Older Adults' Experience with a Novel Fall Detection Device

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Abstract

Background: Falls are a significant concern for the older adult (OA) population, many of whom are unable to get up following a fall. **Introduction:** While many devices exist designed to detect a fall, little work has been conducted to evaluate the usability of such devices. We present a longitudinal usability study of a fall detection (FD) device tested with OAs in real-world settings. **Materials and Methods:** OAs were recruited and asked to use a wearable FD device for up to 4 months. Participants were interviewed at baseline and 2 and 4 months and encouraged to provide direct feedback on their experience. **Results:** In total, 18 OAs participated in the study. Eight completed the 4-month trial. We conducted a total of 38 interviews (16 baseline, 7 midpoint, and 15 final) and logged a total of 78 comments. While participants enjoyed the GPS and automatic detection features of the device, they were unhappy with the volume of false alarms and obtrusiveness of the device. Many also did not see a great need for having the device or were embarrassed by the device. **Discussion:** Engineers must work to better develop this technology so that it is accessible to people with hearing loss, limited dexterity, and low vision. Utilizing age-appropriate design techniques will help make such informatics tools more user friendly. **Conclusion:** We explored the usability of a particular FD device with OAs and provide design recommendations to help future device manufacturers create more age-appropriate devices.

Keywords: behavioral health, technology, telecommunications, m-health

Introduction

Falls are a significant concern for the growing population of people over the age of 65.^{1,2} Falls are the leading cause of injury deaths with around 30% of older adults (OAs) falling at least once a year.^{3,4} In addition to falling, many OAs face the additional danger of being unable to get up independently following a fall. This

point is important as it has been shown that OAs chance of survival increases the faster they are discovered following a fall.^{5,6}

There have been many efforts to develop systems that can identify a fallen individual and trigger a call for aid.⁷⁻¹⁰ Most fall detection (FD) systems are designed to be worn upon the body and involve the user pressing a button to alert someone that they have fallen, although newer devices automatically detect a fallen person. There is, however, limited work evaluating the usability of these devices for their intended populations.⁷ One such study conducted a trial to compare a pendant alarm to a system using multiple sensors¹¹ and found that such a system gave OAs a greater sense of security, however, there were tradeoffs regarding privacy and control.

In this article, we investigate the usability of a wearable FD device. The study is meant to inform usability issues of a typical FD device and provide suggestions on how to design these devices for OAs.

Materials and Methods

SETTING/RECRUITMENT

Subjects were recruited from three independent and assisted living communities around the Puget Sound region. Participants were asked to wear and use a wearable FD device for a period of 4 months during which they were interviewed and monitored to better understand their actual use of and opinions of the device. The second author (SC) recruited participants using information sessions and posting fliers in participating facilities. Participants were screened for eligibility using the Short Fall Efficacy Scale (SFES) and the Memory Impairment Screen (MIS).^{12,13} Participants were excluded if they scored lower than a 14 on the SFES (as this would indicate moderate, low, or no concern about falls), lower than a five on the MIS, if they were unwilling to wear the device for 4 months, were under the age of 62, or could not speak English. The University of Washington's Institutional Review Board approved this research.

The prototype device (henceforth termed Device A) used in this study is able to automatically detect falls and track the location of the subjects through GPS. The device uses the combination of an accelerometer, a magnetometer, and an internal microphone to determine if a participant has fallen. In the event of an alarm, Device A facilitates two-way communication

between the faller and a selected phone number. In the event of a detected or triggered alarm, the device facilitates two-way communication between the faller and a phone number of their choosing. If the person chooses to, they can cancel the call by pressing the button twice and holding for a certain period of time. Each device was set to call the front desk of the participant's respective community, which were manned 24/7. The person could cancel a call by pressing and holding the button twice for a certain period of time.

Device A comes with a charging stand and the choice of either a clip or lanyard attachment, allowing the participant to choose how to wear the device. Its dimensions are 66×40×19 mm (without clip) and a weight of 49 g. Device A also uses colored blinking lights to indicate battery life and signal strength. Finally, the device is supplemented by a secure online interface that provides various pieces of device data, including changes in the device's charging state, changes in the device's location, and if the device had been used to place a call or if the device indicated a fall. The online interface also contains a map that shows participant's GPS location at given points in time. Due to privacy restrictions, only the primary researcher had access to view this map. In the event of a fall, the front desk operators were instructed to contact the primary researcher if they needed to locate the fallen individual.

Participants were given verbal instructions on how the device works and how to use it before their initial interview. Participants were instructed to wear Device A during their waking hours and to charge it at night. The device was not commercially available when the study was initiated.

STUDY PROCEDURES AND ANALYSIS

Interviews were conducted in the participants' homes at baseline and 2 and 4 months. Interviews were recorded and later transcribed. The baseline interview consisted mainly of yes/no questions to better understand demographic information, fall history, and initial perceptions of the device. The midpoint and final interviews followed a semistructured script that allowed for more open discussion on the participant's experience with Device A. Participants were also encouraged to contact the primary researcher if they had any device-related comments. Any such statements were recorded in a written fall/device log. Both the interviews and fall/device log were qualitatively coded by the primary author. Data codes were inductively generated. A content analysis of the data was performed by two members of the research team and validity of interpretations will be checked by a third member. Transcript data were coded by line and sentence for descriptive (first level) and theme (pattern) codes. A list of major thematic elements will be extracted by thorough study and coding of the

interview transcripts. The analysis was organized into an expanding list of themes, arising from content, concepts, and descriptive categories (the process was supported by the use of QSR NVivo8, an index-based qualitative analysis software package). The thematic elements were used to develop coding keywords. Each response was coded along a number of salient dimensions, such as topic, thematic content, and general sentiment, using the previously abstracted keywords. Data were grouped and reviewed for trends and patterns or ideas that give insight into the study participants' experience with the Device A.

Results

In total, 18 OAs participated in the study of whom eight completed the 4-month trial (Demographics are available in *Table 1*). Participants lived in apartments in a residential retirement community. Twelve out of the 18 participants lived alone and the rest lived with a spouse. Some participants lived completely independently, while others received daily visits from residential caregivers. Participants attended events and meals with other residents of their community.

We conducted a total of 38 interviews (16 baseline, 7 midpoint, and 15 final) and logged a total of 78 device-related comments during the course of the study. Of the 10 participants who were partial completers, nine voluntarily chose to leave the study, while one was unable to complete the study after experiencing a fall. Those who chose to leave the study gave a variety of reasons for doing so, including the device being too large, the amount of false alarms, and an inability to control the device. Other participants found the device to be too burdensome without any additional benefit, "I didn't ever see, feel, or hear of anything that I could think of as an actual result and that made me think 'Why am I doing this?'" One participant stopped using the device after the death of her daughter and shortly after left the study.

BASELINE INTERVIEWS

All participants reported experiencing a fall before the study with some resulting in minor or no injury. Other falls were more severe, often causing serious injuries. Examples of those felt to be serious included one participant slipping on a wet shower liner explaining, "I crashed down... there was blood all over." Some participants also reported having multiple previous falls and reported falling multiple times a year. Just as interesting as the falls themselves was how participants handled the falls. Some participants indicated helping themselves up and choosing to not go to the hospital, while others received aid either from a relative or from people around them. One participant had multiple falls where she was

Table 1. Baseline Statistics and Comparisons

	OVERALL (<i>n</i> = 18)	COMPLETERS (<i>n</i> = 8)	PARTIAL COMPLETERS (<i>n</i> = 10)
Age (years), mean (SD)	86.4 (7.0)	83.1 (6.3)	89.1 (6.6)
Female, <i>n</i> (%)	14 (77)	5 (62.5)	9 (90)
SFES score at baseline, mean (SD)	9.5 (5.33)	12.9 (5.93)	6.8 (3.88)
Experienced two or more falls in the last year before enrollment, <i>n</i> (%)	9 (50)	6 (75)	3 (30)
Days on trial, mean (SD)	80.7 (45.26)	123.4 (1.1)	46.6 (30.9)
Living situation			
Alone, <i>n</i> (%)	12 (67)	4 (50)	8 (80)
With spouse, <i>n</i> (%)	6 (33)	4 (50)	2 (20)
Had a preexisting device?, <i>n</i> (%)	8 (44)	2 (25)	6 (60)
Initial wearing choice			
Clip, <i>n</i> (%)	12 (67)	8 (100)	4 (40)
Lanyard, <i>n</i> (%)	6 (33)	0	6 (60)

Completers are participants who completed all study procedures for the entire study period (4 months); partial completers are participants who chose to exit the study before the 4 months, but still provided some study data.

SD, standard deviation; SFES, Short Fall Efficacy Scale.

unable to get up and had to find ways to be discovered, stating, "... happened in the bathroom, but somehow I managed to get to the hallway door and get it open, and I was found lying on the floor of the hallway in my living room."

Before receiving the experimental device, participants were also asked about their plan if they experienced a fall. Some participants had preexisting devices of their own or within their apartment, which they thought they might use. More specifically, eight participants had preexisting personal emergency response system (PERS) devices provided by their facility. All of these devices required manual activation after a fall to trigger an alarm. Depending on the residence, these devices were either worn on the wrist or around their neck. Many residents also had a chain or button around their apartment that they could activate to trigger a device. Neither device had a GPS capability or the ability to trigger an alarm outside of their residence. One participant said she always carried her cellphone and would use that in the case of a fall.

A few participants explained the roles their preexisting FD device played in getting help. One participant was able to press a fall button attached to the wall in her apartment before falling unconscious. She described the experience, "I know I was conscious long enough to hit the button" Another

participant bypassed both her pendant and an emergency pull cord in her apartment to get help, "instead of pressing that necklace I have, I somehow felt like I had to get to a telephone, and so I managed to get myself in to the telephone in the bedroom and call the desk."

When asked what changes they had made to avoid falling, many participants reported changing their walking style or destination: "Well I'm generally more careful of where I walk that sidewalk is really irregular, and that's where I did fall once." Others reported relying more on mobility aids such as canes or walkers or attending exercise or balance classes.

Finally, many participants expressed initial enthusiasm for the device and its features. One participant was excited by the two-way calling feature on the device, "Well I think it sounds great. Especially that you can call somebody, get in touch with somebody." Others saw benefit to the GPS feature: "Well I like the fact that it is useable away from the building ... I am concerned that if I were away from the

building if I could get some sort of aid." However, participants did have concerns in using the device complaining about the size of the device or having to constantly wear it. Others were worried they would not be able to remember to charge or wear the device, and some subjects felt that this device would be a burden, "You know, something else to wear, that's it more than anything else."

Midpoint and Exit Interviews

LIMITATIONS TO DEVICE USE

Some participants experienced unforeseen errors, which prevented proper use of their device. As an example, one participant's clip attachment kept falling off her device. Her first solution was to use a rubber band to keep it together, but she eventually needed help to properly attach the clip. Many participants initially had trouble finding open electrical outlets close to where they intended to charge their device. A few participants had issues where the device would not charge at all and the researcher had to replace the device.

Participants had physical or cognitive issues, which impacted device use. One participant was unable to wear the device as a lanyard as she did not know what effect such a device might have on her pacemaker. Other participants had

difficulty placing the device in the charger, “Well I have a lot of numbness in my hands and it’s difficult for me to insert the device into its holder.” Many participants complained of not being able to hear the device. One participant with a hearing aid described hearing an alarm, but not knowing exactly what was being said. Finally, some participants experienced varying life events, including injuries, falls, strokes, or the death of a family member, which prevented or caused them to stop using the device.

DEVICE BENEFITS

Many of the features described as beneficial before using the device remained so after participants had the device. One participant discussed the value of various device features, “I like the GPS function ... and I like the not having to press the button function.” In addition to appreciating these device features, participants also stated feeling more secure with such a device and that the device even made them more aware of the danger of falling, “Yes, it has made me more conscious of the tendency to fall in situations and I can take more conscious steps to avert it.”

DEVICE LIMITATIONS

Most participant concerns focused on the device alarms. One alarm involved battery life prompting participants to complain about the device’s ability to maintain a charge or the inconsistency of the battery, “it didn’t seem to have any correlation to how long it was charged at night ... some days it would be 6 o’clock in the evening some days it would be 10 in the morning.” This problem was amplified by the fact that these alarms often occurred at inopportune times. One participant described the device interrupting one of her meetings, “I was sitting at a meeting when the device told me that it needed charging so I quickly pulled it out ... Then I settled back in quiet, and in a lapse in which I thought all was well, It went off I was somewhat excused for the commotion, when someone said, ‘It’s not a cell phone.’ ”

False alarms were often blamed on poor button design with one participant describing this flaw in greater detail, “Another design problem: it has a protruding rather than recessed call button. I’ve been carrying it in a fanny pack so it won’t keep slipping off my belt, but if it bumps up against something it sends a signal.” Only a few participants reported canceling a call; rather most participants forgot exactly how to cancel the alarm. One participant described her experience with canceling, “I think I just got flustered, I didn’t know what to do, and if I [had] maybe gone through it one or two times and done what I was supposed to do then maybe I could have turned it off.”

HOW PARTICIPANTS CHOSE TO WEAR THE DEVICE

Participants chose between the lanyard or clip attachment based on personal preference and comfort. Participants who initially chose the lanyard believed it to be more secure. Some participants experienced problems with the length of the necklace, which caused the device to hang around their waist area and to be unintentionally bumped too often. One subject wore the device so that the button faced toward her chest, “Yeah, so the lights were toward the body. That certainly cut down on the number of error calls, however, it’s an awkward way to wear it and it makes you look heavier than you are.” A common problem with the lanyard was the often displeasing aesthetic of the device. One participant described not wanting to wear the device, “... what I was wearing was sheer, and would show this light which, everybody is curious about, and, it just didn’t look good with, I didn’t want to wear it.”

The clip was commonly used to place the device on the participant’s pants or often on bras. While there were fewer complaints about the look of the device when using the clip, there were more concerns about the device staying on their body. Wearing the device on pants was particularly problematic as the device frequently fell off. Two participants lost their devices with clip attachments and chose to write their name and phone number on their device in case they lost them again.

Some participants came up with nontraditional areas to place the device. One participant placed the device on her walker whenever she would go out. Another participant initially placed the device in his fanny pack after having the device fall off too many times.

WHEN PARTICIPANTS CHOSE TO WEAR THE DEVICE

Another point of interest was the times of day participants chose to wear the device. As they were instructed to charge the device at night, most participants put the device on in the morning when getting dressed and removed it before they went to bed. Exactly when they put on the device would usually depend on their morning activities and what they were planning to do during the day. While most participants would wear their device at all times, some participants chose to only wear the device outside as that is where they felt they were most at risk, “I used it when I went on walks.”

Participants gave other reasons for not wearing the device, including forgetting to put on the device. There were also several instances in which they chose to not wear the device. One participant specifically took off her device the day of her MRI saying, “Well, because I couldn’t take it into the MRI.” Many participants would take off the device when they go to public meetings, “... I didn’t want it to go off in a meeting so I

just left it here.” Participants would also travel or go on vacation and did not want to take the device with them as they did not want to lose the device.

Several participants expressed concern about being unprotected at night when the device was in the charger. One participant asked, “Is there some design a person could have where they could wear it 24 hours a day ... Because I’m thinking of people who get up during the night.” Many participants also did not use the device in the shower even though the device was stated to be water resistant. Participants would often place the device near them when they showered, “I have a little place I have it outside the shower.” Although many participants stated not knowing it could be used in the shower, some also asked where they would place the device with the clip attachment.

PERCEIVED NEED

Many participants did not believe they were in danger of falling and saw no immediate need for the device. A participant who experienced four falls during the course of the trial explained he did not need the device as, “I don’t consider myself a faller.” Other participants felt that these devices were for older more physically unable people with one participant saying, “You know if I were a high fall risk ... but at the moment I don’t consider that. When I get old maybe.” There were a few participants who expressed a need for this device with one participant explaining the differences in perceived need between him and his wife, “Since my health isn’t quite as good as hers, I think I would probably want to keep it.” He continued by saying, “It’s annoying and it’s a nuisance, but I know I’ll probably be better protected if I have it.”

STIGMA AND EMBARRASSMENT

Many participants were embarrassed when the device would alarm in public. One participant was especially worried when those around him would pretend not to notice the alarm, “It’s when they don’t say anything you wonder kinda what their thinking looking at that, cause they do take notice of it.” Participants found different ways to handle the embarrassment by saying they were in a study or, as one participant

describes, by simply pretending to not know where the sound was coming from. Some participants were unconcerned about this aspect with one participant stating, “If I need it, I wear it. I don’t look what other people [do] because we all have different needs ...”

SUGGESTIONS FOR IMPROVEMENT

Participants had varying suggestions to improve the device, including making the device smaller or removing the need to charge the device so that it could be worn at all times. One participant explained, “I supposed if you are really wearing something to warn you about falling maybe you should wear one all the time. I mean even at night you can get up and people tell me that all the time, they’ll get up and turn on their light and fall.”

Participants also asked to reduce false alarms and for less obtrusive notifications, “I wish there were a more subtle way of, it telling me that needs to be recharged.” Other suggestions involved fixing the design flaws of the device, including the protruding button or its ability to stay attached to a belt.

Table 2. Exemplar Quotes from Identified Themes

Device benefits	“This is wonderful especially GPS. When I walk up to the library and I fall, I can call someone and talk to someone who knows me.”
	“Very, very comforting to have a two-way conversation, I really appreciate that.”
Device limitations	“Like I’ll put it on early in the morning and then by noon or something it tells me I need to recharge it again.”
	“Except that like I said, when it started going off at irrational times, um then it affected my daily life.”
Wearing time	“I don’t always put it on first thing, I run around in my night gown. And I water the flowers and I get breakfast and I brush my teeth then, then when I get dressed to go out then I take it out of its charger and put it on.”
	“Once I put it on, I wear it all day. I try to put it on in the morning before I leave my room and take it off when I go to bed.”
Embarrassment	“People probably wonder you know, we sort of perceive it as some people wouldn’t say anything at all, we kinda wonder, what, you gotta a big growth there or what is that?”
	“I don’t know, just because it, goes off in strange places and when I haven’t fallen or anything and it’s I keep having to explain to people what this thing is that is talking,” or
Perceived need	“I didn’t see any necessity for wearing it in the building ... Because I’m very cautious, and I wasn’t about to fall.”
	“I’m pretty confident. Everybody thinks they are never going to fall, and I think I’m not going to fall.”
Suggestions for improvement	“Well, I would think, well at least have it very close by, or wear it at night because that’s I think a time when it might be most applicable or something like that.”
	“Don’t know whether you could have a lighter weight button or something that’s a little less intrusive on your person.”

PRIVACY/GPS/MONITORING

Participants' responses varied when shown their GPS data with some being concerned about their privacy and others being indifferent. Many believed they had nothing to hide, "at this stage of the game ... who would care where I go?" Other participants were more concerned, especially with who would be able to see their data. One participant was particularly concerned about the government being able to track her, while another participant had more of a concern over insurance companies, "If they knew you had 20 falls a month, they might reconsider whether or not they would insure you." Some participants accepted the invasion of the privacy as they felt the benefit of the device outweighed the disadvantage of being tracked, "I'm not happy about being tracked all the time, but if it's to be worthwhile, you need it. Don't you?"

Table 2 includes exemplar quotes from these themes.

Discussion

The variety and range of responses seen in these results highlight the complexity of FD wearable device adherence. While it is clear there is no single solution to fix FD devices, there are several pieces of information that can be learned from this study and applied to future FD technology.

In terms of wearability, advances in miniaturization and sensor technology will allow developers to make smaller, less-obtrusive devices that will be more acceptable to OAs.^{14,15} Increases in battery life will also help to ensure participants no longer have to remember to charge these devices and can wear them uninterrupted for longer periods of time. However, there are several aging-related issues with these devices that need to be addressed. Engineers must work to better develop this technology so that it is more accessible to people with hearing loss, limited dexterity, and low vision.¹⁶ Affordances also need to be more clear and visible to enable people with memory problems to remember not only what the device is meant to do but also how to use it in their time of need. Designers should include simple instructions and pictographs to ensure correct use of these devices. Utilizing age-appropriate design techniques will help make these devices more user friendly. Finally, while it is important to give OAs options for wearing the device, manufacturers should expect this population to be extremely varied in their wearing habits and should plan for this device to pass specificity and sensitivity testing. Obtaining satisfactory levels of sensibility and specificity of FD with an unobtrusive (small form factor) wearable sensor worn at a convenient location still remains a challenge. Manufacturers should also ensure device compatibility with other instruments possibly worn by this population (e.g., pacemakers).

Additional existing device features, such as GPS and two-way calling, are already encouraging more participants to use the device. Unfortunately, even with further functional improvements, it is difficult to imagine automatic FD devices becoming a popular technology among OAs in the near future.¹⁷ There was little perceived need for such a device in many of our participants, despite a history of multiple recent falls or high fall risk. Although some subjects expressed needing or liking these devices, most participants were unhappy having to use such a device. Along with device-associated stigma, many participants have a variety of existing methods to ensure their safety during a fall. In short, these devices do not appear to provide enough additional benefit for the amount of agitation they add to the subjects.¹⁸ Further work and innovation are necessary to develop devices that not only detect that a person has fallen but also have the ability to prevent a fall or reduce participant injury.¹⁹ Increased usage of these devices among OAs may also require a larger cultural change reducing the stigma of these devices and educating participants in the importance of preparing for fall. We suggest more age-appropriate device designs and other functional recommendations to help future device manufacturers make these devices more appropriate for OAs.

This work was limited by a convenience sample of participants. In addition, we were limited by only testing one wearable FD device; it does, however, have features similar to many commercially available FD products. A future comparison of multiple device types may lead to more comprehensive conclusions. Despite these limitations, this pilot study adequately investigated the usability of a wearable FD device in the real world.

Conclusion

Fall detection devices may prove to be useful tools in supporting older adults' independence and facilitate aging in place. Our study emphasizes the importance of testing fall detection devices in real world settings and with end users selected from the target population as findings in a laboratory setting obtained in sessions with younger adults or stunt actors asked to simulate falls may generate different sensitivity and specificity findings. Deployment of fall detection devices in the community highlights the importance of user acceptance including potential concerns about usability or stigma, as well as technical challenges pertaining to user adherence. Our study findings informed a set of design recommendations that can inform the design of future wearable fall detection devices that may be more appropriate for older adults and thus, ultimately, improve adherence and the overall user experience.

Acknowledgments and Funding

We would like to thank all those who participated in the study and their respective communities. We would also like to thank the HEALTH-E team members for all their help (<http://health-e.info/>). This research was supported, in part, by the Biomedical and Health Informatics Training grant from the National Library of Medicine (T15LM007442).

Disclosure Statement

No competing financial interests exist.

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Received: October 31, 2015

Revised: January 9, 2016

Accepted: January 11, 2016