Technology for Healthy Independent Living: Creating a Tailored In-Home Sensor System for Older Adults and Family Caregivers

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ABSTRACT

Sensing technologies hold enormous potential for early detection of health changes that can dramatically affect the aging experience. In previous work, we developed a health alert system that captures and analyzes in-home sensor data. The purpose of this research was to collect input from older adults and family members on how the health information generated can best be adapted, such that older adults and family members can better self-manage their health. Five 90-minute focus groups were conducted with 23 older adults (mean age = 80 years; 87% female) and five family members (mean age = 64; 100% female). Participants were asked open-ended questions about the sensor technology and methods for interacting with their health information. Participants provided feedback regarding tailoring the technology, such as delegating access to family and health care providers, receiving health messages and alerts, interpreting health messages, and graphic display options. Participants also noted concerns and future likelihood of technology adoption. [*Journal of Gerontological Nursing, 46*(7), 35-40.]

Over the past decade, strides have been made in the development of sensing technologies to assist older adults in managing their health. Technologies such as environmentally embedded sensors, smart homes, robotics, and wearable devices help facilitate the aging process and allow older adults to age in place. In-home sensor systems, in particular, hold enormous potential for the early detection of health changes that can dramatically affect the aging experience. These systems use unobtrusive and environmentally embedded technologies that track health parameters, such as gait, walking speed, bathroom usage, time in bed, bed restlessness, heart rate, and respiration rate, among many other health indicators.

Data gathered by these technologies allow older adults and their caregivers to manage many aspects of older adult health, such as chronic diseases and fall risk. Chronic disease affects 80% of older adults (Centers for Disease Control and Prevention [CDC], 2017) and is the leading cause of death among the aging population (National Center for Health Statistics, 2017). Difficulties with chronic disease management can cause loss of independence for older adults, which can often mean relying on in-home care supports or institutional care (CDC, 2013a). Sensing technologies address this challenge by monitoring for health changes so that early interventions can be offered when treatment is most effective, prevention of decline is still possible, and costs can be controlled. Chronic illness management and early detection of health changes are key to promoting health and function of older adults, assisting them to age independently (Rantz et al., 2011).

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Dr. Skubic reports small ownership in Foresite Healthcare, outside the submitted work. In addition, Dr. Skubic has a patent Integrated Sensor Network Methods and Systems licensed to Foresite Healthcare, and a patent Hydraulic Bed Sensor and System for Non-Invasive Monitoring of Physiological Data, Status pending, licensed to Foresite Healthcare. The remaining authors have disclosed no potential conflicts of interest, financial or otherwise.

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Sensing technology has also been shown to detect and reduce fall risk among aging adults using an environmentally mounted depth sensor (Rantz et al., 2013; Sun & Sosnoff, 2018). The CDC reports that one in four people age ≥65 experience a fall every year (Bergen et al., 2016). These falls result in 3 million older adults being treated through the emergency department each year due to injuries sustained by falling, such as a head or hip injury (CDC, 2019). Although falls can dramatically impact the health of older adults, depth sensors that track normal movement in older adults' homes have been clinically validated to detect fall risk (Rantz et al., 2013). Through early detection, older adults, family members, and health care providers can work together to decrease environmental hazards to falling and improve health indicators that lead to falls.

Family caregivers often play a vital role in assisting community-dwelling older adults manage their health. However, caregiving tasks can place a large burden on family members (Adelman et al., 2014), which can ultimately impact the health of their older relatives (Kuzuya et al., 2011). Sensing technologies can reduce caregiving burden and improve overall health outcomes for older adults (Czarnuch & Mihailidis, 2011; Madara Marasinghe, 2016; Masterson Creber et al., 2016; Tomita et al., 2010). There has been some research that examines the adoption of sensing technology by family caregivers (Kanis et al., 2012; van Hoof et al., 2011); however, more research is needed to understand how sensing technologies can be adapted for in-home use by older adults and their family caregivers. Therefore, the purpose of this qualitative study was to explore how health information generated from in-home sensor technology can be tailored for in-home use by older adults and family members who may provide caregiving support.

METHOD

Five focus groups were conducted to solicit participant feedback, consisting of two independent groups of participants. Four focus groups were conducted with individuals age ≥60 (n = 23), and one focus group was conducted with family members (n = 5) who provide caregiving to an older relative. All study activities received Institutional Review Board approval. Participants were consented into the study prior to participation, and participants' rights were outlined in the consent document and verbally prior to their participation.

Recruitment

Older adults were recruited through four independent living facilities, two of which were designated as affordable housing units. Study investigators conducted an information session at each site to provide an overview of the research and recruit study participants, and flyers were distributed. Family members were recruited with the assistance of a staff member at one of the independent living facilities in which the older adults lived.

Data Collection

Focus groups were facilitated by two investigators, using a semi-structured interview guide to initiate the question-asking process. Focus groups lasted approximately 90 minutes. Upon arrival, participants were asked to complete a brief survey eliciting demographic and technology use information. Participants were then provided with a thorough overview of the sensor technologies and their capabilities. The sensor technology presented to participants included: (a) a wall mounted depth sensor that collects in-home walking speed, stride time, and stride length data; (b) motion sensors that detect activity within a room; and (c) hydraulic bed sensors that capture pulse, respiration, restlessness, and time spent in bed.

When presenting these technologies, facilitators described the type of data produced by each sensor and how those data can be used for health management purposes. To illustrate this, a scenario was presented to participants involving an older adult with an elevated heart rate during the overnight hours. Participants were also asked for feedback regarding the method(s) in which they would want to interface with the sensor-generated health information. They were provided with the following options: phone, computer, tablet, television, Amazon Echo device, and Google Home device. Participants were encouraged to ask questions and provide feedback throughout the entirety of the focus group. At the end, participants answered two written questions pertaining to their likelihood of adopting the sensor technology and their preference of technology to interface with the sensor information.

Analysis

Focus groups were audio recorded and transcribed verbatim. Transcripts were initially reviewed by two members of the study team to generate a codebook. Qualitative content analysis techniques were used to analyze the transcripts, as supported by Graneheim and Lundman (2004). Two members of the study team separately engaged in the coding process using Nvivo 11, and iteratively compared and revised their coding during a thorough consensus building process. Cohen's Kappa coefficient was used to demonstrate strong interrater agreement for each code (range = 0.70 to 1.00), with an overall Kappa of 0.98.

RESULTS

Older adults (n = 23) were predominately female (87%), White (91%), and ranged in age from 61 to 97 years (mean = 80). Family members (n = 5) were exclusively female (100%) and White (100%) and ranged in age from 59 to 69 years (mean = 64). All family members identified as a daughter of an older parent(s).

Current Technology Adoption

Participants were asked questions about their current technology own-

ership, access, and use (**Table 1**). The majority of older adults (*n* = 20, 87%) and all family members (*n* = 5, 100%) owned a cell phone at the time of the focus group. Of those who owned a cell phone, 70% (*n* = 14) of older adults and 100% (*n* = 5) of family members reported that their cell phone was a smartphone. Of older adults who owned a cell phone, 35% (*n* = 7) reported that they only used it for phone calls and texting, whereas the remaining participants reported using it for phone calls, email, texting, social media, keeping track of their calendar, playing games, browsing the internet, reading the news, paying bills, and online shopping.

Participants were also asked about their computer access and use. The majority of older adults (*n* = 18, 78%) reported that they had access to a computer and 74% (*n* = 17) said they had access to the internet. However, 26% said that they had never learned how to use the computer and did not use the computer at all. All family members reported that they have access to a computer and the internet, and they use the computer frequently.

TABLE 1
Current Technology Adoption

Technology Type	*n* (%)	
	Older Adults (*n* = 23)	Family Members (*n* = 5)
Owns a cell phone	20 (87)	5 (100)
Cell phone is a smartphone	14 (70)	5 (100)
Has access to a computer	18 (78)	5 (100)
Has access to the internet	17 (74)	5 (100)
Uses a computer	17 (74)	5 (100)
Owns a tablet	8 (35)	5 (100)
Owns an Amazon Echo or Google Home device	3 (13)	1 (20)
Owns a wrist-worn device (e.g., Fitbit®, Apple Watch)	3 (13)	4 (80)

Tailoring the Technology for In-Home Use

Older adults and family members had a lot of questions and feedback regarding the functionality of the sensor technology and how it could be tailored for in-home use. In particular, four major areas of feedback were initiated by participants in multiple focus groups, pertaining to: (a) access delegation; (b) flexibility in receiving health messages and alerts; (c) interpreting health messages and alerts; and (d) graphic display preferences.

Access Delegation. In each of the focus groups, participants reflected upon who would be the designated person to receive health messages, health alerts, and have access to the sensor-generated health data. Many older adults expressed a desire for their sensor-generated health information to be shared with their health care providers, potentially through their electronic medical records, to assist in medical decision making. Participants also envisioned their health alerts (e.g., fall alerts) and other health messages to be sent directly to their health care providers. For instance, one participant who initially asked about the technology's ability to interface with her physician said, "Well, if it's something important. Somebody ought to know, you know, besides me or you." Similarly, family members also expressed a desire for health care providers to receive the alert messages (e.g., fall alerts) so they could immediately dispatch an emergency response team.

In addition, older adults and family members expressed a desire to delegate access to multiple individuals who may provide caregiving supports, such as other family members, close friends, and neighbors. These participants discussed how multiple people are often involved in the caregiving process, each fulfilling their own role (i.e., direct and indirect day-to-day supports, as well as supplementary and less frequent supports). Therefore, they would want different people to have various levels of access to the sensor-generated health information, health messages, and health alerts.

Flexibility in Receiving Health Messages and Alerts. Related to feedback regarding access delegation, participants also discussed a need for flexibility in receiving health messages and alerts. As participants pointed out, many people may be involved in the caregiving process and fulfill different caregiving roles. Therefore, each individual may have unique preferences for accessing the health information and receiving health messages/alerts.

To illustrate this point, one family member described her family with three daughters and one son who provide caregiving supports to their mother. Two of the daughters provide direct, day-to-day assistance and live in the same community as their mother. These two daughters would most likely want full access to all information, messages, and alerts, and the alerts to come straight to their smartphones so they can act quickly in the case of an emergency. The participant pointed out that her brother would also likely want access to their mother's health information via the computer or through a cell phone application (app), but he

would not likely want the health alert messages sent to his phone via text message (as he would not be the person immediately responding). In addition, she pointed out that her sister who lives out of state and provides additional levels of care may have different preferences.

Interpreting Health Messages and Alerts. Participants described potentially needing assistance in interpreting the health messages. When it comes to fall alerts, participants believed those interpretations were straight forward. However, participants envisioned having more difficulty interpreting the other health messages. For example, when participants were provided with the focus group scenario of an elevated heart rate, they inquired about how to interpret the example health message and the appropriate response needed (e.g., watchful waiting, contact their physician, make changes to their activity levels before bed). This uncertainty in responding to their health information related back to conversations regarding access delegation, with many participants expressing a desire for this type of health information to go directly to their health care providers so that they could interpret it and make the appropriate decisions.

Graphic Display Preferences. Lastly, participants also provided feedback regarding how they would like their health information to be graphically displayed. To initiate this feedback, participants were shown various graphic display options (e.g., line graphs, bar graphs). These example images varied in degree of complexity of information, as well as the amount of information shown over time. Although many participants expressed a firm desire for the more simplistic graphs, several participants noted that they would not want to sacrifice important health information for simplicity's sake.

Technology Concerns

Older adults and family members noted several concerns about using the sensor technology to manage their health or the health of their family member. Three main areas of concern were especially prevalent: (a) technology access; (b) privacy; and (c) health obsession.

Technology Access. The most prominent concern expressed by older adults and family members was older adults' ability to access their sensor-generated health information using certain technology platforms. Older adults who did not own or know how to use a smartphone, tablet, or computer expressed this concern, as well as older adults who owned and knew how to use these technologies. One participant commented, "Well, but there are people, several people in this building that don't have smartphones. They just have little handheld phones, or they just have a land line." Family members also noted this concern for their older relatives. Internet connectivity was also mentioned in these conversations as a potential barrier, especially for participants who lived at the two affordable housing units. Related to access, in every focus group, participants asked about the potential cost of the sensor technology for in-home use. The ability to afford the technology was cited as a huge factor in an individual's decision to adopt the technology.

Privacy. Some older adults specifically expressed privacy concerns about having the technology in their own homes. These participants feared that the digital images and videos generated from the depth sensors would intrude upon their privacy when they were in their bedrooms and bathrooms. For instance, one participant said, "I don't want anyone to see me use the bathroom," and another participant added, "Or getting out of the shower." Similarly, another participant remarked, "I don't like the idea of somebody knowing every time I go to the bathroom" in reference to a motion sensor being placed in her bathroom.

Although some older adults expressed these privacy concerns, family members did not share these concerns. These participants noted that the images and videos captured from the depth sensors would not indicate whether their older relative was clothed. They also believed that the benefits outweighed any privacy concerns that their older relatives may have about placing the sensors in their bedrooms or bathrooms. They believed that if their older relative were to fall in their bedroom or bathroom, then a depth sensor would be able to capture that fall and alert the family member immediately so that help and medical intervention could be provided.

Health Obsession. Some older adults discussed a reluctance to use the in-home sensors because they do not want to obsess about their health. Although it was a small number of participants (n = 5) who expressed such sentiments, they had strong opinions regarding the sensors. For instance, one participant said, "I think the hypochondriac would love it, but I don't want to know that much…. I don't want to be that overly concerned that I'm thinking about what's happening to me, you know. I think that can be counterproductive at times." Similarly, another participant said, "I can't imagine worrying about all of this stuff. It's just too much. For me, it would not be valuable. To other people it may be, but to me, I would not, I would never use it."

Interestingly, family members did not agree with these sentiments. When the focus group facilitator presented this information to family members, they unanimously agreed that they would want access to their older relatives' health information and receive health messages/alerts even if their older relative did not want to worry about it. They believed that they would have a responsibility to manage their older relatives' health, and therefore they would want the technology installed in their older relatives' home.

Future Technology Adoption and Preferences

Upon completion of the focus groups, participants answered a ques-

tion about their likelihood of adopting the technologies. This question was presented in a written format with response options on a 5-point scale (1 = *very unlikely*, 2 = *somewhat unlikely*, 3 = *neutral*, 4 = *somewhat likely*, and 5 = *very likely*). On average, older adults said they were *neutral* to *somewhat likely* to use the technology (mean score = 3.7, range = 1 to 5). On average, family members said they were *somewhat likely* to *very likely* to use the technology (mean score = 4.8, range = 4 to 5).

Participants were also asked which technology they preferred to use in accessing their sensor-generated health information and receiving health alerts (**Table 2**). The majority of older adults (*n* = 14, 61%) and all family members (*n* = 5, 100%) indicated they would prefer to use their smartphone/cell phone to access such information and receive alerts.

TABLE 2
Technology Preferences for Accessing Sensor-Generated Health Information and Receiving Health Alerts

Technology Type	Older Adults (*n* = 23)	Family Members (*n* = 5)
Cell phone	14 (61)	5 (100)
Computer	4 (17)	0 (0)
Tablet	2 (9)	0 (0)
Amazon Echo or Google Home device	1 (4)	0 (0)
None – "I do not prefer to use technology to manage my health"	2 (9)	0 (0)

DISCUSSION

The current study highlights several important considerations when adapting in-home sensor technology for use by older adults and family caregivers. Participants indicated an interest in using the technology in their own homes, with family members more eager to adopt the technology than older adults. Although some older adults indicated that they would not use the technology because they did not want to obsess about their health, family members unanimously agreed that they would want access to their relative's health information and receive health messages and alerts to assist in their caregiving-related tasks and to manage their older relative's health. This finding suggests that family caregivers may be an important consumer of the technology and further efforts to tailor in-home sensor systems for private use should take their perspectives into consideration.

Participants shared a great deal of feedback regarding access considerations and receiving health messages and alerts. It is evident from these focus groups that older adults and family members wish to customize their user experience with the technology, to meet their unique health management needs. Therefore, options in how older adults and caregivers are able to access the sensor-generated health information are important. Although both groups of participants preferred using their cell phones to receive health messages and alerts, other options must also be available. Future usability research is needed to explore the various ways in which older adults and family caregivers may access the health information (e.g., smartphone app, web-based portal via smartphone, web-based portal via computer/tablet) and receive health alerts (e.g., text messages, emails, smart phone app, web-based portal).

When deploying in-home sensor systems for private use by older adults and family caregivers, the accompanying training component is an important consideration. Participants had logistical questions about how the sensor systems worked, the type of health information they produced, and how to interpret that information for health management purposes. Although interpreting health information for individuals may be beyond the scope of research investigating how to develop in-home sensing technologies, participants suggested linking the technologies with their health care providers to help interpret health information and provide emergency support (e.g., in the case of a fall). Connecting in-home sensor systems with older adults' electronic medical record may also be a viable solution and should be further explored.

Some older adults discussed privacy concerns regarding images generated by the depth sensors. Although only a small number of these participants expressed such concerns, they are important to note. Integrating a discussion about privacy concerns into the training component when deploying in-home sensor systems can potentially help ease older adults' apprehension about the technology. Family members did not express such concerns, as they noted the images captured could not reveal any distinguishable characteristics. They also believed that the benefits outweighed any perceived risks, which again reinforces that family caregivers are an important user of the technology.

The current study highlights the need to take consumers' considerations in mind when developing in-home sensor technologies and data access platforms. The CDC (2013b) offers insight and guidance to developers of these technologies, as well as a plethora of examples, for ensuring older adults' needs and preferences are considered. Although there was some

disagreement in the current research regarding technology adoption and overall concerns, focusing on the benefits of the technology may assist older adults in feeling comfortable with using in-home sensor technologies. This finding is supported by previous research (Young et al., 2014), where it is suggested that a focus on how the advantages outweigh the risks may help technology adoption. Therefore, a discussion about the sensing technology's ability to detect and reduce fall risk (Rantz et al., 2013; Sun & Sosnoff, 2018), as well as the impact sensing technologies can have in reducing caregiver burden and improving overall health outcomes for older adults (Czarnuch & Mihailidis, 2011; Madara Marasinghe, 2016; Masterson Creber et al., 2016; Tomita et al., 2010), may demonstrate the utility of such technologies and encourage user adoption.

LIMITATIONS

Although the current study yielded valuable insight, it is limited in generalizability due to the small sample size and heterogeneous sample characteristics. Focus group methodology worked well for this exploratory study; however, usability studies are needed to further validate actual user preferences and build upon the current literature. Future research should expand the total number of participants, particularly family members, and consider community-dwelling older adults living in more diverse housing situations.

CONCLUSION

In-home sensor systems have the potential to assist older adults and family caregivers in managing older adult health through early detection and intervention. Taking into account user feedback is important in developing such technology, as it sheds light on important preferences and concerns. This study highlighted several considerations for tailoring in-home sensor technology to help older adults age in place and findings can be used in future development of in-home sensor systems.

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