Older Adults’ Perceptions of and Preferences for a Fall Risk Assessment System
Exploring Stages of Acceptance Model

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Aging in place is a preferred and cost-effective living option for older adults. Research indicates that technology can assist with this goal. Information on consumer preferences will help in technology development to assist older adults to age in place. The study aim was to explore the perceptions and preferences of older adults and their family members about a fall risk assessment system. Using a qualitative approach, this study examined the perceptions, attitudes, and preferences of 13 older adults and five family members about their experience living with the fall risk assessment system during five points in time. Themes emerged in relation to preferences and expectations about the technology and how it fits into daily routines. We were able to capture changes that occurred over time for older adult participants. Results indicated that there was acceptance of the technology as participants adapted to it. Two themes were present across the five points in time—safety and usefulness. Five stages of acceptance emerged from the data from preinstallation to 2 years postinstallation. Identified themes, stages of acceptance, and design and development considerations are discussed.

KEY WORDS: Aging in place, Older adults’ fall risk, Technology acceptance

It is projected that there will be approximately 72.1 million older adults by 2030.1 The increase in life expectancy offers additional living choices for this older adult population. The overwhelming preference of this growing population is to remain at home or to age in place.2

Aging in place is a cost-effective approach for senior living, and with the assistance of home- and community-based programs, it has the potential to reduce inappropriate or premature institutionalization of older adults.3,4 Many older adults wish to live in their homes for as long as they are able, although health issues may pose challenges to aging in place.2,5

Technology has an important role within aging in place; it helps older persons maintain their health and independence.6–8 The use of technology in the home offers an alternative to long-term care options such as assisted living.3,4 In addition, it has been demonstrated that technology can assist in meeting the specific needs and requirements of seniors, improves healthcare cost-effectiveness, and supports caregivers.6–8 Therefore, an examination of older adults’ perceptions, attitudes, and preferences toward technology and technology use is important to learn more about functional and psychosocial factors in technology acceptance and adoption.

Older adults’ positive attitudes toward technology are most often related to how the technology helps daily activities and facilitates convenience. Perceived usefulness and ease of use are reported to be two salient factors that explain technology acceptance and use for older adults as articulated in the technology acceptance model.6 Negative attitudes are related to inconveniences created by technologies. According to Peek and colleagues,2 some community-dwelling seniors report various concerns when they consider using new technology for aging at home. High cost and consequences of using technology are the major concerns of older adults. Seniors worry about forgetting or losing the device, false alarms, burdening children, or obtrusiveness. Some seniors express concerns about negative effects on health from the technical devices, the fear of stigmatization, or no control over technology.2 In addition, older adults raised concerns about the learning curve in adopting new technology and the perceived difficulty of learning.9

In other research, there were mixed opinions about technology use and privacy. In one study, more than 72% of older participants expressed acceptance of an in-home monitoring system and indicated a willingness to share the collected data with their families or physicians. However, approximately 60% of participants expressed some concern about potential privacy issues in using the monitoring technology.
Even with these reservations, participants expressed a high regard for the monitoring assistance.10

One major functional problem for older adults that affects aging in place is instability and an increase in falls. Statistics reveal that, on an annual basis, one in every three people 65 years and older fall, and 2 million are treated in emergency departments for fall-related injuries. Frequent falls and fall-related injuries have the potential to affect an individual’s ability to age in place.11

In conclusion, the perceived benefits of in-home monitoring may exceed concerns about privacy issues. Learning more about the perspectives, attitudes, and preferences of older adults toward technology will assist in our understanding of factors that influence adoption and use, features crucial for well-designed technology, and the adjustment process in living with the technology. In particular, this study adds to our knowledge about older adults’ perceptions of in-home sensor monitoring systems within independent living environments. It will also provide information about whether and how these perceptions change over time.

FALL RISK ASSESSMENT SYSTEMS

In response to this issue, our team installed fall risk assessment sensor systems (FRASs) in the apartments of consenting older adults. The FRAS consisted of pulse Doppler radar, a Microsoft Kinect (Microsoft, Redmond, WA), and two Web cameras as a part of a more complete sensor network for in-home use (Figure 1). The radar and the Kinect systems are set up to detect motion within their fields of view. For fall detection specifically, the radar system produces radar signals (electronic wave forms) and uses signal processing techniques that detect sudden changes in motion and then filter out false alarms such as sudden door closing or housekeeping activities. The Kinect system produces images in three-dimensional space, uses machine learning approaches to detect falls, and has fewer errors since it can differentiate sudden motion between different directions (eg, lateral motion vs vertical motion). Two Web cameras are used to produce traditional video images, as well as anonymized images in three-dimensional space.12

The radar unit is installed in a decorative wooden box located next to the front door of the apartment. The Kinect is discreetly placed on a small shelf over the front door. Privacy of the resident is preserved through the use of a depth image, which presents as a moving silhouette; this depth image and the radar data are captured on a continuous basis.12 Figure 2 provides an example of a fall captured by the FRAS.

Fall risk assessments were also completed using six clinically validated fall risk assessment tools: Timed Up and Go, Berg Balance Scale, Short Physical Performance Battery, Functional Reach, Single Leg Stance, and 10-ft walk time × 2. The assessments were completed concurrently with sensor data collection so that the automated fall risk assessment using the sensors could be validated.12 The assessments were facilitated and scored by the clinical research staff.

In addition to these quantitative data, consumer perception interviews were conducted independently of the fall risk assessment process. These interviews were recorded and analyzed using qualitative methods. All methods were reviewed and approved by the institutional review board.

QUALITATIVE STUDY METHODS

One objective of this study was to explore the perceptions and preferences of older adults and their family members about the FRAS so that we could address any concerns or
problems that emerged as we were developing it. This was achieved through individual face-to-face interviews with the older adults living with the sensor system, and face-to-face or telephone interviews with the family members of participants and who the older adults gave us permission to contact. After study introductions and the consent process, an initial set of interviews were conducted at the preinstallation phase of the project using a structured interview guide. This interview guide was developed by experienced qualitative researchers and was based on a quality-of-life technologies approach, which stipulates that understanding the needs and preferences of the end user, in this case, the older adult, is a first step in the technology development process. The technology acceptance model was also used to inform the development of the interview guide. The structured interview guide included open-ended questions and prompts that encouraged the participant to expand on the answer. Questions covered content such as “Describe your experience living with the FRAS,” “How does the FRAS affect your daily living?” “Has the FRAS helped in any way?”, “Is the information you receive from the FRAS helpful?”, and “How might you change any part of the FRAS?” These are examples of the kind of information that was collected in the interviews.

After this initial interview, the FRASs were installed in the participants’ apartments. Thirteen participants were actually interviewed during the course of the study. The participants ranged in age from 67 to 98 years, with five men and eight women. The mean (SD) age was 86.86 (7.62) years. Five family members participated in the study and were interviewed once during the study at various times when they were available. All five family members were daughters of the participants.

Interviews were then conducted every other quarter for four additional times as residents lived with the sensor system. Using the same structured guide as in preinstallation, interviews were completed by a member of the research staff. Interviews were from 15 to 20 minutes in duration. Interviews were tape recorded, and field notes were taken.

A content analysis was performed on the collected data. A predetermined coding scheme was not used since the content analysis was data driven and inductively generated from the collected data. Naturally occurring variations in the data were noted; patterns, codes, and themes emerged from the data. Analyses were performed by two members of the research team. The analyses were performed separately and then together. Consensus in interpretations was achieved through discussion.

RESULTS
Family Responses
All family members interviewed were aware of the sensor system in their parents’ apartments. Three daughters reported that they were informed about the equipment at the point of installation. One remarked that her parent showed her the new equipment. The installation and new sensor system placed in the apartment was perceived as something novel and interesting to talk about—at least initially.

While all of the family members interviewed knew about the sensor system, two mentioned that they knew what the FRAS did, and one family member reported the periodic checking in by staff as a benefit. One family member expressed pleasure about her father’s involvement in the project, particularly the monitoring aspect. While family members expressed awareness about the system, two family members stated that they were uninvolved. Three family members articulated no personal benefit from the sensor system. However, there was anticipation of future benefits, and two family members expressed hope in the use of such a product.

Most of the daughters provided ideas for sensor system changes. Aesthetics emerged as important, particularly regarding the visibility of the radar box and Kinect. One daughter stated: “I notice the box whenever I try to rearrange and make the apartment look nice.”

Family comments emphasized the need for the FRAS to address safety issues. One family member suggested: “Could the system prompt Mom to use her walker?” Another family member suggested that the data collected be used to provide instruction to the family on how to make the home environment safer. Daily feedback reports and enhanced coordination with nursing and rehabilitation staff were other suggested features offered by family members. The development of
feedback and assessment information for people who are struggling with memory decline was another idea offered by one daughter: “How can this information be presented in a way that is useful since she (Mom) forgets so quickly?” One last suggestion for improvement was to expand the range where the equipment senses movement. One daughter noted that the bathroom contained areas not picked up by the sensors.

Overall, family reactions to the FRAS were positive. Only one family member identified privacy concerns, particularly about being watched. However, as her mother lived with the system, she went from being concerned about privacy to bragging about her mom having the equipment in the apartment. We see from this information that, for family members, there is an adjustment period. Initial concerns may decrease because the benefits of the FRAS are realized over time.

Resident Responses
Table 1 displays the themes that emerged or continued during the five data point times throughout the study.

Preinstallation
Themes that emerged at the preinstallation phase in terms of expectations about the system were security, unobtrusiveness, aesthetics, usefulness, and privacy. When asked about how the system would help them, themes of security and usefulness surfaced. Specifically, residents felt more secure about their safety and that they would receive assistance quicker. One resident remarked: “It gives me assurance that if something were to happen, I would have help.” Relief was expressed in knowing that the healthcare staff would be monitoring unsafe movements, and one resident remarked: “It could be a lifesaver if I fall.” Unobtrusiveness, privacy, and aesthetics materialized as several residents commented that they did not anticipate that the sensors would interfere with their day-to-day routine and that the FRAS would blend into their apartment surroundings. For example, when the FRAS was explained to one resident, she remarked that she was pleased that her privacy would be protected and stated that it was not going to intrude on her home environment.

Residents also anticipated the usefulness of the FRAS. They believed that their safety would be improved because falls would be recorded and staff would be monitoring these falls. There were several comments about how the system would help them examine their behavior so that they could prevent falls or correct their movement to prevent or avoid falls. One resident mentioned: “It will help me be more careful when I am walking around both inside of my apartment and outside of it.”

Finally, at the preinstallation phase, residents were asked to identify what information would be helpful to them and what they would like the FRAS to display. The primary feature they wanted to see were individualized health alerts that contained their own personal health data. In particular, residents were interested in knowing how their health data were changing. They wanted the FRAS to track improvements and activity or movements that could improve their fall risk.

First Interview After Installation
As the residents began to live with the FRAS, they had an increased understanding about it that influenced their expectations. They remarked that they were settling in with it and getting used to it. Emerging themes included positive regard, serving a purpose, and connection. Positive regard was identified in their expressions about having the system in their apartments; “feeling good about it” and “glad that it is here” were some of the comments. In terms of serving a purpose, residents remarked that the study overall would help older adults in the future with fall risk detection and that their participation in the study had the potential to improve the quality of life of others. Connection was another emergent theme in this phase. Some residents reported that they liked having “extra” contact with the researchers, study staff, and clinical staff associated with the project. Others felt a strong connection to their own health information, which they believed might help them to monitor and improve their behavior.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Time Frame</th>
<th>Emergent Themes</th>
<th>Recurrent Themes</th>
<th>Helpful Features Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preinstallation</td>
<td>Before FRAS installation</td>
<td>Security, unobtrusiveness, aesthetics, privacy, usefulness</td>
<td>Individualized health alerts</td>
<td></td>
</tr>
<tr>
<td>Postinstallation 1</td>
<td>6 mo after installation</td>
<td>Positive regard, serving a purpose, connection</td>
<td>Unobtrusiveness, aesthetics, usefulness, security</td>
<td>Monthly feedback reports, learning techniques for safety</td>
</tr>
<tr>
<td>Postinstallation 2</td>
<td>1 y after installation</td>
<td>Complacency, motivation</td>
<td>Unobtrusiveness, security, usefulness connection, aesthetics</td>
<td>Monitoring by healthcare staff</td>
</tr>
<tr>
<td>Postinstallation 3</td>
<td>18 mo after installation</td>
<td>Normalized</td>
<td>Security, usefulness motivation, connection</td>
<td>Individual data and how they differ from the norm</td>
</tr>
<tr>
<td>Postinstallation 4</td>
<td>2 y after installation</td>
<td>No new themes emerged</td>
<td>Normalized, security, usefulness, connection</td>
<td>Expansion of the sensors to monitor more areas</td>
</tr>
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</table>
Unobtrusiveness and aesthetics continued as themes; residents stated that the system was barely noticeable, the FRAS blended in with the living environment, and there was no interference with their daily routine. When residents were asked about how the system had helped them in day-to-day living, the same themes of security and usefulness identified in the preinstallation interviews surfaced in postinstallation interviews. They continued to feel assured that health professionals were watching for risks and that the alerts would summon help if one got into trouble. One resident articulated: “If I fell at night, someone would know. I really do feel safer because I fear falling.” In terms of usefulness, comments about the system being helpful due to increased awareness of actions and movements were articulated again. Some residents believed that the fall alert system helped them be more careful in the home environment. When asked whether the information they received from the FRAS was helpful, several residents pointed out that they liked the regular fall risk assessments and they used these assessments as a guide to help them improve their identified weak areas. Participants stated that it was interesting to see how they improved over time. Receiving feedback and reports continued to be a highlight for the residents. When asked about what information they would like to receive, there were a few comments about learning techniques to help keep them safer.

**Second Interview After Installation**

At this phase, when asked to comment about their experience living with the system and whether it interfered with their daily living, themes of complacency and motivation emerged. Complacency materialized since, at this point, no respondent raised objections or articulated any negative comment about how the FRAS operated, and they were settling in with the system. Comments such as “the system is fine,” “it doesn’t bother me,” and “I don’t mind having it in my apartment” expressed this emerging complacency. When residents were asked about how the FRAS had helped them, themes of safety, usefulness, and connection continued to be articulated. Residents stated that, if they were to fall, they knew that someone would help them. One resident believed that the system encouraged more monitoring by the healthcare staff. In terms of connection, residents continued to remark that they enjoyed the contact with researchers and students. One emergent theme in this phase was motivation. Several residents reported that the FRAS had helped them “try a little harder to be active.” One resident stated: “It inspires me to do more activities.” The aesthetics of the system was mentioned as something that could be improved; some residents did not like the color, location, or style of the wooden box that held the equipment.

**Third Interview After Installation**

At this point in the research project, there was some attrition of residents due to deaths and relocations for functional reasons. Of the remaining residents who continued in the project, they were adjusted to the FRAS, and the theme normalized emerged. Residents stated that they “forget that the sensors are in the apartment” and “do not think about them nor notice them.” There was no interference with daily routine. One resident stated: “I don’t even know that it is there. It has become part of the scenery.” It is interesting to note that aesthetics was not an issue in this phase.

Security and usefulness continued as themes, and residents mentioned that the system was helpful overall and they liked the monitoring by healthcare staff. One resident stated: “I feel reassured that if there was a change in fall risk, someone, the care staff, would be aware.” The theme of motivation was present as residents continued to link their increased effort with the project. There was a sense of confidence that greater effort would result in improved activity, as observed in this quote: “The fall risk assessments have made me more aware of my ability and inability to walk, stand, and balance in my environment. I make a greater effort, so I am able to do well each month.” Residents continued to make comments about how they enjoyed the extra contact they had with students and researchers, which continued the theme of connection. Finally, when asked what information the residents would like to see, in addition to wanting their own individual data and report, there was a request to add information about how the individual data differ from the norm.

**Fourth Interview After Installation**

At this final phase, the theme of normalized continued in relation to the residents’ perceptions of living with the sensor system in their home environment. One resident remarked: “I forget it’s there.” In terms of how the sensor system has helped the resident, safety as a primary benefit continued. One resident stated: “I have been involved a long time. I am happy to help. I have not fallen yet, but think it’s neat that they (care staff) can be alerted if I were to fall.” Residents also made comments about the usefulness of the FRAS in helping them remain in their homes. The theme of connection continued, and residents remarked again about how much they enjoyed interacting with the researchers and staff and the benefit of seeing more people. No new themes emerged at this phase as data saturation was achieved. When asked what they would change about the system, there was a suggestion about expanding the sensors to monitor more areas in the apartment, such as the bathroom.

**Stages of Acceptance**

Resident reactions and perceptions were tracked over time, and the data were examined for both consistency and changes
in perceptions. Researchers reviewed these data for patterns and themes; stages of acceptance regarding the use of gerontechnology emerged from this analysis. Table 2 provides information on each stage, the phase of the project in which these stages emerge, and a description of the stage.

Table 2. Stages of Acceptance  
<table>
<thead>
<tr>
<th>Stage</th>
<th>Phase</th>
<th>Description</th>
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<tbody>
<tr>
<td>Anticipation</td>
<td>Preinstallation</td>
<td>Foresee life with the sensors; expectations about benefits and burdens</td>
</tr>
<tr>
<td>Transition</td>
<td>Postinstallation</td>
<td>Transition from expectations to reality; settling in to reality</td>
</tr>
<tr>
<td>Adjustment</td>
<td>Postinstallation</td>
<td>Adapting to the technology in the home environment</td>
</tr>
<tr>
<td>Normalization</td>
<td>Postinstallation</td>
<td>Technology becomes a standardized feature of the living environment.</td>
</tr>
<tr>
<td>Acceptance</td>
<td>Postinstallation</td>
<td>Technology is an accepted part of everyday living.</td>
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DISCUSSION

This study demonstrated that sensor monitoring was regarded positively by the residents and family members who were interviewed. Sensor monitoring was viewed as a means to hold on to independence and allowed residents to age in place. The high regard for the sensor system remained intact during five points in time. Overall, for both groups, privacy issues did not emerge as a major concern. Instead, participants and their family members focused on the benefits of such a system in terms of usefulness, safety, and security. The lack of expressed concerns about privacy may be due to the fact that the sensor images, while tracking movement, do not reveal detailed features of an individual. Rather, the image displayed is that of a shape. For the one family member who had privacy concerns initially, the concerns were alleviated over time as her loved one lived with the system. These findings are congruent with other studies that reported that usefulness and need balance out privacy concerns for individuals, and these findings support the technology acceptance model. In addition, information collected by the FRAS is only shared with healthcare providers who are selected by the older adult, so in this study, older adults were involved in all decisions about who saw their data. Using this resident-centered approach to sharing information may have also lessened concerns about privacy.

Furthermore, in line with a resident-centered approach, for this independent population of older adults, family members were not involved with the collection and monitoring of the sensor data. Most knew about the FRAS and could envision a future benefit of the system to assist in communication of their loved one’s changing status. Most expressed support for their resident family member’s involvement with the FRAS. However, they saw it mostly as the resident’s project. When they were involved, they advocated for the FRAS to be aesthetically pleasing to the environment or offered ideas for how the system could evolve to be helpful to caregivers and other family members.

Another phenomenon that occurred through the sensor monitoring is that residents felt compelled to move more safely and to adopt healthier habits as a result of the connection they felt with the healthcare and research team. Perhaps the fact that participants knew people were paying attention to them served as an encouragement to do better. The connection to healthcare professionals seemed to be a positive facet of having the monitoring system in place. They enjoyed interacting with the researchers and clinical staff. This enjoyment is something to be considered as further research and services of the future when sensors are commercialized for home use.

The findings of this study are significant in that they demonstrate that sensor technology may be a solution to assist people to age in place for longer periods and to avoid institutionalization. An implication for practice is that health can be monitored using this technology, thus avoiding premature and costly institutionalization of older adults who have health conditions.

There are strengths and limitations to this study. The strengths are that the collected data contain a thorough examination of the perspectives and preferences of older adults in independent living environments and their family members. The research provides insight into how a small group of older adults with some functional limitations cope and adapt to the infusion of technology resources to help them age in place.

In addition, since data were collected at five points in time, we were able to track expectations and the adjustment process over time. We were able to capture information related to whether the initial expectations about the technology system were met over time and whether other expectations emerged. We were also able to track the perceptions of the value and usefulness of the technology system for older adults over time and to depict which perceptions and values changed and which continued to be present through the course of the project. In the tracking of how perceptions and attitude change over time, stages of acceptance in the use of gerontechnology emerged from the data.
The small sample size and qualitative nature of the research limit the generalization of results to other contexts. In addition to this limitation, the research focused on the use of an FRAS, which is one specific type of gerontechnology in one independent living environment. It is not known whether the results will transfer to other settings, other population groups, and other types of gerontechnology. Our study participants were at a point in their lives where they were searching for ways to remain independent, and this factor may have affected their willingness to accept sensors and their perceptions over time. Additional research is needed with a larger sample of older adults with varying levels of abilities in a variety of living environments to further test acceptance and perceptions of gerontechnology.

In conclusion, this study provided an opportunity to examine resident opinions and preferences about a developing FRAS during five points in time. In addition to resident opinions, family/caregiver opinions and preferences were collected about the sensors. For this sample population, the FRAS was regarded as a tool that helped increase their safety and activity level and served as a motivator to do better. The results suggest that, for this limited sample, interest and acceptance of the FRAS were motivated by a declining functional status and a desire to age in place. Future research should examine for the emergent and recurrent themes and stages of acceptance with gerontechnology that were discovered in this study.

References