tested against a dataset containing activities of daily living and fall data to train the device to successfully differentiate between a true fall event and performance of activities of daily living [50]. An automated FDD may accidentally trigger a fall event when a fall has not occurred or not detect when a fall event did occur. These limitations could result in unnecessary alerts or an individual not getting the help they need. Further, automated FDDs have been designed for ambulatory individuals' fall patterns, thus would not be appropriate for wheelchair or scooter users.

Despite the limitations, both types of FDDs have been shown to be effective in detecting falls and summoning assistance [50, 51]. However, the current automated FDD on the market are designed for ambulatory adults. Utilization of these FDDs by full time wheelchair and scooter users is inappropriate because the algorithms were tested and developed on young ambulatory adults simulating falls from a standing position in a laboratory setting [50]. Due to differences in fall patterns among ambulatory and non-ambulatory individuals, the current FDD devices on the market would not be able to accurately detect a fall. This design would not be feasible for older adult wheelchair and scooter users. The algorithm would be completely different and the device would not be able to successfully detect when a fall occurs. In addition, a commercially available device with fall detection (Apple Watch series 4) has been shown to have poor reliability in detecting wheelchair falls in a laboratory setting. Preliminary research has shown that falls from a wheelchair were detected at a rate of 4.67 per 100 falls in a laboratory setting. The falls in a laboratory setting mimicked forward, sideways, and backwards falls out of wheelchair in order to replicate real-life fall events. This FDD would not be viable for wheelchair and scooter users.

2.2.1 Technology Acceptance Model

In 1989 Davis, et al. developed the Technology Acceptance Model (TAM) [23]. The model incorporates the ideas of: perceived ease of use, perceived usefulness, behavioral intention to use and actual use. The foundation of the model centers around how users will perceive and use a new piece of technology [23]. The perceived usefulness measure focuses on the benefits the user will receive after adopting a new technology. This adoption will then influence the behavioral intention to use a new technology. If the user deems the technology as advantageous then they are more likely to use the product, thus, developing a positive relationship between user and product [23]. In addition, the user will need to perceive the device as easy to use. The use of the device should be viewed as effortless to have the most positive user-experience [23]. Additionally, users are more likely to accept products that are easy to use [23]. Moreover, the combination of these two principals results in the individual thinking about wanting to use the device, that is, their behavioral intention to use [23].

The TAM was not originally designed for healthcare technologies, thus was not initially used in the design of healthcare technologies. Holden and Karsh analyzed the effectiveness of the TAM in use of healthcare technologies. It is recognized that perceived usefulness and acceptance of the technology have a positive relationship [24]. Thus, to make an accepted healthcare product, the product must be perceived as useful. Further, perceived ease of use is not as strong of an indicator as perceived usefulness in the acceptance of health technology [24]. Therefore, establishing that a product is advantageous in improving healthcare outcomes, is important to foster accepted by a target population.

2.2.2 Technology acceptance in older adults

Contrary to popular belief, older adults are open to learning and using new technology [4]. However, older adults may be less inclined to try a new healthcare technology or approaches as some believe they cannot control their own health outcomes [4]. Many older adults have lower levels of technology self-efficacy, which in turn leads to decreased confidence with learning a new technology [4]. Lower levels of self-efficacy might be a result of increased technology anxiety found in older adults. Therefore, when designing healthcare technology for older adults it is important to mitigate these challenges and provide support [4]. Moreover, older adults have lower rates of technology adoption due to heightened anxiety and feeling less comfortable using new technology [4]. In a study that compared the rates of internet use among different age groups of adults, adults over the age of 65 used the internet significantly less than the other age groups [4, 52]. The cause of the lack of internet use was due to older adults believing it is not useful and it is difficult to use [4, 52].

2.2.3 Designing for older adults

Current research indicates that, in general, older adults show age related declines in movement control, cognitive functioning, perception, and psychosocial factors [4]. Older adults may experience lower vision, difficulties with balance control, and difficulty hearing. Therefore, it is important to take these age-related changes into consideration when designing new technology intended for use by the population. In addition to physical limitations, cognitive and perceptual declinations may alter the design of a targeted product, thus, designers must be aware of these age-related differences in consumers. One way to mitigate these limitations is to design based on past experience of the intended user [4]. Designers can then rely on the semantic memory of older adults to create the easiest and most useful product they can.

CHAPTER 3: METHODOLOGY

This chapter, co-written with Laura Rice, Wendy Rogers, Mikaela Frechette, Libak Abou, Peter Presti, Rachel Brokenshire, Harshal Mahajan, and Jacob Sosnoff is currently under review for publication in a journal. The co-authors gave permission for this publication in this thesis.

3.1 STUDY DESIGN

A qualitative research study was implemented to examine user needs and preferences regarding the use of an automated fall detection device designed for wheelchair and scooter users. The Institutional Review Board at the University of Illinois at Urbana-Champaign approved the study protocol and all participants provided electronic informed consent prior to data collection.

3.2 QUESTION DEVELOPMENT

Interview questions were developed by trained researchers with experience working with people living with disabilities. These researchers included individuals with backgrounds in physical therapy, engineering, kinesiology and human factors. The combination of these backgrounds fostered a comprehensive range of questions. The questions were designed to gather information on characteristics of a FDD desired by the target population. The questions included an inquiry into the form of the device (watch, necklace, pin, or other), how/how often the device should be charged, when, where and how often the device will be used, placement of the device on the individual's body, the desired look of the device, notification protocols and settings, preferences on manual or automated detection, and what instructions are required on how to use the device. The questions were open ended, but guided, to produce a dialogue around the specific area of interest. Moreover, interview questions were designed around the TAM developed by Davis, et al. in 1989. The TAM provides insights into users' overall attitude towards a new technology. In addition to open ended questions, other questions were asked on a Likert scale to gather objective responses on technology acceptance. These questions surrounding perceived ease of use can be found in Table 1. The questions about perceived usefulness are in Table 2.

3.2.1 Opening questions

Opening questions were asked to get to know the participant better. These questions were:

A) What do you like to do when you have free time?
B) Do you tend to perform recreational activities inside or outside of your home/place of residence?
C) What activities do you use your wheelchair for indoors? Outdoors?
D) Do you need assistance performing daily activities?
E) Do you have someone at home with you or are you alone most of the time?

The purpose of these questions were get a better understanding of the participant's functional status and wellbeing. It also helps the participant become more comfortable with the interviewer and leads to more openness in the following questions.

3.2.2 Perceived ease of use questions

The goal of the perceived ease of use questions is to gather feedback on the usability of a potential fall detection device. It allows the participants to talk freely about challenges they may experience with current technology they possess. By understanding challenges currently faced by individuals in the target population, the design team can attempt to mitigate those challenges during the development of the FDD. In addition, participants were asked if they currently wear any accessories to better understand the daily routines of individuals in the target populations. We hypothesized that if an individual currently wears specific accessories or poses no aversions and challenges to accessories, then it will be easier to fit an FDD into their everyday life. This method allowed us to gather feedback on the potential design of the device and to ensure it meets the users' needs of a functioning FDD. Further, the interview gives the designers and developers preliminary insight on how to make the FDD accessible and easy to use.

Categorical questions were designed to provide specific feedback on different characteristics found in wearable technology in terms of ease of use. The questions were developed with a senior researcher, who has an expertise in designing wearable technology and will oversee the design of the device. The questions are broken down into specific categories: charging specifications, form of the device, device function, and provided instructions.

Charging: Questions were designed to gather insight into charging preferences of study participants. For instance, questions were asked regarding preferences on wired vs. wireless chargers. Due to challenges with fine motor skills, participants may have difficulties with wired charging cables. Therefore, asking about certain challenges a participant may have will indicate solutions to make charging easier. Participants were asked how often and how long the FDD should be charged. The questions gauges participants' insights into the usefulness of an FDD with different battery qualities.

Form of device: We also asked participants their opinions of different form ideas and their preferences of those forms or other forms they believe would be better. This ensures we develop a device that is preferred and accessible to individuals in the target population. For example, some individuals may have issues with the form of a device, such as not being able to clasp a standard watchband or necklace. The questions on the form of the device will reveal certain challenges or preferences of a device.

Device Functions: Participants were asked about different functions of the device. For example, questions were asked if the device should automatically send a notification that a fall occurred or if the participant would prefer to manually contact someone through the device. These questions will help researchers understand the perceived ease of use of the potential FDD. Also, we asked participants if they wanted the ability to cancel the notification in the event of a false alarm or if a fall did occur but they can recover.

Instructions: We asked participants their opinions on how instructions to use the fall detection device should be formatted. Participants may have difficulties understanding different forms of instructions, there it is necessary to understand the easiest form of instructions to distribute to potential users.

It is important to receive participant insight into these categories to design around potential users. Some questions were open ended to produce a dialogue around specific features of an FDD, while other questions had structured responses to acquire specific details from participants. These specifics can then be manifested into the actual design of the device.

Table 1: Perceived Ease of Use Questions of Device Design and Current Technology and Accessories

Current Technology

-
- Do you need to charge any device on at least a weekly basis (e.g. phone, electric toothbrush, razor, etc.)
  If yes,
  a. Do you have any challenges using the charger?
  b. Is there anything you can think of that would make the charging process easier?

Table 1 (cont.)

c. Do you need assistance from someone to charge or operate the device?
d. What type of charger do you use for your phone?

If no,

a. Why do you refrain from using one of these devices?
b. Does the need to charge a device on an ongoing basis deter you from using a device such as this?

Current Accessories

- Do you wear any other items, such as a watch or jewelry on a daily basis?
    a. If yes, what are these items and where do you wear the item?
        i. Is there anything that bothers you about wearing this/these items?
    b. If no, why do you choose not to wear a watch or jewelry?

Charging Specifications

- How often do you think it is reasonable to charge the fall alert device?
- What type of charger would you prefer? Wired vs. wireless?
- What if it needed to be charged twice a day? Once a day? Once a week?
- What if it took 1 hour, 2 hours, or 5 hours to charge fully?

Form of the Device

- What do you like or dislike about a standard watch? How easy would it be to put on/take off a watch?
- What do you like or dislike about a necklace? How easy would it be to put on/take off a necklace?
- What do you like or dislike about a small pin? How easy would it be to put on/take off a small pin?

Device Functions

- When a fall occurs would you like the device to:
    a. trigger automatically?
    b. manually?
    c. both?
    d. Please describe why feel this way?
- Would you like an option on the device that disables the call to someone?
    a. How much time would you like to be able to cancel the call?

Provided Instructions

- How would you prefer to receive instructions on how the device works?
- We are considering different instruction options. Would you like:
    a. a written document available online?
    b. an online video guide?
    c. paper based written instructions?

    something else?

3.2.3 Perceived usefulness questions

The goal of the perceived usefulness questions was to better understand the potential usefulness of an FDD for wheelchair and scooter users. Participants were asked about their current smart devices or fall detection devices. Asking about current smart devices may allude to a participant's attitude toward adopting new technologies. Participants were asked questions relating to perceived usefulness of specific features of a fall detections device. The specific features include duration and location of use, notification settings and device features. It is important to understand individuals' attitudes and needs of new technology in order to make the best product.

Smart Devices: Questions regarding current use of smart devices or fall alert devices may reveal attitudes about adoption of a new technology. We hypothesize if a participant already uses a fall alert device or a smart device they would be more willing to use the proposed device. Further, we asked participants about discontinuation of a previous FDD. This may expose participants' current attitudes towards adopting a new device and/or highlight previous problems experienced that can be avoided in the design of a new device. If an individual used a device in the past they may be more willing to adopt a new device, if the device fits the individual's needs.

Duration and Location of Use: Participants were asked about how often and where a participant would use the device. Specifically, participants were asked if they would only use the device in their own homes or would they use it everywhere they go. If the device would not be used all of the time the device may not be seen as useful to participants. Researchers also inquired about the location of use as participants may find the device useful in different settings.

Notification Preference: Questions were also asked regarding notification preference; such as who and how should the device contact someone when they have experienced a fall. How the notifications are sent will influence the design of how the device will operate via the participants cell phone or as a stand-alone device.

Device Features: Researchers inquired about the potential of an application that stores the fall records of the user. If participants believed that this would be a useful feature, then it will be implemented into the design of the device. It is important to see the perceived usefulness of the device in regards to individuals adopting a technology. The complete list of questions can be found in Table 2.

Table 2: Perceived Usefulness Open Ended Questions

Smart Devices

- Do you currently wear any fall alert devices or smart devices; such as a life alert button or smart watch?
  If Yes
    a. Please tell me specifically what you use.
    b. Why did you choose to get this device?
    c. How long have you had the device?
    d. What do you like about the device?
    e. What do you dislike?
    f. Do you have to manually trigger the device if a fall occurs?
  If No:
  a. Why don't you use any of these types of devices?
  b. Have you ever considered using a fall alert device? Why or why not?
- Have you ever used a fall alert device in the past and stopped using it?
  a. If yes, why did you stop using it?
- Do you have a smart phone?
  a. If yes, where do you keep your phone on you?

Table 2 (cont.)

Duration and Location of Use

- How often would you be willing to wear the fall alert device if it is able to accurately detect a fall?
- Would you be willing to wear it a few hours per day?
- Would you want to only wear it when leaving the home?
- Would you wear it the whole day?
- If no, when would you not wear it?

Device Notification Settings

- Who would you like to be notified when a fall occurs?
  - Significant other/family member/care partner?
  - Emergency services?
  - Both?
- How would you like to send these notifications? (Example: text message on a cell phone, phone call etc.)

Device Features

- Would you like your device to display/sound an alarm on detecting the fall?
- Would you like the device to provide a record of each fall that has occurred that you could access through a secure app?
- Would you want others to have access to this information also? Please answer yes or no to the following individuals:
  a. Family
  b. Friends
  c. Care Partners
  d. Primary Care Physician
  e. Insurance Company
  f. Wheelchair Manufacturer
  g. Makers of the fall detection device

Finally, the interview concluded with seven objective questions regarding perceived usefulness and perceived ease of use using a Likert scale. This gives researchers further insight into the attitudes of accepting an FDD. The Likert scale used was a five-point scale: strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. Strongly agree was rated as a 5 and strongly disagree was rated as a 1. The Likert scale questions can be found in Table 3.

Table 3: Likert Questions

Perceived usefulness	Perceived ease of use
Using a fall detection device would increase my ability to recover or get up after a fall occurred.	Learning to operate a fall detection device would be easy for me.
Using a fall detection device would decrease the time I spending lying on the ground or floor after a fall.	I would find a fall detection device to be easy to use.
Using a fall detection device would decrease my fear of falling.	

Table 3 (cont.)	
I would find a fall detection device useful inside of my home.	
I would find a fall detection device useful outside of my home.	

All questions were answered on a scale of strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree.

The full interview script is attached in Appendix A.

3.3 PARTICIPANTS

Individuals were invited to participate in the study if they met the following inclusion criteria: 1) ≥60 years old, 2) uses a wheelchair (power or manual) or scooter for at least 75% of their mobility, 3) has used a wheelchair or scooter for at least 1 year, 4) able to understand/read English, 5) self-reported fall history (at least 1 fall in 3 years) and 6) able to communicate with research staff through video conferencing software or telephone. Participants were recruited through word of mouth, posting of the announcement on social media, use of the DRES research registry, flyers, use of the NARCOMS registry for Multiple Sclerosis, and TechSAge research registry. Interested participants contacted the Disability, Participation and Quality of Life Research Laboratory using the contact information provided on the recruitment materials. Interested participants were contacted by a trained researcher for screening to determine eligibility based on the inclusion criteria listed above. If eligible, participants were scheduled for an interview. Additionally, participants were sent a demographic questionnaire and electronic informed consent document to be filled out prior to the interview.

3.4 DATA COLLECTION

After participants signed an electronic informed consent document, participants completed a demographic survey via REDCap. Demographic information that was collected included: age, gender, race, educational status, marital status, income, perceived health, type of disability, type of wheeled mobility device, and duration of wheeled mobility use. In addition, participants self-reported the number of falls they experienced in the past 12 months and if they needed assistance rising from the fall. A fall was defined using the World Health Organization's definition, “inadvertently coming to rest on the ground, floor or other lower level. [53].” All data was collected online through REDCap (Research Electronic Data Capture) which is hosted at the University of Illinois at Urbana-Champaign. REDCap is a secure, web-based software to safely and easily collect research data.

After the completion of the demographic survey, the participants were interviewed. Interviews were then conducted by a trained member of the research staff through an online video platform using a structured interview script (Appendix A). Interviews were conducted through Zoom. To enhance the security, participants joined the Zoom meeting through a link sent to them via email. The host of the Zoom meeting set up a waiting room locked with an ID and password. After participants joined the Zoom meeting, the host locked the Zoom meeting and began the interview. During the interview, the audio was recorded, and a second research assistant took notes on the participants’ answers. The recordings were uploaded immediately to a secured Box folder and then deleted from the researcher’s computer. Interviews lasted approximately an hour. All participants were compensated $10 for their participation after the conclusion of the interview. Participant recruitment and testing continued until a redundancy in themes occurs or until 15 participants were interviewed [54]. A redundancy of themes were denoted as a recurrence of themes and codes during data analysis [54]. All interviews were recorded and transcribed verbatim.

3.5 DATA ANALYSIS

The demographic data were analyzed using SPSS version 24.0 (SPSS Inc., Chicago, IL). Measures of central tendency were calculated to characterize the study participants.

The interview data was analyzed using a thematic analysis approach [54]. The thematic analysis was done by two researchers who are experienced in qualitative research and familiar with the field of assistive technology. One researcher was a graduate student pursuing a degree in Kinesiology and the other researcher was an undergraduate student pursuing a degree in Kinesiology. Two researchers read and reread the transcriptions of the interviews and reviewed the audio recordings, when necessary. Then the two researchers separately generated initial codes and described the features of each code. After generating a list of codes, the two researchers segmented the codes into overarching themes based on commonality of the data. Commonality was determined by repeated answers to the interview questions. A thematic map was developed that maps each code into a thematic category. The thematic map also included a list of sub-themes to further group the codes. The final common themes and thematic map were discussed between the two researchers until a consensus was reached. Any discrepancies were resolved by a senior researcher not involved with creating the themes or codes, and not involved in data collection. The thematic analysis was performed on an ongoing basis in groups of 5.

CHAPTER 4: RESULTS

This chapter, co-written with Laura Rice, Wendy Rogers, Mikaela Frechette, Libak Abou, Peter Presti, Rachel Brokenshire, Harshal Mahajan, and Jacob Sosnoff is currently under review for publication in a journal. The co-authors gave permission for this publication in this thesis.

4.1 PARTICIPANTS

Fifteen fulltime wheelchair and scooter users (9 females, 6 males) living with a variety of disabilities participated in the study. Health conditions represented included multiple sclerosis (n= 8, 53%), spinal cord injury (n= 3, 20%), cerebral palsy (n=1, 7%), osteoarthritis (n=1, 7%), stroke (n=1, 7%), and spina bifida (n=1, 7%). Their mean age was 67.5 ± 4.7 years. Participants reported use of a wheeled mobility device for an average of 22.9 ± 16.5 years. Participants self-reported that they have fallen 2.5 ± 3.2 times in the past 12 months with a range from 0 to 12 times. Fourteen of the fifteen participants reported they needed assistance rising from their most recent fall with an average lie time of 14.8 ± 11.1 minutes. Five participants live in either a supportive living facility (n = 1), independent living facility (n = 2) or continuing care retirement community (n = 2). All other individuals (n = 10) live independently or with family. A full overview of participant demographic information can be found in Table 4.

Table 4: Participant demographic and descriptive data

Variable		**N**	**Mean (SD)**
Age (years)		15	68±5
Years mobility device use (years)		15	23±17
Falls in past 12 months		15	3±3
Lie times (minutes)		15	15±11
	Categories	**N**	**%**
Gender	Female	9	60.0
	Male	6	40.0
Race	White	13	86.7
	More than one race	1	6.7
	Other	1	6.7
Educational Status	High school graduate/GED	1	6.7
	Some college/Associate’s degree	3	20
	Bachelor’s degree	6	40
	Master’s degree	2	13.3

Table 4 (cont.)

	Doctorate degree	2	13.3
	Do not wish to answer	1	6.7
Marital Status	Single	3	20
	Married	9	60
	Divorced	2	13.3
	Widowed	1	6.7
Income	< $25,000	2	13.3
	$25,000 - $49,999	5	33.3
	$50,000 - $74,999	0	0
	>$75,000	6	40
	Do not wish to answer	2	13.3
Perceived Health	Fair	7	46.7
	Good	6	40
	Very Good	2	13.3
Cause of Mobility Impairment	Multiple sclerosis	8	53.3
	Spinal cord injury	3	20
	Cerebral palsy	1	6.7
	Stroke/transient ischemic attack	1	6.7
	Osteoarthritis	1	6.7
	Spina bifida	1	6.7
Wheeled Mobility Device	Manual wheelchair	3	20
	Power wheelchair	4	26.7
	Scooter	1	6.7
	Manual wheelchair and power wheelchair	4	26.7
	Manual wheelchair and scooter	2	13.3
	Power wheelchair and scooter	1	6.7

4.2 OVERALL FINDINGS

The findings of the study determined specifications, perceived ease of use and perceived usefulness of an FDD. Participants preferred a wireless charger that charged the device overnight. Further, participants indicated that a watch model was preferred over other suggested models. Additionally, participants discussed the need to disable a call and ability to change which contact will be notified in the event of a fall. Participants indicated that they would use the device all the time and in any setting. Participants believed it would be beneficial to keep a record of fall events in a secure phone application. Written instructions were preferred over other forms of instructions. Moreover, participants believed that an FDD would be easy to use and useful for fall recovery. Due to the diverse nature of the questions, the results are analyzed in 2 specific sections: 1) perceived ease of use and 2) perceived usefulness.

4.3 PERCEIVED EASE OF USE THEMES

In response to questions designed to gather feedback on the potential perceived ease of use of an FDD and the design of an FDD, participants discussed their challenges or lack of challenges they have with their current devices. The majority of participants have no issues using their current technology or accessories. Some participants proposed challenges with wearing specific device models, such as not being able to clasp a necklace or watchband. Participants were also asked about specific design features of a FDD in response to ease of use. After compiling the interview data, six themes emerged: 1) current technology, 2) current accessories, 3) device charging specification, 4) form of the device, 5) device functions, and 6) instructions on how to use the device. The complete list of themes, sub-themes, codes and sub-codes can be found in Table 5 below.

Table 5: Perceived Ease of Use Themes

Theme	Sub-theme	Code	Sub-codes
Current Technology	Challenges using a charger	Lacking fine motor skills	
		Poor eye sight	
	Making charging easier	Something to set it on top of	
		Docking station	
		Modified set ups	
Current Accessories	Wearing accessories	Refrain from it	
		Gets in the way	
Device Charging Specifications	Duration of charge	An hour	
		Overnight	
	How often to charge	Daily	
		Overnight	
	Type of charger	Wired	
		Wireless	
		Magnetic	
Form of the Device	Looks	Sleek	
		High tech	
		Colorful	
		Small, not bulky	
		Flat	
	Watch	Not my preference	
		Watchband	Wearability
		Preference	
		Uncomfortable	
	Necklace	Can’t clasp it	
		Unsafe	
		Gets in my way	
		Big enough	
		Preference	
	Pin	Bad idea	
		Magnets	

Table 5 (cont.)		Too difficult
		Preference
Device Function	Detection	Automatic
		Manual
		Option to toggle
	Disable call	Time
		Yes
		False alert
Instructions	Video	
	Written	
	Audible	
	Other	

4.3.1 Current technology

In response to the questions associated with participants' current technology we recognized two sub-themes: 1) challenges using a charger and 2) making charging easier.

Challenges using a charger

Less than half of the participants indicated challenges associated with charging their current devices. Participants were asked a question in reference to their current devices. We asked "do you have any challenges using a phone charger?" Participants who had issues with charging, listed that plugging in wire charging cords were difficult because of diminished fine motor skills or poor vision. These challenges persisted over multiple interviews who listed they have challenges using that type of charger.

> *""I wish it was easier because you're always trying to put the connection in the wrong way or something. And my eyesight is not very good."*(Participant 4)
> *"Plugging it in and out of the phone. That little piece that goes in and out? It's hard for me to pull up to sometimes hold. It's so tiny."*(Participant 1)
> *"Sometimes the, you know, the, you have to do put it on the bottom of the of the cursor. Smash the thing down into the hole and for the person. I do it both clumsy and probably pretty hard. So I never feel comfortable. So I often take it downstairs or ask somebody to come up and do it."* (Participant 5)

Making Charging Easier

Participants were asked the question "is there anything you can think of that would make the charging process easier?" The majority of participants believed that charging their devices were easy for them to do and nothing would make it easier. However, participants mentioned that a wireless charger or a docking station would make charging their devices even easier.

"Charging -- I know they got those cradles you can like lay down." (Participant 8)

Furthermore, some participants have specialized set ups that have made the charging easier. For instance, one participant has magnetic charging cords so he does not have to plug anything in. *"I've got some special wires that had just had magnets on so I don't have to fish with the little tiny connectors."* (Participant 11)

While the majority of participants stated that charging their devices was easy to do, the participants who had issues with charging their devices most commonly listed wireless charging as a solution.

4.3.2 Wearing accessories

Questions were asked to participants about the accessories they currently wear. The most common accessory worn, out of the participants who wore accessories, was a watch. A handful of participants noted that they wear a watch every day and do not go a day without it. Other participants indicated that a watch would get in the way of their daily routines or cause irritation in their everyday life. Different challenges arose between people's perception on wearing accessories. Some participants did not wear accessories as a personal choice and not because it caused inconveniences or challenges in their daily lives. Below is an example of a necklace causing challenges in a participant's life.

"Yeah, sometimes putting it on if it has a clasp that's difficult, can be hard. Like I said earlier, if it's too heavy and bulky. Oh, I don't usually wear necklaces or anything like that in nature." (Participant 10)

""Some of them are the bracelet type that it's like a clasp, which I can't do okay, but I prefer just to stretch bands where they do slip over your wrist." (Participant 4)

"They (accessories) get in my way when I transfer." (Participant 1)

4.3.3 Device charging specifications

In response to the questions associated with charging an FDD we recognized three sub-sections: 1) duration of charge, 2) how often to charge, and 3) type of charger.

Duration of charge

Participants were asked "What if it (charging) took 1 hour, 2 hours or 5 hours to charge fully?" Majority of participants answered they could charge the device overnight. Some participants believe that one hour is a reasonable time length to charge the device.

"I think an hour, but the seven hours over night wouldn't be bad." (Participant 2)

"I just charge everything overnight." (Participant 3).

How often to charge

Participants were asked "how often do you think it is reasonable to charge the fall alert device?" Majority of participants answered that charging the device daily or overnight is reasonable. They noted that it would not deter them from using the device if they had to charge it overnight.

"Do it every night, then it gets to be a habit to do it" (Participant 2)

"I prefer once a day or once overnight." (Participant 4)

Type of charger

Participants were asked "What type of charger would you prefer?" and then a follow up question of "Wired vs Wireless?" Majority of participants identified that a wireless charger would be easier; however, a wired charger would not deter them from buying the device.

"A wireless charger would be easier" (Participant 5)

4.3.4 Form of the device

Participants were asked a variety of questions about potential design ideas for the fall detection sensor. The questions focused on different form ideas like a watch, necklace or pin. Additionally, participants were asked "what type of look would you like the fall detection device to have?" This series of questions identified four subthemes: 1) looks, 2) watch model, 3) necklace model and 4) pin model.

Looks

Majority of participants noted that they would like a more conservative, sleek, and small design for the fall detection device. One participant was enthusiastic about the device being as colorful as it can be. However, most participants would rather the device to not be a fashion statement and to blend in with their everyday clothes.

"Have a look high tech like, so it doesn't look out of the ordinary that everybody has one" (Participant 1)

"It looks like, yeah, out of normal and people would talk about it or what it was, I think it should look high tech. From the past they've (necklaces) been so bulky and sometimes heavy and then they become more of your outfit. Where I don't think a wristwatch is that way at all." (Participant 10)

"Most of the time when I wear it I can slip it under my shirt and it would not be –some people where it in front –but I'm kind of vein. People know I'm disabled but I do not want to call attention to it." (Participant 12)

Watch

Eight of the fifteen participants believed that the watch model would be best for them. However, participants noted some challenges associated with a watch model and how to mitigate these challenges. Participants identified that a watch model may get in the way of transferring or might be difficult to put on. Some participants reported that the use of an elastic band would make the device easier to use.

"A standard watch gets in my way when I transfer." (Participant 1)

"I prefer just to stretch bands where they do slip over your wrist. I do not have very good dexterity in my hands. Because of cerebral palsy, I have difficulty with some of that kind of stuff (traditional watch band)" (Participant 4)

"It (watch) was just biting into my skin and it just gave me a clench, it was just irritating. You could have something with a, you know, almost elastic band" (Participant 5)

Necklace

Three of the fifteen participants liked the idea of a necklace or pendant. Some participants believed that the necklace would not be a safe idea. Others noted that if the design was a necklace it would have to come with a strap that fits directly over their head and nothing that clasps. Further, some participants believed that the look of a necklace would draw too much attention and that caused individuals to not want to choose that as an option.

"But not that goes around your neck, not only would it be unsafe…so it (fall detection device) would be something that is more not around my appendages or arms." (Participant 3)

"I got this key chain so I usually carry it on my neck for my keys in my mailbox, and I don't like it because it's always like you said it's always in the way or getting stuck on my clothes" (Participant 4)

"I would rather not have it as a necklace. I'd rather have it as a wristband or something off my neck. So something that is unobtrusive or as small as it can get. But easier, easy to use, of course" (Participant 10)

Pin

Majority of participants when asked if they would like the idea of a pin design said that it would not be preferred. It was noted that a pin design would draw attention, be difficult to use and would be difficult to remember to put it on every day. Of those who believed that a pin design would be okay, participants believed the clasp design of a pin should be a magnet.

"Something that attaches to your clothes, but like a magnet. A regular broach is too difficult." (Participant 1)

"I'd probably like the one where you could just pin it on to your clothing. And if you could, I don't know if this is feasible. But you know, I've had like name badges and things that come like with a bag, a magnet. And like that can just make it stick on with the magnet." (Participant 15)

4.3.5 Device functions

Participants were asked a series of questions regarding specific functions of the fall detection device. One question identified the type of detection, whether it is automatic or manual. Additionally, we asked participants if they would like the option to disable the detection of the device. This theme of device function were further broken down into sub-themes: 1) type of detection and 2) disable calls.

Type of detection

Only a couple of participants noted that they would prefer a manual detection over an automatic detection. However, a majority of participants indicated that they would like the option to toggle between both. Participants indicated that they would like the option to manually trigger the device as a failsafe to the device not successfully detecting that a fall has occurred.

"I would like to prefer being able to set mine to either both" (Participant 1)

"Well, if I fell, and God forbid, knock myself out or something, you know, the ability to have to act on me falling would definitely be a positive feature. And, you know, having the backup of a manual, in case by some chance, the fall detection device that you're creating doesn't work. You know, it gives me a backup way of giving someone contacted." (Participant 15).

Disable calls

All but one participant indicated that they would like the option to disable the detection before the device sent out a text or a call. Participants noted that a false alert can happen and they would like to be able to disable it before help arrives. Majority of participants said a minute when asked "how much time would you like to be able to cancel the call?"

"A false alert definitely can happen, so I definitely want it…If you hit your head, you don't know what state you're going to be in so yeah, not too long. Maybe even five minutes (to disable it)." (Participant 3)

"I think I would like to receive the call and decide if I needed help or not. Just to be safe." (Participant 6)

"Um, but that might. Yeah, that would probably be a nice feature. I mean, if, by some strange reason I, you know, like, I have no problem reaching down for something, and possibly, you know, because I've moved down so quickly, it might activate it, you know, it'd be nice to have the ability to be able to back out and not have this device." (Participant 15)

4.3.6 Instructions

Participants have a wide range of preferences on how to receive instructions. It was noted that ten participants preferred written instructions. However, the other participants believed that an online video guide would be helpful. This is reflected in the subthemes: 1) Audio, 2) written,

3) video and 4) other. Some participants indicated that reading manuals may be difficult for them so the option of a video would work best.

> *“”Well for me, because of my eyesight, sometimes it’s hard to read the manuals. Usually go to YouTube and find it and do it that way. YouTube is a great place. Find a bunch of instructional videos.”* (Participant 4)

Other participants believed that reading a written manual would suit them best.

> *“Better for me if it was printed out and electronically on my phone.”* (Participant 5)
>
> *“I’m more interested in written documents. I would like to have a phone number that I could call and say, “Hey your instructions say this when I do this, this, this is what I get, not what you claim on what I’m supposed to get.”* (Participant 7)

4.4 PERCEIVED USEFULNESS THEMES

The final group of questions were designed to gather feedback on the perceived usefulness of a potential fall detection device. The responses to these questions gathered attitudes on past fall detection devices used, the prospect of a future device, and on smart devices. Participants were asked about the duration and location of use for the potential fall detection device. Further, participants were asked about notification settings of the potential FDD. Lastly, participants were asked about specific device features. The themes that emerged were: 1) smart devices, 2) duration and location of device use, 3) device notification, and 4) device features.

Table 6: Perceived Usefulness Themes

Theme	Sub-theme	Code	Sub-code
Smart Devices	Current or Past fall detection device	Use only when alone	
		Slow response time	
		Stopped using	
	Never used an FDD	Not worth the money	
		Doesn’t see the need	
		Lives in assistive living facility	
		Smart phone is within reach	
		Potential uses	
	Uses a smart phone	Android	
		Apple	
Duration and Location of Device Use	Duration	All the time	
		Two days	
	Location	Everywhere	
Device Notification	Who to contact	Family member	
		Emergency Services	
		Care Partners	

Table 6 (cont.)		Assistive living facility
	Type of notification	Text
		Call
Device Features	Fall record	Provide record
		Who can see it
	Alert that a fall has been detected	Working properly
		Help is on the way

4.4.1 Smart devices

Participants were asked about their current smart devices or fall detection devices. The three sub-themes that emerged were: 1) current or past fall detection devices, 2) never used an FDD, and 3) uses a smart phone.

Current fall detection devices

Six participants currently wear an FDD consistently. The main times these participants wore these devices are when they are home alone. One participant describes not liking to wear one because the emergency response is too slow. However, another participant indicated that the use of their fall detection device helped them recover from a fall when no one was around to help them. Further, one participant noted that they have used a device in the past but have since stopped wearing it because it was too noticeable.

"I do have a button that I can wear around my neck if I was by myself and if I were by myself, I'd push the button for help. We have EMT's in this community 24/7 so when I have fallen in the apartment Bill goes and pulls the cord so we want to prevent him from hurting his back and two EMT will come" (Participant 12)

"When my significant other was in the hospital having his last cancer surgery and they spent a week in the hospital. So yes, I wore their button and felt dumb, because then I could be lay on the floor dying, and they wouldn't come. They don't respond quickly" (Participant 13)

"The wristband you know that if I fall, I hit that button. They're pretty good about coming in. You know those if you fall in or you need help. So yeah, can you call the fire department of the rescue squad you need help getting up, you know, back in the chair" (Participant 2)

Never used an FDD

Several participants reported not purchasing an FDD because they believe the money does not justify the use.

> *"Money. I just don't want to spend the money I still feel like I'm okay. I mean, I'd like I said, I had that one fall and it was coming out of my brother's house and stepping down the stairs and caught myself and everything, it was a good, nice, smooth fall. So anyway, I feel like I try to be pretty careful." (Participant 6)*
>
> *"No, basically for the same reason. And I've heard that they don't they cost like 20 bucks a month or something just to add to surface need to know how much it was what it was worth it. You know, if I if I have if I was one that fell a lot then I would probably consider it, but because I fall them once every six months that I not I felt it was worth it."* (Participant 15)

Participants also believe that they do not have the need for it or has not found one that fits their needs. One participant noted that they do not need help recovering from a fall, so they believe there would be no need for it. Additionally, a participant described that using an FDD would show weakness, so they did not want one or see the need for it.

> *"Well, I've never, I've not found something that, that would fit my needs, I think, uh in terms of sending a signal to my first line of defense would be my wife and others in the house." (Participant 11)*
>
> *"Yeah, don't want to. It shows weaknesses, I just don't want it."* (Participant 8)

One participant described that an FDD is not allowed in their assistive living facility. They described that they would have purchased an FDD if they did not move into an assistive living facility.

> *"Well, to be honest living here in the facility, I talked to previous directors and they, they didn't really want you to have because we have pull cords in our rooms. They, they just they didn't really want you to have it."* (Participant 4)

Participants also expressed the potential usefulness of an FDD. As participants may not need one in their current state, but may want one in the future. A participant describes that their children want them to get a device, but at this moment such a device is not needed.

> *"I might want a fall device out in the garden as I lean over quite a bit. Yeah. And I hang on to my chair and then lean over, because I do have pretty good balance. But I do worry that at times I might let loose and fall when I'm trying to get a weed or something. It can*

happen so that would be the time like the most Yeah. I feel a need for a device like that." (Participant 10)

"One of my kids that thought about getting one but and paying for it, but I don't want them to. As long as I can. I'm sure eventually I'll probably end up having to get one and they'll make me get one. Which is fine." (Participant 6).

Furthermore, participants had a variety of reasons why they currently do not use an FDD or why they do use an FDD. Participants who refrain from using an FDD mostly believe they currently do not possess a need for it. Participants indicated that it would be useful, but not necessarily at this time.

Uses a smart phone

Fourteen of the fifteen participants currently use a smart phone. Participants indicated that they can use their cell phone to call for help if a fall occurs. They described being able to reach their smart phone and can call for help if they cannot recover. Only one participant uses a wearable smart device other than an FDD. Most participants are comfortable using wearable smart devices but just have not felt the need for them.

"Um, just haven't really felt the need, I guess. Um, you know, Apple watches. We've got a couple in the house. I didn't really see how it might be extremely useful for me, so I just haven't." (Participant 14)

"I just know that if I keep my cell phone handy. I can you know call someone if I have to if I do fall." (Participant 15)

4.4.2 Duration and Location of Device Use

Participants were asked how often, when, and where they would wear an FDD. Most participants would wear the device all the time. In some situations, participants reported they would only wear the device when they are home alone or by themselves. However, the majority of participants would wear it all time and regardless of where they are going. Two subthemes associated with device use were identified: 1) duration and 2) location.

Duration

"I think I would wear it all the time" (Participant 2)

"Anytime (their significant other) is not around –if I was to go to a meeting then I'd put it on because (their significant other) doesn't come with me." (Participant 12)

Location

"Not so much inside but when I go outside in the backyard when I'm not so close to, when I can't yell as loud." (Participant 10)

4.4.3 Device Notification

Participants were asked who they would like the device to notify when a fall occurs and how the notification should be sent. The identified subthemes were: 1) who to contact and 2) type of notification.

Who to contact

Participants indicated a wide variety of individuals who would like the device to contact in the event of a fall including family members, care givers or emergency services. However, the majority of participants would like the option to toggle between a variety of contacts. In some circumstances, participants indicated that the person they would like to contact first might not be available, so they would like the option to change it to another contact. Further, some participants would like the option to contact multiple people when a fall occurs.

"My significant other and my caregiver and I would like it to be able to be changed, like two different caregivers so that you could adjust it. I would rather contact my significant other. In case it isn't anything in an emergency" (Participant 1)

"I'd want the EMTs to be notified. I'd want the fire station or whoever runs the ambulance in your place. Most of my falls have been slip downs, I've only had one really serious fall." (Participant 12)

Type of notification

Participants were split on the decision between a text or a call. Some participants indicated that if a call occurred, they might not be able to speak if they sustained a significant injury. However, some participants indicated that receiving a phone call will provide them ease with the knowledge that help is on the way.

"I would say a text. You want the same prompts that over and over say like yeah, you sent this specific message that is catered towards someone." (Participant 1)

"Yeah, I mean, probably the phone call would probably be the best way. If you know, if the fire department would accept a text message that would be okay too. I'm just, I'm thinking more in the sense that if you're going to be making something for a global use, you know, would each Fire Department be so good about wanting to take a text message and agree to it? I'm just thinking the phone, I'm thinking the phone number might be the most, most successful way for you to get someone connected, I would think." (Participant 15)

4.4.4 Device Features

Participants were asked questions about features associated with the fall detection device. Participants were asked if they would like a record of their falls and if they would like an alert to display after the device recognizes a fall. The two subthemes that emerged were: 1) fall record and 2) alert that a fall has been detected.

Fall record

Every participant indicated that they would like the device to save a record of their falls. The majority of participants wanted this feature as primary care physicians often ask them how often they fall, when the fall occurred and where they were when the fall occurs. Participants noted that at times they did not remember the exact circumstances of their falls and reported inaccurate recalls to their doctors.

"Absolutely, that will help your caregiver and physician" (Participant 3)

"*I'd be interested in that. Because sometimes I get hurt and I don't I don't realize it or I don't feel it for a couple days .And I could What? Oh, no wonder I fell isn't always I usually get hurt right away. But I mean, yeah it's happened."* (Participant 13)

Alert that a fall has been detected

It was indicted that a majority of participants would like feedback from the FDD about the success of the device notifying an emergency contact after a fall occurs. Participants reported that feedback will help them feel safe as they know someone is on the way to help them recover from their fall. Participants described that they would like to know if the device was working properly.

> *"Just some kind of audible alert that you can hear, might give you a message that you know it is working properly"* (Participant 4)

4.5 LIKERT QUESTIONS

Participants were asked questions on a Likert scale regarding perceived ease of use and perceived usefulness. These questions were designed to give researchers an objective value for perceived ease of use and perceived usefulness. The responses to the questions provide insights into the attitudes of accepting an FDD.

Likert Perceived Ease of Use Questions

Participants were asked the following two questions on a Likert scale: 1) learning to operate an FDD would be easy for me and 2) I would find a fall detection device easy to use. The Likert scale range is from strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), and strongly agree (4). The first question had a median score of 4 (4, 5). Participants would agree that learning to operate an FDD would be easy to do. The second question had a median of 4 (3.5, 4). Participants would also agree that using an FDD would be easy to do.

Likert Perceived Usefulness Questions

Participants were asked five questions regarding perceived usefulness on a Likert scale. Participants agreed or strongly agreed that an FDD would increase their ability to recover from a fall, decrease their lie time after a fall, decrease their fear of falling, and be useful inside or outside of their place of residence. Participants viewed the potential fall detection device as useful. The median and IQR of the results are in Table 6.

Table 7: Perceived Ease of Use and Perceived Usefulness Likert Questions – Median (IQR)

Perceived Ease of Use Questions	Median Score (IQR)
Learning to operate a fall detection device would be easy for me	4 (1)
I would find a fall detection device easy to use	4 (0.5)
Perceived Usefulness Questions	

Table 7 (cont.)	
Using a fall detection device would increase my ability to recover or get up after a fall occurred.	4 (1.5)
Using a fall detection device would decrease the time I spending lying on the ground or floor after a fall.	5 (1)
Using a fall detection device would decrease my fear of falling.	4 (2)
I would find a fall detection device useful inside of my home.	4 (1.5)
I would find a fall detection device useful outside of my home.	5 (1)

CHAPTER 5: DISCUSSION

This chapter, co-written with Laura Rice, Wendy Rogers, Mikaela Frechette, Libak Abou, Peter Presti, Rachel Brokenshire, Harshal Mahajan, and Jacob Sosnoff is currently under review for publication in a journal. The co-authors gave permission for this publication in this thesis.

This study examines the desired specifications, perceived ease of use and perceived usefulness of a FDD through remote semi-structured interviews. Fifteen participants offered feedback on potential design features, ease of use and usefulness of an FDD. This is a unique study as there are no fall detection devices specifically designed for wheelchair and scooter users. The feedback obtained will help researchers and designers understand the needs of the target population and implement participant preferences into the design of the device in an effort to increase acceptance and prevent technology abandonment. This study also examined the amount of falls annually and lie time of wheelchair and scooter users over the age of 60, which provides additional context to existing literature surrounding fall circumstances.

5.1 PERCEIVED EASE OF USE

The results indicate that potential users would find using a new FDD an easy thing to do and an easy adjustment. Participants highlighted charging and wearability of the device as areas of concern. However, participants offered areas to improve both charging and wearability. The majority of participant preferred a battery that can be charged over night with a wireless charger. In addition, a watch form was preferred over other forms discussed with participants. Participants preferred the option of automated fall detection and having the option to disable the call in the event of a false alarm. Written instructions were favored over other instruction options. Finally, participants agreed or strongly agreed that using an FDD would be easy for them to do. Finally, findings of the study revealed that device design preferences differs between potential users of the device. The device design preferences differs based on functional ability and user preference.

5.1.1 Current Technology and Accessories

The majority of participants reported no current issues with learning and using technology, and felt confident in their abilities to learn a new technology. Overall, participants had few issues with their own technology and accessories. In addition, several participants already wear accessories similar to the proposed fall detection forms. Previous literature indicates that already wearing a similar accessory would make the transition to an FDD easier [55].

5.1.2 Device charging specifications

Participants discussed potential challenges associated with charging. Challenges could persist from having limited fine motor function. A challenge with charging is plugging a wired charger into a device. To manage those challenges, participants report use of custom set ups. It is important to design a charger that is accessible for people with a variety of functional capabilities. Rashidi and Mihailidis indicated that batteries should have inductive charging mats or wireless charging to attribute to the ease of use of charging assistive living technologies [56]. Having a more accessible charging approach would facilitate increased use of the fall detection device.

It was common for participants to report charging their mobile devices overnight and many felt that it would be reasonable to charge the FDD overnight also. More frequent charging would not be acceptable. These findings are consistent with research performed by Rashidi and Mihailidis in which they indicate that charging a device should be minimal and easy to encourage the frequency of use [56]. Although charging a device overnight would be acceptable and practical for users, it is important to note falls can occur at night due to unavoidable toileting activities [9]. It is therefore important to consider rapidly charging the FDD when participants are not using the device, thus allowing the device to be used overnight.

5.1.3 Device looks and model design

Overall, participants indicated that the FDD should be small and discreet, and should not draw other peoples' attention. Participants favored the design of a watch model with a watchband that is easy to don and doff. However, the topic of device appearance and design varied the more than other topics of the interview. This suggests that there are a lot of individual differences in design and speaks on the possibility of having multiple device designs in the future.

Some participants discussed that they have stopped using fall detection devices in the past because they were too big and caused peers to ask about them. A bulkier and heavier design may deter individuals from purchasing and using an FDD. Previous literature also suggests that the device should be thinner, smaller and unnoticeable [55, 56]. Further, participants would rather the device go unnoticed or be a part of the outfit they are wearing. Similarly, Rashidi and Mihailidis discussed that assistive technologies should avoid drawing attention to minimize stigmatization of using assistive technologies [56].

The majority of participants believed that a watch form would fit them best. However, some participants noted concern that a watch form would be difficult to don/doff due to limited fine motor abilities. Participants suggested to make the watchband elastic to make donning the device easier. Further, a few participants described situations where a watch caused challenges in their transfers or functional mobility. The fall detection device interfering in one's activities of daily living might cause an individual to refrain from using or buying it. Moreover, participants discussed that a watch model design should also function as a watch. It was common for participants to already wear a watch, thus, having two devices on their wrist may cause inconveniences and would not be acceptable. It is denoted in previous literature that older adults are familiar with watches, which may promote the acceptance and ease of use of this device [55]. From a reliability standpoint, Zeagler reported that accelerometers and gyroscopes worn on the wrist provide accurate movement measurements [57]. As a result, the watch form is both acceptable in terms of form by individuals in the target population and able to accurately assessment movement.

Findings of this study revealed that a necklace or pendant design would not be desired by the target population. Participants described that a loose hanging pendant would get in the way of transfers and could also pose as a choking hazard. From a reliability standpoint, the findings from Zeagler suggest that an accelerometer worn on the chest must be fastened to the individual and not be loosely hanging. As a result, a loose hanging pendant may not provide sufficient reliability [57]. In addition, participants identified that fastening traditional necklace clasps would be difficult. The chain of the necklace or pendant would have to fit over an individual's head without the need for fastening it. In addition, participants believed that a necklace design would draw too much attention. Previous research is consistent with our findings that assistive technology should be discreet to others [56]. As a result, a necklace form of an FDD would not be feasible or accepted by the target population.

Participants were also not keen on the idea of a pin. Participants thought that a pin model design would draw too much attention and be difficult to use. Participants described not wanting something obvious on their clothing that would attract the gaze or inquiry of others. This finding is similar to published research regarding the need for assistive technology to be discreet [56]. In addition, participants were worried about how easy it would be to put on a pin every day. To increase the ease of putting on a pin, participants suggested using a magnetic clasp design. The use of magnets to adhere the fall detection device to an individual's shirt would make the device more accessible and easier to use.

5.1.4 Device detection and disable calls

The findings of this study indicated that automatic fall detection is preferred by individuals in the target population. Depending on the severity of the fall, an individual may not be able to manually trigger the device. Participants discussed that in the event of a fall they would feel safer if the fall detection device notified their emergency contact for them. In addition, a few participants also wanted to be able to manually trigger the device. Manually being able to send a notification would provide individuals with a failsafe if the device did not function properly.

Participants also indicated that they would like to have the option to cancel the call or text to an emergency contact if the device was triggered. The ability to cancel a call during a false alert or if the user recovered adds to the ease of use of the device. Previous research suggests that increased ease of use in assistive technology would help foster the acceptance of an FDD [24].

5.1.5 Device instructions

The majority of participants agreed that written instructions would work best for them. Participants report they would prefer a step-by-step guide included with their new technologies to help with the setup of the device. Previous research suggests that older adults are familiar and comfortable with reading and following written instructions [4]. Czaja, et al. suggested that when designing instructions for older adults, the instructions should be based on existing knowledge and provide a step-by-step detailed guide with pictures and diagrams to follow [4]. The instructions must provide solutions to anticipated errors with the device, whether the solutions can be found at the end of a manual or online [4].

5.2 PERCEIVED USEFULNESS

Study results indicate that a FDD is perceived as useful by wheelchair and scooter users. Approximately half of the participants currently use or have previously used an FDD. Many participants reported that they feel the FDD would be useful anytime and anywhere. Participants indicated that it would be most useful to be able switch between emergency contacts while using the device and to notify contacts via text or phone call. Further, participants reported that the device having a fall record would be useful. In addition, participants discussed that the device should provide feedback that a notification has been successfully sent to their emergency contact after a fall occurs. On a Likert scale, participants agreed or strongly agreed that an FDD would increase their recovery from a fall, decrease their fear of falling, decrease their lie time after a fall and would be useful inside and outside of their home.

5.2.1 Previous interactions with fall detection devices

Six of the 15 participants have used an FDD in the past. Research suggests that participants, who have used an FDD in the past, will perceive a new and improved FDD as useful [55].One participant stopped using an FDD because they did not like wearing a heavy pendant around their neck. This finding is consisted with previous research suggesting that assistive technology should be small to improve accessibility and increased use [55, 56]. Another participant indicated that they are interested in buying an FDD; however, they have never found a device on the market that fits their needs.

Other participants described not buying an FDD because the monthly subscriptions are too expensive. The proposed FDD would utilize the data plan of a cellular telephone and would not require an additional monthly subscription. This design could lessen the cost of the FDD, which may foster the acceptance of this device. These findings suggest that the negative aspect of FDDs like costs or design, have prevented individuals from buying or continuing the use of an FDD.

Participants that do wear fall detection devices have described scenarios when using the device has helped them recover from a fall. This finding is consistent with previous research discussing the usefulness of FDDs for fall recovery [50, 51]. Falls can happen in any place or situation, thus there is a need and use for an improved device. Additionally, participants have expressed that a potential FDD would be useful; however, many participants believe they do not need one currently. To inform older adult wheelchair and scooter users of the usefulness of an FDD, it may be important explain the risks associated with falls and to emphasize that an FDD could increase the safety and foster of independent living.

5.2.2 Smart phone use

The proposed fall detection device would connect with a user's smart phone, therefore comfort with smart phone use was also investigated. Fourteen of the 15 participants currently use a smart phone in their daily lives. The literature regarding smart phone use among older adults has conflicting findings. Thilo, et al. suggests that older adults who already utilize smart phones will have an easier time adjusting to a smartphone based FDD [55]. However, Thilo, et al. described that smart phone use poses difficulty for aging adults, due to decreased eyesight, touch sensitivity, and cognition [55]. While, our participants indicated comfort with the use of smart phones and devices, other individuals in the target population may not. Older adults may need enhanced instructions or someone to demonstrate how to use a smart phone. Showing individuals how to use the fall detection device in relation to their smart phone might increase the usefulness of the device.

5.2.3 Device duration and location of use

The findings of our study suggest that if the device was useful and effective in detecting falls, then participants would likely wear the device all of the time. Participants declared that the device would be useful anywhere, as they are aware that falls can happen anywhere and everywhere. A few participants indicated that they would use the device mostly when they are alone and did not think the device would be as useful when someone else was around.

5.2.4 Notification preferences

Participants identified that having an option in the settings of the device on who to contact when a fall occurs would be preferred. For instance, some participants want to be able to change their emergency contact number from emergency services to another person and vice versa. Individuals indicated that if their first contact is not available, they would like the option to toggle between a variety of contacts. Additionally, some participants did not want to contact emergency services, as they believed not all of their falls would be classified as an emergency. Therefore, having the option to input specific people and being able to change that option was important to potential users.

Participants had a variety of opinions on the type of notification to be sent out. Participants discussed a concern that a text message may be ignored by their emergency contact and help not received. In contrast, other participants were worried that if they suffered a concussion as result of a fall, then they would not be able to talk on the phone. Furthermore, a participant discussed the possibility of emergency services not being able to receive a text message. As a result, a need exists to provide options to participants in who is notified when a fall occurs, the ability to easily modify who is contacted and in what form the contact is made (call or text).

5.2.5 Features of the fall detection device

All participants agreed that the device should keep a record of the time and date when a fall occurs. Participants indicated that their primary care physicians often ask how many falls they have experience in the past six months, thus having a record of the number of falls would be a useful feature. Individuals would not need to remember or track their fall frequency, which allow users to easily track and record fall frequency. Currently, only the Apple Watch has a fall tracking feature.

Participants report that they would like to know when the sensor detects a fall. It was indicated that an alarm or a vibration would be helpful to provide feedback so that end-users know that the device is working properly. Ensuring the device is working properly with the use of an audio or haptic notification could increase the usefulness of the device. A systematic review by Chaudhuri, et al. reported that older adult users of automated FDDs wanted to know what the system was doing at all times [51]. For instance, the users wanted a notification from the device indicating that the device successfully registered a fall [51]. These findings by

Chaudhuri, et al. are consistent with our findings suggesting users would want their FDD to notify them when a fall occurs. However, Chaudhuri, et al. discussed that older adult users were annoyed by false alarms [51] highlighting the importance to giving end-users the option to cancel a call or text to an emergency contact.

5.2.6 Fear of falling and lie time

Participants suggested that an automated FDD would decrease their fear of falling and lie time. Brownsell, et al. reported that ambulatory older adult users of automated FDD revealed trends of decreased FoF [58]. Their findings are consisted with our findings, in which wheelchair and scooter users indicated that they feel that use of an automated FDD would decrease FoF. In addition, a systematic review on the use of FDDs suggested that ambulatory older adults are willing to use automated FDDs and have found that automated FDDs provide older adults with a greater sense of security [51]. Furthermore, participants reported an average lie time of 14.8 ± 11.1 minutes, higher than the previously reported findings of lie time among wheelchair users. [9, 10]. As a result, older adults who use wheelchair and scooter may be a greater risk for a long-lie further increasing the need for a reliable, automated fall detection device.

5.3 IMPLICATIONS

This study has contributed to the advancement of literature examining the desired specifications, perceived ease of use and usefulness of an automated FDD for wheelchair and scooter users. The literature surround fall detection devices for wheelchair and scooter users is limited. This study has provided insights into the needs and wants from potential users of an FDD. Designers and manufacturers of fall detection devices should be aware of these design specifications to make the product more accessible to users. To increase the accessibility, designers and manufactures should provide wireless charging to avoid challenges associated with limited fine motor skills. To improve the ease of donning/doffing a FDD in the form of a watch, designers should provide elastic band options, as standard watchbands may cause difficulties for individuals with diminished fine motor skills. Additionally, designers should provide action-based tasks in the form of a step-by-step instructional guides to improve the accessibility of following written instructions for assistive technologies catered toward older adults. Future research should provide sustainability testing of fall detection devices for wheelchair and scooter users to have a better understanding of the challenges and uses associated with them.

5.4 LIMITATIONS

The study findings are informative but it should be noted that they were obtained from a relatively small sample. In addition, eight of our fifteen participants use a wheelchair or scooter as a result of symptoms associated with multiple sclerosis, which may cause greater mobility limitations and fine motor skills compared to other wheelchair users. However, the rest of the study population is rather diverse in cause of mobility impairment. Our findings may only be representative of the participants interviewed and not of the general population due to a small sample size. Therefore, having a more widespread study and interviewing participants with a greater diversity of backgrounds would improve the generalizability of the results. Also, participants may have had trouble visualizing the functionality of a new fall detection device, as they could not see or touch the device. The interview questions may have been misinterpreted some of the device design ideas leading to a skew in preferred form. Participant may have been confused on the device forms because they could not see, feel or use the proposed FDD. Still, with little literature surrounding automated fall detection devices for wheelchair and scooter users, this study will help inform larger, future studies.

CHAPTER 6: CONCLUSION

This chapter, co-written with Laura Rice, Wendy Rogers, Mikaela Frechette, Libak Abou, Peter Presti, Rachel Brokenshire, Harshal Mahajan, and Jacob Sosnoff is currently under review for publication in a journal. The co-authors gave permission for this publication in this thesis.

This study examined the perceptions of wheelchair and scooter users regarding a potential automated fall detection device. Participants in the study believed an FDD in the form of a watch with an easy to use wrist band would be the best model. Participants discussed that the fall detection device should be charged wirelessly and overnight. Additionally, an FDD should be automated with the ability to easily change who is notified in the event of a fall. Participants discussed that emergency contacts could be notified via text message or phone call, depending on the preferences and ability to receive text messages of the contact. Further, participants discussed that an FDD would be easy to use and useful in their lives. These findings provide insights from potential users of what they want, like, and dislike in an FDD that may help to influence the design of an FDD. There are limited studies surrounding fall detection device design for wheelchair users and these findings may influence the fall detection device form, charging and notification settings.

REFERENCES

1. Taylor, D.M., *Americans with disabilities: 2014.* US Census Bureau, 2018.
2. Kirby, R.L., et al., *Wheelchair-related accidents caused by tips and falls among noninstitutionalized users of manually propelled wheelchairs in Nova Scotia.* American Journal of Physical Medicine and Rehabilitation, 1994. **73**(5): p. 319-330.
3. Gavin-Dreschnack, D., et al., *Wheelchair-related falls: Current evidence and directions for improved quality care.* Journal of Nursing Care Quality, 2005. **20**(2): p. 119-127.
4. Czaja, S.J., et al., *Designing for older adults: Principles and creative human factors approaches*. 2019: CRC press.
5. Nelson, A., et al., *Fall-related fractures in persons with spinal cord impairment: A descriptive analysis.* SCI Nursing: A Publication of the American Association of Spinal Cord Injury Nurses, 2003. **20**(1): p. 30.
6. Peterson, E.W., C.C. Cho, and M.L. Finlayson, *Fear of falling and associated activity curtailment among middle aged and older adults with multiple sclerosis.* Multiple Sclerosis Journal, 2007. **13**(9): p. 1168-1175.
7. Sung, J., et al., *Fear of falling, community participation, and quality of life among community-dwelling people who use wheelchairs full time.* Archives of Physical Medicine and Rehabilitation, 2020.
8. Tinetti, M.E. and L. Powell, *Fear of falling and low self-efficacy: a cause of dependence in elderly persons.* Journal of Gerontology, 1993.
9. Rice, L.A., et al., *Perceptions of fall circumstances, recovery methods, and community participation in manual wheelchair users.* American Journal of Physical Medicine and Rehabilitation, 2019. **98**(8): p. 649-656.
10. Rice, L.A., et al., *Perceptions of fall circumstances, injuries and recovery techniques among power wheelchair users: A qualitative study.* Clinical Rehabilitation, 2018. **32**(7): p. 985-993.
11. Lord, S., et al., *Falls in older people: Risk factors and strategies for prevention*. Cambridge University Press, 2001.
12. Bagalà, F., et al., *Evaluation of accelerometer-based fall detection algorithms on real-world falls.* Public Library of Science, 2012. **7**(5): p. 37062.
13. Nevitt, M.C., et al., *Risk factors for recurrent nonsyncopal falls: A prospective study.* Journal of the American Medical Association, 1989. **261**(18): p. 2663-2668.
14. Mallinson, W. and M.F. Green, *Covert muscle injury in aged patients admitted to hospital following falls.* Age and Ageing, 1985. **14**(3): p. 174-178.
15. King, M.B. and M.E. Tinetti, *Falls in community-dwelling older persons.* Journal of the American Geriatrics Society, 1995. **43**(10): p. 1146-1154.
16. Wild, D., U. Nayak, and B. Isaacs, *How dangerous are falls in old people at home?* British Medical Journal (Clinical Research Edition), 1981. **282**(6260): p. 266-268.
17. Vellas, B., et al., *Prospective study of restriction of acitivty in old people after falls.* Age and Ageing, 1987. **16**(3): p. 189-193.
18. Fleming, J. and C. Brayne, *Inability to get up after falling, subsequent time on floor, and summoning help: prospective cohort study in people over 90.* British Medical Journal, 2008. **337**.

19. Rajagopalan, R., I. Litvan, and T.-P. Jung, *Fall prediction and prevention systems: Recent trends, challenges, and future research directions.* Sensors, 2017. **17**(11): p. 2509.
20. Gurley, R.J., et al., *Persons found in their homes helpless or dead.* New England Journal of Medicine, 1996. **334**(26): p. 1710-1716.
21. Porter, E.J., *Wearing and using personal emergency.* Journal of Gerontological Nursing, 2005. **31**(10): p. 26-33.
22. Rajendran, P., et al., *Falls, fall prevention, and fall detection technologies*, *in eldercare technology for clinical practitioners*, M. Alwan and R.A. Felder, Editors. Humana Press, 2008. p. 187-202.
23. Davis, F.D., *Perceived usefulness, perceived ease of use, and user acceptance of information technology.* Management Information Systems Quarterly, 1989: p. 319-340.
24. Holden, R.J. and B.-T. Karsh, *The technology acceptance model: Its past and its future in health care.* Journal of Biomedical Informatics, 2010. **43**(1): p. 159-172.
25. Nie, Q., L.A. Rice, J.J. Sosnoff and W.A. Rogers, *Investigating falls and rehabilitation use among wheelchair users from the national health & aging trends study*. In *Gerontological Society of America 2020 Annual Scientific Meeting*, 2020.
26. Stalenhoef, P., et al., *A risk model for the prediction of recurrent falls in community-dwelling elderly: A prospective cohort study.* Journal of Clinical Epidemiology, 2002. **55**(11): p. 1088-1094.
27. Nelson, A.L., et al., *Wheelchair-related falls in veterans with spinal cord injury residing in the community: A prospective cohort study.* Archives of Physical Medicine and Rehabilitation, 2010. **91**(8): p. 1166-1173.
28. Kirby, R.L. and S.A. Ackroyd-Stolarz, *Wheelchair safety--adverse reports to the united states food and drug administration.* American Journal of Physical Medicine and Rehabilitation, 1995. **74**(4): p. 308-312.
29. Krause, J.S., *Factors associated with risk for subsequent injuries after traumatic spinal cord injury.* Archives of Physical Medicine and Rehabilitation, 2004. **85**(9): p. 1503-1508.
30. Moore, Z.E., M.T. van Etten, and J.C. Dumville, *Bed rest for pressure ulcer healing in wheelchair users.* Cochrane Database of Systematic Reviews, 2016(10).
31. Legters, K., *Fear of falling.* Physical therapy, 2002. **82**(3): p. 264-272.
32. Tennstedt, S., et al., *A randomized, controlled trial of a group intervention to reduce fear of falling and associated activity restriction in older adults.* The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 1998. **53**(6): p. 384-392.
33. Tinetti, M.E., M. Speechley, and S.F. Ginter, *Risk factors for falls among elderly persons living in the community.* New England Journal of Medicine, 1988. **319**(26): p. P1701-P1707.
34. Myers, A.M., et al., *Psychological indicators of balance confidence: Relationship to actual and perceived abilities.* The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 1996. **51**(1): p. M37-M43.
35. McAuley, E., S.L. Mihalko, and K. Rosengren, *Self-efficacy and balance correlates of fear of falling in the elderly.* Journal of Aging and Physical Activity, 1997. **5**(4): p. 329-340.
36. Howland, J., et al., *Fear of falling among the community-dwelling elderly.* Journal of Aging and Health, 1993. **5**(2): p. 229-243.

37. Lachman, M.E., et al., *Fear of falling and activity restriction: the survey of activities and fear of falling in the elderly (SAFE).* The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 1998. **53**(1): p. P43-P50.
38. Lawrence, R.H., et al., *Intensity and correlates of fear of falling and hurting oneself in the next year: Baseline findings from a roybal center fear of falling intervention.* Journal of Aging and Health, 1998. **10**(3): p. 267-286.
39. Howland, J., et al., *Covariates of fear of falling and associated activity curtailment.* The Gerontologist, 1998. **38**(5): p. 549-555.
40. Vellas, B.J., et al., *Fear of falling and restriction of mobility in elderly fallers.* Age and Ageing, 1997. **26**(3): p. 189-193.
41. Tinetti, M.E., et al., *Fear of falling and fall-related efficacy in relationship to functioning among community-living elders.* Journal of Gerontology, 1994. **49**(3): p. M140-M147.
42. Aoyagi, K., et al., *Falls among community-dwelling elderly in japan.* Journal of Bone and Mineral Research, 1998. **13**(9): p. 1468-1474.
43. Rice, L., et al., *Fall prevalence in people with multiple sclerosis who use wheelchairs and scooters.* Medicine, 2017. **96**(35).
44. Hindmarsh, J.J. and E.H. Estes, *Falls in older persons: Causes and interventions.* Archives of Internal Medicine, 1989. **149**(10): p. 2217-2222.
45. Campbell, A.J., M.J. Borrie, and G.F. Spears, *Risk factors for falls in a community-based prospective study of people 70 years and older.* Journal of Gerontology, 1989. **44**(4): p. M112-M117.
46. Maki, B.E., P.J. Holliday, and A.K. Topper, *Fear of falling and postural performance in the elderly.* Journal of Gerontology, 1991. **46**(4): p. M123-M131.
47. Tinetti, M.E., W.-L. Liu, and E.B. Claus, *Predictors and prognosis of inability to get up after falls among elderly persons.* The Journal of the American Medical Association, 1993. **269**(1): p. 65-70.
48. Cox, T.B. and K. Williams, *Fall recovery intervention and its effect on fear of falling in older adults.* Activities, Adaptation and Aging, 2016. **40**: p. 106-93.
49. Li, Q., et al. *Accurate, fast fall detection using gyroscopes and accelerometer-derived posture information*: i*n sixth international workshop on wearable and implantable body sensor networks*. Institute of Electrical and Electronics Engineers. 2009.
50. Ren, L. and Y. Peng, *Research of fall detection and fall prevention technologies: A systematic review.* Institute of Electrical and Electronics Engineers Access, 2019. **7**: p. 77702-77722.
51. Chaudhuri, S., H. Thompson, and G. Demiris, *Fall detection devices and their use with older adults: A systematic review.* Journal of Geriatric Physical Therapy, 2014. **37**(4): p. 178-196.
52. Berkowsky, R.W., J. Sharit, and S.J. Czaja, *Factors predicting decisions about technology adoption among older adults.* Innovation in Aging, 2018. **2**(1), igy002.
53. WHO., *WHO global report on falls: Prevention in older age*. World Health Organization, 2007.
54. Cresswell, J.W., *Qualitative inquiry and research design: Choosing among five traditions*. SAGE Publications, 1998.
55. Thilo, F.J., et al., *Involvement of the end user: Exploration of older people's needs and preferences for a wearable fall detection device–a qualitative descriptive study.* Patient Preference and Adherence, 2017. **11**: p. 11.

56. Rashidi, P. and A. Mihailidis, *A survey on ambient-assisted living tools for older adults.* Institute of Electrical and Electronics Engineer Journal of Biomedical and Health Informatics, 2013. **17**(3): p. 579-590.
57. Zeagler, C. *Where to wear it: Functional, technical, and social considerations in on-body location for wearable technology 20 years of designing for wearability*. In *Proceedings of the 2017 Association for Computer Machinery International Symposium on Wearable Computers*. 2017.
58. Brownsell, S. and M. Hawley, *Fall detectors: Do they work or reduce the fear of falling?* Housing, Care and Support, 2004. **7**(1): p. 18-24.

APPENDIX A: INTERVIEW SCRIPT

Opening Questions:

Hi, thanks for coming in. As we discussed before, we are interested in gathering your feedback on a fall detection device designed specifically for wheelchair and scooter users. I'll give you more information on the device in a moment but first I would like to get to know a little bit about you.

A) What do you like to do when you have free time?

B) Do you tend to perform recreational activities inside or outside of your home/place of residence?

Let's talk about the activities you use your wheelchair or scooter for on a daily basis.

A) What activities do you use your wheelchair for indoors? Outdoors?

B) Do you need assistance performing daily activities?

Questions about a fall sensor:

We are currently developing a sensor that automatically detects if a wheelchair or scooter user has fallen. The device would then be able to automatically send an alert to emergency services and/or family members or a care partner when a fall has occurred based on your preferences. We are in the early phases of the design process and would like to get your feedback on the design of this type of alert system.

A) Do you currently wear any fall alert devices or smart devices; such as a life alert button or smart watch?

If Yes:

a. Please tell me specifically what you use.

b. Why did you chose to get this device?

c. How long you have had the device?

d. What do you like about the device?

e. What do you dislike?

f. Do you have to manually trigger the device if a fall occurs?

If No:

a. Why don't you use any of these types of devices?

b. Have you ever considered using a fall alert device? Why or why not?

B) Have you ever used a fall alert device in the past and stopped using it?

a. If yes, why did you stop using it?

C) Do you have a smart phone?

If yes:

a. Where do you keep your phone on you? (e.g. pocket, purse, belt clip?)

b. Do you charge the device on a daily basis?

c. What type of a charger to you use for the device? (iPhone/micro USB plug, stand charger base, wireless charger)?

D) Do you need to charge any device on at least a weekly basis (e.g. phone, electric toothbrush, razor, etc.)

If yes,

a. Do you have any challenges using the charger?

b. Is there anything you can think of that would make the charging process easier?

c. Do you need assistance from someone to charge or operate the device?

If no,

a. Why do you refrain from using one of these devices?

b. Does the need to charge a device on an ongoing basis deter you from using a device such as this?

E) Do you wear any other items, such as a watch or jewelry on a daily basis?

If yes,

a. What are these items and where do you wear the item?

i. Is there anything that bothers you about wearing this/these items?

If no,

b. why do you choose not to wear a watch or jewelry?

F) What type of "look" would you like the fall alert device to have?

G) We are considering different options. For example, the device could look like a standard watch, a small pendant worn around your neck, a small pin you could attach to your clothing. Do you have any preference?

H) How often would you be willing to wear the fall alert device if it is able to accurately detect a fall?

I) Would you be willing to wear it a few hours per day?

J) Would you want to only wear it when leaving the home?

K) Would you wear it the whole day?

a. If no, when would you not wear it?

L) How often do you think it is reasonable to charge the fall alert device?

M) Who would you like to be notified when a fall occurs?

a. Significant other/family member/care partner?

b. Emergency services?

c. Both?

- Why do you feel this way?

N) How would you like to send these notifications? (Example: text message on a cell phone, phone call etc.)

a. Would you like your device to display/sound an alarm on detecting the fall?

O) When a fall occurs would you like the device to:

a. trigger automatically?

b. manually?

c. both?

- Please describe why feel this way?

P) Would you like an option on the device that disables the call to someone?

a. How much time would you like to be able to cancel the call?

Q) How would you prefer to receive instructions on how the device works?

R) We are considering different options. Would you like:

a. a written document available online?

b. an online video guide?

c. paper based written instructions?

d. something else?

S) Would you like the device to provide a record of each fall that has occurred that you could access through a secure app?

T) Would you want others to have access to this information also? Please answer yes or no to the following individuals:

a. Family

b. Friends

c. Care Partners

d. Primary Care Physician

e. Insurance Company

f. Wheelchair Manufacture

U) Are there any other aspects of an automated fall alert device you would like to discuss?

V) Do you have any other comments for us?

Thank you very much for your time!

APPENDIX B: INFORMED CONSENT DOCUMENT

Online Consent Form

FIND-Wheels Fall Detection Device Feedback Interviews

You are being asked to participate in a voluntary research study. The purpose of this study is to perform interviews with full wheelchair and scooter users 60 years old and older to gather information on preferences and barriers to use of a fall detection device designed specifically for wheelchair and scooter users. Participating in this study will involve completing an online survey and participating in an online interview. Your participation will last a total of 1.5 hours. Risks related to this research include a breach of confidentiality. There are no direct benefits associated with this study, however the information you provide will assist in the development of a fall detection device that might benefit you in the future. The alternative to participating in this study is to not participate.

Principal Investigator Name and Title: Dr. Laura Rice
Department and Institution: Kinesiology and Community Health at the University of Illinois at Urbana-Champaign
Contact Information: ricela@illinois.edu or 217-333-4650
Sponsor: National Institute on Disability, Independent Living, and Rehabilitation Research

What is the purpose of this study?

The purpose of this study is to perform interviews with full wheelchair and scooter users 60 years old and older to gather information on preferences and barriers to use of a fall detection device designed specifically for wheelchair and scooter users. Falls are a common occurrence among wheelchair and scooter users. Studies show that around 30-50% of wheelchair and scooter users have experienced significant injuries resulting from a fall. In addition, research indicates that laying on the floor/ground for an extended period of time after a fall results in a greater risk of injury. Due to the injurious nature of falls, the development of a fall detection device specifically for wheelchair and scooter users is necessary. At this stage of development, we are interested in gathering feedback from full time wheelchair and scooter users about the needs and specifications of such a device. The feedback obtained from the interviews will be used to inform the development of a fall detection device.

What procedures are involved?

You are being asked to participate in this research study because you are a current wheelchair or scooter user, 60 years old or older, who uses a wheelchair or scooter for the majority of your daily movements, have used a wheelchair or scooter for at least 1 year, have experienced at least one fall in the past year, able to read and understand English, and able to communicate through video conferencing software or over the telephone. The study will take approximately 1.5 hours of your time.

After you have agreed to participate in this study, you will be asked to answer questions through an online survey to verify that you meet the inclusion criteria described above by reporting yes or no to a series of questions regarding your age, wheelchair/scooter use and fall history and communication abilities. Next, you will be asked to complete an online survey that includes more detailed information about your reasons for wheelchair users, wheelchair use and fall history. Once you have completed this online survey, a research assistant will call or send you an e-mail to schedule a time to perform a 1-hour interview with you at a time convenient for you. During this interview, you will be told about a device that is currently being developed to detect a fall from a wheelchair or scooter and then be asked to provide your opinion on various aspects of the device and what would make use of the device easier and more convenient for you. The interview will be audio recorded to ensure accurate transcription of interview answers. If the interview is being performed through a video conference site, the video will be recorded also. No one other than trained researchers associated with this study will have access to the recordings and they will be deleted after 7 years. If you are not comfortable with audio or video recording, please tell the researcher and the researchers will take written notes during the interview instead. You will then be asked to review your statements to ensure accuracy. You may also receive a brief follow-up phone call to clarify any items discussed in the interview. The interview will take approximately one hour.

The risks associated with this study involve a potential breach of confidentiality. The efforts used to keep your study information confidential are listed below in the next section.

This research will be performed in an online environment with UIUC faculty and staff. The research staff will contact you once to perform the screening activities and then one additional time to perform the interview. The entire study will require about 1.5 hours of your time.

Are there benefits to participating in the research?
There is no direct benefit of the research to you at this time. However, your feedback will aid in the development of the fall detection device that you may benefit from in the future.

Will my study-related information be kept confidential?

We will use all reasonable efforts to keep your personal information confidential, but we cannot guarantee absolute confidentiality. When this research is discussed or published, no one will know that you were in the study. But, when required by law or university policy, identifying information may be seen or copied by: a) The Institutional Review Board that approves research studies; b) The Office for Protection of Research Subjects and other university departments that oversee human subjects research; c) University and state auditors responsible for oversight of research; d) Federal regulatory agencies such as the Office of Human Research Protections in the Department of Health and Human Services; or e) National Institute on Disability, Independent Living and Rehabilitation Research, the funder of this research.

Will I be reimbursed for any expenses or paid for my participation in this research?

You will be paid $10 in the form of an Amazon gift card after the completion of the study. The Amazon gift card will be sent electronically via email.

Can I withdraw or be removed from the study?
If you decide to participate, you are free to withdraw your consent and discontinue participation at any time. Your participation in this research is voluntary. Your decision whether or not to participate, or to withdraw after beginning participation, will not affect your current or future dealings with the University of Illinois at Urbana-Champaign.

The researchers also have the right to stop your participation in this study without your consent if they believe it is in your best interests, you were to object to any future changes that may be made in the study plan, and/or the funding for the research study is taken away.

What other options are there?
You have the option to not participate in the study.

Will data collected from me be used for any other research?
Your de-identified information could be used for future research without additional informed consent.

Who should I contact if I have questions?
If you have questions about this project, you may contact Dr. Laura Rice at 217-333-4650 or ricela@illinois.edu. If you have any questions about your rights as a participant in this study or any concerns or complaints, please contact the University of Illinois at Urbana-Champaign Office for the Protection of Research Subjects at 217-333-2670 or via email at irb@illinois.edu.

Please print this consent form if you would like to retain a copy for your records.

I have ready and understand the above consent form. I certify that I am 18 years old or older. By clicking the “Submit” button to enter the survey, I indicate my willingness to voluntarily take part in this study.

SUBMIT

APPENDIX C: IRB APPROVAL LETTER

I ILLINOIS

OFFICE OF THE VICE CHANCELLOR FOR RESEARCH & INNOVATION

Office for the Protection of Research Subjects
805 W. Pennsylvania Ave., MC-095
Urbana, IL 61801-4822

Notice of Exempt Determination

May 20, 2020

Principal Investigator	Laura Rice
CC	Libouk Abou, Alexander Fliflet, Amelia Woods, Anne Ordway
Protocol Title	*FIND-Wheels Fall Detection Device Feedback Interviews*
Protocol Number	20878
Funding Source	National Institute on Disability, Independent Living, and Rehabilitation Research
Review Category	Exempt 3 (ii)
Determination Date	May 20, 2020
Closure Date	May 19, 2025

This letter authorizes the use of human subjects in the above protocol. The University of Illinois at Urbana-Champaign Office for the Protection of Research Subjects (OPRS) has reviewed your application and determined the criteria for exemption have been met.

The Principal Investigator of this study is responsible for:

- Conducting research in a manner consistent with the requirements of the University and federal regulations found at 45 CFR 46.
- Requesting approval from the IRB prior to implementing major modifications.
- Notifying OPRS of any problems involving human subjects, including unanticipated events, participant complaints, or protocol deviations.
- Notifying OPRS of the completion of the study.

Changes to an **exempt** protocol are only required if substantive modifications are requested and/or the changes requested may affect the exempt status.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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