International Journal of Technology Assessment in Health Care, **24:1** (2008), 120–124.

DOI: 10.1017/S0266462307080154

Senior residents' perceived need of and preferences for "smart home" sensor technologies

George Demiris
University of Washington

Brian K. Hensel, Marjorie Skubic, Marilyn Rantz
University of Missouri–Columbia

Objectives: The goal of meeting the desire of older adults to remain independent in their home setting while controlling healthcare costs has led to the conceptualization of "smart homes." A smart home is a residence equipped with technology that enhances safety of residents and monitors their health conditions. The study aim is to assess older adults' perceptions of specific smart home technologies (i.e., a bed sensor, gait monitor, stove sensor, motion sensor, and video sensor).
Methods: The study setting is TigerPlace, a retirement community designed according to the Aging in Place model. Focus group sessions with fourteen residents were conducted to assess perceived advantages and concerns associated with specific applications, and preferences for recipients of sensor-generated information pertaining to residents' activity levels, sleep patterns and potential emergencies. Sessions were audio-taped; tapes were transcribed, and a content analysis was performed.
Results: A total of fourteen older adults over the age of 65 participated in three focus group sessions Most applications were perceived as useful, and participants would agree to their installation in their own home. Preference for specific sensors related to sensors' appearance and residents' own level of frailty and perceived need. Specific concerns about privacy were raised.
Conclusions: The findings indicate an overall positive attitude toward sensor technologies for nonobtrusive monitoring. Researchers and practitioners are called upon to address ethical and technical challenges in this emerging domain.

Keywords: Technology, Housing for the elderly, Telemetry, Home care

The ongoing growth of the elderly population and increase in life expectancy have led to new models of positive aging, empowering older adults to longer maintain functionality, autonomy, and higher quality of life. Independence is a critical issue for many older adults as they age and face health-related challenges such as falls, sensory impairment, immobility, and isolation. The twin goals of meeting the desire of older adults to remain independent in the home setting while controlling healthcare costs has led to the conceptualization of "smart homes." A smart home is a residence equipped with technology that enhances safety of patients at home and monitors their health conditions.

This work was supported in part by the National Science Foundation (NSF ITR award IIS-0428420), the U.S. Administration on Aging (Grant no. 90AM3013) and the National Library of Medicine Biomedical and Health Informatics Research Training Grant T15-LM07089-14.

Worldwide, smart home initiatives are demonstrating the potential of technology to support aging. The Aware Home developed by Georgia Tech in the United States, for example, is a project developed in two identical independent living spaces that allow for controlled experiments with technology (9). In Sweden, the SmartBo project explores the use of sensors, visual and tactile signaling devices, and speech synthesizers for elders with mobility impairments and cognitive disabilities (8). The PROSAFE project in France uses infrared sensors to identify abnormal behavior and to collect

representative data on Alzheimer's patients' nocturnal and daily activity (4). The "Hospital Without Walls" in Australia is a project that includes a wireless fall monitoring system in which patients at home wear small sensors that measure heart rate and body movement (6).

The study presented here is part of the TigerPlace project. This project is facilitated by the framework of Aging in Place, a new model of long-term care for older adults (12). This model aims to allow older adults to age in the least restrictive environment of their choice. Clients' needs determine the timing and intensity of health and personal care services, delivered to them in their residence. A demonstration site of this model is TigerPlace, a 34,000 square foot facility in Columbia, Missouri, developed by the University of Missouri–Columbia with Americare Systems, Inc., of Sikeston, Missouri. TigerPlace opened in Spring 2004 and includes thirty-two apartments. Emphasis has been placed on a state of the art building and apartment design that supports independence (14). This study is a part of a larger investigation of the use of smart home technologies in this setting as tools that can support the Aging in Place model. The focus of the larger project within TigerPlace is to investigate the use of sensors to monitor and assess potential problems in mobility and cognition of elders. The components of the system include an in-home monitoring system, an event-driven anonymized video-sensor network, and a component for activity analysis and behavior reasoning.

The In-Home Monitoring System (IMS) (2) consists of a set of wireless infrared proximity sensors that detect motion, and pressure switch pads (sensor mats) that can be used to infer specific activities. A stove temperature sensor and switches on cabinet doors are being used. The system is also augmented with a bed sensor capable of detecting presence, respiration, pulse, and movement in the bed. Finally, the system includes a passive gait monitor that relies on a highly sensitive displacement sensor that detects small deflections in the floor induced by a person walking up to ten feet away. This monitor extracts basic gait characteristics (1).

The event-driven anonymized video-sensor network complements the IMS as the visual information helps reduce false alarms generated by the sensors. To preserve the privacy of the residents, algorithms are used to identify a person in the image and extract a silhouette (16).

The final component of the system is an activity analysis and behavioral reasoning system that distinguishes a typical pattern for an individual from an abnormal pattern. In this context, we are investigating Hidden Markov Models (HMMs) for learning and recognizing short-term activity patterns. The output of each activity analysis process is a descriptor that reports the likelihood of an activity.

In previous work (7), the research team investigated older adults' attitudes and perceptions of smart home technologies in general, asking subjects to identify what activities of daily living could be enhanced by technology. This work indicated that older adults were concerned about falls and that they perceived technologies that monitor activity levels and sleep patterns as useful. This work informed the design of specific technologies that were installed in the TigerPlace apartments.

The study presented here is a follow-up of this previous work and is aimed at investigating the following: older adults' perceptions of the specific smart home technologies used by the TigerPlace project (i.e., a bed sensor, gait monitor, stove sensor, motion sensor, and video sensor); perceived advantages and concerns associated with these types of technology; willingness to adopt such technologies in their own residence; and preferences about recipients of sensor-generated information pertaining to their activity levels, sleep patterns, and potential emergencies. This study provides insight into older adults' attitudes toward specific sensor technologies and captures the level of willingness to allow installation of such technologies and to share associated personal data with other stakeholders.

METHODS

We conducted a series of focus group sessions to assess older adults' perceptions and expectations of specific smart home technologies, including perceived advantages and disadvantages and degree of willingness to adopt such technologies in their homes. The sessions were facilitated by members of the research team and followed facilitation guidelines for focus groups by Krueger (11). Special considerations for elderly focus group participants as suggested by Barrett and Kirk (3) were followed. To avoid fatiguing participants and conflicts with their usual activities, the sessions were scheduled to last approximately 1 hour. At the beginning of each session, the facilitator introduced the purpose of the study. The sessions were audiotaped for later analysis by team members. We used purposeful sampling in the recruitment of focus group participants. An invitation to participate was placed in residents' individual mailboxes and posted at several locations within TigerPlace.

The focus group protocol included questions about participants' perceptions of the usefulness of specific devices and sensors. These objects included a bed sensor, a motion sensor, a gait monitor developed by the University of Virginia, a kitchen sensor, and a video-based fall detection sensor.

Supplementary Figure 1 (available online at http://www.journals.cambridge.org/jid_thc) depicts examples of these sensors and describes their intended use. For each sensor, the facilitator explained briefly its purpose by describing its function and providing an example of usage. The facilitator showed and passed around the actual sensors, allowing participants to touch and directly observe the devices. The examples used by the facilitators were chosen to increase understanding as recognition, comprehension, and memory for information in older people have been shown to benefit from prior context cues (15). Questions pertained to perceived

advantages and disadvantages associated with the usage of such systems, participants' willingness to allow installation in their residence, and opinions about who should be receive the data produced by the sensors.

To ensure the protocol's validity, the questions were reviewed by a team consisting of researchers experienced in instrument development and knowledgeable about healthcare providers. The protocol was also pilot-tested for readability with a senior resident in a different facility following Krueger's recommendation to test the wording of questions with people similar to the target participants (11).

The audiotapes were transcribed, and a content analysis was performed. The content analysis was data-driven; thus, a predetermined coding scheme was not used for coding the data (5). Data codes were inductively generated by the data collected. The goal of the qualitative content analysis was to summarize the information gleaned from the analyses of the content. Analyses were performed by assigned members of the research team, and consensus in interpretations was achieved through discussion between these members. The validity of interpretations was then discussed and agreed upon with other members of the research team (10).

RESULTS

A total of fourteen older adults over the age of 65 participated in three focus group sessions (four in the first, three in the second, and seven in the third session). Each session lasted approximately 1 hour (the average length was 64 minutes). Five participants were male and nine were female. All participants were older than 65 years of age.

The bed sensor was perceived overall as useful. Two participants asked questions about the installation on top of the mattress. One participant stated that she relied on her spouse to detect restlessness or problems during the night and felt no need for technology-based monitoring. The stove sensor was perceived by some participants as useful, but most responded that they do not use the stove as they receive meals prepared by the facility and, therefore, are not concerned about accidentally leaving the stove turned on. The sensor mat was also perceived as useful by most participants. The motion sensor was perceived as an application that could provide ease of mind. Participants focused primarily on the usefulness of such a device in detecting intruders and thus providing additional security, more so than on its usefulness in monitoring their activity levels. The gait monitor was perceived overall as very useful, as most participants expressed concerns about falling and being helpless or not detected in a timely manner. Finally, the video sensor was seen as beneficial in detecting health emergencies, particularly falls, but raised greater privacy concerns than the other technologies. Ten participants stated that they would not want to have a video sensor installed in their residence.

Findings suggest that participants focused on the potential of smart home features to detect emergency situations rather than their potential for prevention through early detection of potential health problems. Their comments emphasized the technologies' function of emergency detection rather than their function of proactive monitoring.

Some participants addressed the issue of stigmatization resulting from installing the technology. One participant stated "as long as it is installed in the others' [apartments], as long as it would be something they were going to use all over and I would not be different. . . ."

Many subjects found the technology useful for residents with greater levels of frailty than themselves. One participant stated, "I don't need this now, but perhaps at a later point—I have friends who'd benefit from this a great deal, I am not there yet . . . ." In this context, readiness to adopt the technology resulted from perceived need, and some participants found that their functional and physical status was such that there was no need for monitoring at the time.

Two participants expressed concerns about privacy violation resulting from the use of the technology. One subject stated "I don't like for anyone to know that I went out and didn't get back until midnight or something like that—I don't think anyone needs to know that."

When asked who should have access to the data generated by the sensors, participants stated that they would want their healthcare providers to have this information. Six participants also added that they would like their close family members to be recipients of the data sets. Four participants said that they, themselves, would like to see the information. One participant followed-up indicating that residents should have control of the amount and frequency of information distribution, stating that he would "need to see the information first, before anybody else is bothered".

Preferences for specific sensors were based on different criteria. For some participants, the size of the device played a role. One participant made a comment about the motion sensor: "I like this one the best; it's so small, really not intrusive . . . ." Other participants determined the usefulness of the devices based on previous personal adverse health events. One participant stated, "If you had told me 2 months ago [about these technologies] I'd say who needs it, but after what I have been through, I see the benefits." This participant had experienced a fall in the apartment and had felt helpless until someone discovered the event. Participants also addressed the issue of integration of the technology in the residence and its degree of visibility to visitors. One participant stated, "If you can hide them and you don't really see them but you know that they are there, that would be my preference."

Two participants expressed concerns about the accuracy of the devices. One of them specifically addressed the issue of false alarms that could prove burdensome to both residents and facility staff members. Other participants, however, expressed the need to balance safety with privacy and that they would be willing to allow others to monitor their activity

levels if that provided an added layer of safety and enhanced their well-being.

DISCUSSION

Overall, participants had a positive attitude toward smart home technologies in general. As previously stated, their perceptions of the potential of the technology focused on a reactive role (detecting emergencies) rather than a proactive one (monitoring a situation to detect trends or predict issues or concerns). Fall detection was a function that appeared to be uniformly supported as important. Participants believed that none of the technologies presented to them would interfere with daily activities. Half of all participants specifically stated that they would agree to having these technologies installed in their own apartment. Most participants saw a balance to be struck between the benefits of such monitoring, determined by level of need, and the perceived intrusion into privacy. From a methodological point of view, our study confirms the challenges of conducting focus groups with older adults, identified by Barrett and Kirk (3). These challenges include the fact that older people show a lowered ability to focus attention over longer periods of time, or to suppress irrelevant information (13;15). Our protocol was designed so as not to overload the working memory of older adults during the sessions.

This study suggests additional, potentially fruitful areas of inquiry. For example, was the participants' focus on the technologies' benefit in reaction rather than prevention, a basic orientation or a matter of not having learned enough about the potential preventive benefit? The potential mediating role of control also poses interesting questions, such as whether perceived control (e.g., ability to turn technology off) mediates the level of privacy concern. Smart home design is an emerging domain and researchers and practitioners are called upon to explore the challenges associated with the introduction of these technologies in one's home.

POLICY IMPLICATIONS

Further evidence of the effectiveness of smart home applications is required before issues of reimbursement and integration into standard practice can be explored and guidelines can be defined for technology performance and maintenance standards. A dialogue among administrators and healthcare providers of long-term care institutions and independent retirement communities on the one hand, and system designers and policy makers on the other, will further the ongoing work and address ethical and practical challenges.

CONTACT INFORMATION

George Demiris, PhD (gdemiris@u.washington.edu), Associate Professor, Department of Biobehavioral Nursing and Health Systems, School of Nursing & Biomedical and Health Informatics, School of Medicine, University of Washington, BNHS Box 357266, Seattle, Washington 98195

Brian K. Hensel, PhD, MSPH (henselbk@health.missouri.edu), Postdoctoral Fellow, Department of Health Management & Informatics, School of Medicine, University of Missouri–Columbia, 324 Clark Hall, Columbia, Missouri 65211

Marjorie Skubic, PhD (skubicm@missouri.edu), Associate Professor, Electrical and Computer Engineering; Director, Center for Eldercare and Rehabilitation Technology, College of Engineering, University of Missouri–Columbia, 221 Engineering Building West, Columbia, Missouri 65211

Marilyn Rantz, RN, PhD, FAAN (RantzM@missouri.edu), Professor, Sinclair School of Nursing; Associate Director, MU Interdisciplinary Center on Aging, University of Missouri–Columbia, S406 Nursing Building, Columbia, Missouri 65211

REFERENCES

1. Alwan M, Dalal S, Kell S, Felder R. *Derivation of basic human gait characteristics from floor vibrations*. 2003 Summer Bioengineering Conference. Key Biscayne, FL; 2003.
2. Alwan M, Kell S, Dalal S, Turner B, Mack D, Felder R. *In-home monitoring system and objective adl assessment: Validation study*. Presented at the International Conference on Independence, Aging and Disability. Washington, DC; 2003.
3. Barrett J, Kirk S. Running focus groups with elderly and disabled elderly participants. *Appl Ergon.* 2000;31:621-629.
4. Chan M, Bocquet H, Campo E, Val T, Pous J. 1999, Alarm communication network to help carers of the elderly for safety purposes: A survey of a project. *Int J Rehabil Res*. 1999;22:131-136.
5. Creswell JW. *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage Publications; 1998.
6. Dadd M, Doyle B, Wilson L, Gunaratnam M. Lessons learned from the Hospital Without Walls project. *J Telemed Telecare.* 2002;8(Suppl 3):11-14.
7. Demiris G, Rantz MJ, Aud MA, *et al.* Older adults' attitudes towards and perceptions of 'smart home' technologies: A pilot study. *Med Inform Internet Med.* 2004;29:87-94.
8. Elger G, Furugren B. *SmartBo-an ICT and computer-based demonstration home for disabled people*. Proceedings of the 3rd TIDE Congress: Technology for inclusive design and equality improving the quality of life for the European citizen. Helsinki, Finland; 1998.
9. Kidd CD, Orr RJ, Abowd GD, *et al. The aware home: A living laboratory for ubiquitous computing research*. In the Proceedings of the Second International Workshop on Cooperative Buildings—CoBuild '99; 1999.
10. Krueger RA. *Analyzing & reporting focus group results*. Thousand Oaks, CA: Sage Publications; 1998.
11. Krueger RA, Casey MA. *Focus groups: A practical guide for applied research*. 3rd ed. Thousand Oaks, CA: Sage Publications; 2000.

12. Marek KD, Rantz MJ. Aging in place: A new model for long term care. *Nurs Adm Q.* 2000;24:1-11.
13. Morrow DG, Stine-Morrow EA, Leirer VO, Andrassy JM, Kahn J. The role of reader age and focus of attention in creating situation models from narratives. *J Gerontol B Psychol Sci Soc Sci.* 1997;52:73-80.
14. Rantz MJ, Marek KD. TigerPlace: A partnership with Americare and the Sinclair School of Nursing. *Nurs Outlook*. 2004;52:68.
15. Tun PA, Wingfield A. Language and communication: Fundamentals of speech communication and language processing in old age. In: Fisk AD, Rogers WA, eds. *Handbook of human factors and the older adult*. San Diego, CA: Academic Press; 1997:125-149.
16. Wang L, Tan T, Ning H, Hu W. Silhouette analysis-based gait recognition for human identification. *IEEE Trans Pattern Anal Mach Intell*. 2003;25:1505-1518.