Facilitating interdisciplinary design specification of "smart" homes for aging in place

George DEMIRIS [a,1], Marjorie SKUBIC [a], Marilyn J. RANTZ [a],
Karen L. COURTNEY [a], Myra A. AUD [a], Harry W. TYRER [a],
Zhihai HE [a], and Jia LEE [a]

[a] *University of Missouri - Columbia, USA*

Abstract. "Smart homes" are defined as residences equipped with sensors and other advanced technology applications that enhance residents' independence and can be used for aging in place. The objective of this study is to determine design specifications for smart residences as defined by professional groups involved both in care delivery to senior citizens and development of devices and technologies to support aging. We assessed the importance of specific devices and sensors and their advantages and disadvantages as perceived by the interdisciplinary expert team. This work lays the ground for the implementation of smart home residencies and confirms that only an interdisciplinary design approach can address all the technical, clinical and human factors related challenges associated with home-based technologies that support aging. Our findings indicate that the use of adaptive technology that can be installed in the home environment has the potential to not only support but also empower individual senior users.
Keywords: Medical Informatics, Smart Homes, Assistive Technology, Aging, Residential Facilities.

1. Introduction

As the segment of the population over the age of 65 years keeps growing and average life expectancy increases, new models of positive ageing are being developed to allow senior citizens to adapt to degenerative changes and maintain functionality, autonomy and quality of life. Such models aim to address ways with which seniors can cope with health-related issues such as falls, sensory impairment, immobility, and medication management. The development of "smart homes" aims to meet older adults' desire to remain independent at home by proactively addressing older adults' needs. The term "smart home" refers to a residence equipped with a set of advanced electronics and automated devices designed to enhance health care delivery and remote physiological monitoring of residents, to enable early identification of possible problems or emergency situations and to maximize residents' safety and overall well-being. Smart home features usually include motion-sensing devices for automatic lighting control,

---

[1] Corresponding Author: George Demiris, 324 Clark Hall, University of Missouri – Columbia, Columbia, MO 65211 USA. E-mail: gdemiris@gmail.com

motorized locks, door and window openers, mobilized blinds and curtains [1], smo ;
and gas detectors and temperature control devices.

The study presented here is part of an initiative placed within the framework f
Aging in Place, a model of long-term care for older adults [2]. In this model, senic ;
direct the timing and intensity of health and personal care services delivered to them
their residences, and thus, have the opportunity to 'age in place.' The specific initiati :
includes Tiger Place, a 34,000 square foot facility in Columbia, Missouri [3].
preliminary work [4] assessing older adults' perceptions of the technology, senio ;
identified potential application areas for advanced technologies such as emergen '
help, prevention and detection of falls, and monitoring of physiological parametei
Overall, older adults had an overall positive attitude towards devices and sensors th :
can be installed in their homes in order to enhance their lives.

The objective of this study is to determine design specifications for sma
residences as defined by an interdisciplinary team of experts, namely, profession
groups involved both in care delivery to senior citizens and development of devices at
technologies to support aging. This work lays the ground for the implementation <
smart home residences and is based on the belief that only an interdisciplinary desi
approach can address all the technical, clinical and human factors related challeng<
associated with home-based technologies that support aging.

2. Material and Methods

2.1. Design

This study utilized a focus group approach which included both clinical and noi
clinical domain experts. The focus group protocol was based on structured and opei
ended questions defined by published literature and previous work. Both qualitativ
and quantitative data analysis methods were employed. Specifically, a content analysi
of the sessions was performed and ratings were analyzed using SPSS.

2.2. Sample

We conducted focus groups with a convenience sample of experts in delivery of care t
older adults and/or design of smart home applications. In order to include a divers
group of professionals we recruited experts from both the clinical and non-clinic;
sector. Experts in the clinical domain included nursing researchers with clinic;
gerontological nursing experience, social workers and health psychologists. Experts i
the development of "smart home" devices and technologies included engineers an
computer scientists. The sample was selected from an academic setting and all subject
had research experience and an extensive publication record in their domain for mor
than 10 years. Participants were invited to discuss the design specifications of a smai
residence for the typical TigerPlace resident who is a senior in his/her eighties, retire<
and still independent in most basic and instrumental activities of daily living.

2.3. Data Collection

The focus group protocol included a structured questionnaire and open-ende<
questions. The participants were asked to rate the importance of specific devices an<

features for a smart residence in the context of TigerPlace and its typical residents. The devices and features included actuators for environmental control (i.e., mechanical devices such as window or door openers that are simple to use and allow users to control specific environmental attributes), heating ventilation and air conditioning, infra red sensors, iris recognition, personal data assistants, pressure pads (that send a signal to a control unit and instigate an action if triggered by the weight of a person's step), smart cards (with an embedded microprocessor for data storage) and emergency communication systems (that can be used to send an emergency alarm or allow two-way communication between resident and care provider). These items included in the protocol were identified during focus groups with senior adults in a previous study [4] and also defined by Dewsbury et al [5] as common "smart" home features. Participants were asked to provide a rating on a 5-point Likert scale for each of the items and discuss explanation for their ratings. The engineering experts were then asked to discuss the advantages and disadvantages of different types of smart home network protocols, namely bluetooth, busline based technology, X10.

2.4. Data Analysis

Ratings for the structured questions were entered into an SPSS program for analysis. Responses to open-ended questions and comments were reviewed and coded by two of the authors. The participants of every group were asked to identify the desired and undesired features of smart home technology resulting from consensus among all members of every focus group session. During this exercise focus group participants had to work as a group and identify ways to exceed their professional silos by interacting and debating with experts in other fields. These items were identified by the two coders independently and findings were compared to identify inter-rater reliability. Finally, the preferences of the experts were entered into the CUSTODIAN software system. This system was funded by the European Union and is managed by the Robert Gordon University in the UK [5]. This software suite is publicly available and provides a visualization tool that enables users to test scenarios and set-up configurations. Based on the ratings and feedback of the experts, a model apartment was created to visualize the concepts discussed during the focus group sessions and provide a blue print for the system design.

3. Results

A total of twelve subjects participated in four sessions. The sessions lasted in average 64 minutes (SD 7.3 min). Participants included three nurses, four computer engineers, two social workers and three health psychologists. Table 1 summarizes the ratings of the participants.

All participants found pressure pads to be very important. One participant stated that a pressure pad can provide means of monitoring the residents in a non-obtrusive manner and without violating their privacy. Another participant stated that it is important to have this feature on many locations throughout the residence to allow for a continuum of monitoring.

Smart cards were perceived as useful by most participants. One participant stated that a smart card can be very useful for residents who have dementia and find themselves in an unfamiliar setting assuming that the infrastructure is in place to allow

for the smart card use. Two participants saw benefits in smart cards that entail parts of the medical record and would allow for residents to use these when they interact with health care providers. All participants rated emergency communication systems as very important. Infra-red sensors were also perceived as useful by participants. Two of them stated that such sensors can be utilized to detect presence of people or pets in the apartment or detect movement. Heating and air conditioning were perceived by all participants as very important; however, most commented that climate controls and thermostats are already in place.

Table 1: Participant ratings of devices & systems

Perception of importance of smart home devices and features (N=12) (1: Not Important At All; 5: Very Important)		
	Average	SD
Pressure Pads	5	0
Smart Cards	5	0
Emergency Communication system	4.91	0.3
Infra-Red sensors	4.55	0.69
Heating Ventilation and Air Conditioning	4.45	0.93
Actuators for environmental control	3.36	0.50
Personal Data Assistants (PDAs)	3.22	0.83
Iris Recognition	1.55	0.52

Actuators for environmental control were perceived as very helpful. Three participants emphasized however that a possible dysfunction of such devices can be very problematic and frustrating to users who have learned to rely on them. Two participants stated that door openers in this context appear more important than window openers. One participant emphasized that the operation of doors and windows needs to be studied carefully when considering a potential automation so as to prevent unexpected injuries. One participant stated that voice control over window or door openers would be ideal; however, voice recognition has not reached an optimal state. One participant stated that a Personal Data Assistant (PDA) could function as a reminder tool or to enable residents to control their medication. Three participants commented that the current interfaces of PDAs are not user-friendly for people with visual impairments and thus, PDAs could be difficult to operate for senior citizens. Specifically, one participant stated that the keys are too small and the finger coordination can be problematic for elderly users with functional limitations. Another participant acknowledged these problems but stated that both the interface and the operation of a PDA can be easily modified to address the user needs of senior citizens. As can be seen in Table 1, an iris recognition feature was not perceived as very important for the typical resident. One participant saw a potential implementation for the purposes of medication management if there is a need to ensure the identity of the individual handling medication. Most participants, however, saw no obvious benefit to utilizing this technology.

There was no significant difference in the scoring between professional groups, and the concordance was high (ICC Coefficient 0.85, F=1.7). Two items had less concordance between the professional groups, namely iris recognition and Personal Data Assistants, where engineers rated these in average slightly higher than nurses,

social workers and health psychologists (difference in average scores of 1.2 and 0.7 respectively, p<0.05).

One of the respondents commented that these technologies should be integrated to support the functional independence of older adults. The sensors should trigger coordinated responses so that the sensor that recognizes the situation of a stove left on too long alerts the resident and/or the care provider. Another participant saw great benefit in a technology that can provide clinicians with information about daily and long term trends. Two participants stated that they can see increased efficiency of the use of smart home technologies if they involve family and friends. Table 2 summarizes the most important features of smart home technology as defined by the experts.

Table 2: Desired and Undesired Features of Smart Home Technology as Defined by Experts (n=12)

Desired Features:	Undesired Features:
Non-intrusive	Introduce new risks or hazards
User friendly	Place burden on the residents
Usable, accessible	Limit activities of the residents
Accurate	Increase anxiety
Reliable	"stigmatize" residents as being frail or in need of special assistance
Easy to maintain	

All engineering experts defined the network protocols as complementary rather than competing because each can play a great role in the infrastructure of a "smart" residence. Two respondents stated that the advantage of X10 is that it can control household appliances easily and in a cost-efficient way. They also emphasized that bluetooth is a wireless low power solution with limited range but with advantages in interconnecting wirelessly objects that are close together. Three respondents rated bus technology as easy and convenient and useful in minimizing electromagnetic noise. They perceived this technology as reliable. All experts stated that wire connection makes sense when there is close proximity of objects and that safety conditions need to be taken into consideration to minimize potential safety hazards (such as a resident tripping over a cord).The preferences and ratings of the experts were taken into consideration when a prototype "smart" residence was designed with the CUSTODIAN software platform. All items that received a rating higher than 3 on the five-point ordinal scale as well as other suggestions were incorporated into the design. General actuators for environmental control such as window openers, control units for doors and light were integrated in all rooms. The prototype was then reviewed and approved by the experts as a blue print that reflects their statements and views.

4. Discussion

An interdisciplinary approach is essential to design a home that is flexible and responsive to the needs and limitations of the residents. The value of interdisciplinary teams is not a new concept in gerontology. Such teams overcome the problems of the traditional health care organizational model, which reinforces functional specialties and silos of expertise. The interdisciplinary team approach promotes integrated and coordinated care for older adults in which all participants in the care-delivery process are focused on the older adult rather than their specialty. During both the design and

development phases of a smart home, experts from different disciplines need to be included. Furthermore, end-users should participate in the early discussions and be able to provide feedback during the design specification phase as there may be a "disconnect" between expert beliefs and end user perceptions. The study presented here results from a previous study assessing end users perceptions of "smart" home technologies [4] and describes an effort to document experts' feedback and integrate it into the design of the smart home application. As Rogers [6] points out, we need to shift from a model of "technological determinism", namely that technology itself should be the impetus for change, to a model of the social construction of technology where technology is influenced by societal norms and needs.

5. Conclusion

The success of smart homes will depend on the level of compliance with universal design principles that are holistic and inclusive [7]. Many of the challenges that older adults face, whether functional or cognitive limitations, have been traditionally addressed by the utilization of mechanical adaptive devices, which allow the user to adequately function in their environment, but not necessarily actively participate in it. The use of adaptive and assistive technology that can be installed in the home environment has the potential to not only support but also enable and empower individual users. This study contributes to the emerging field of smart home technologies as it provides insight into the typical features of smart homes and their advantages and disadvantages as perceived by professional experts.

Acknowledgements

References

[1]   Elger G, Furugren B. SmartBo-an ICT and computer-based demonstration home for disabled people. 3rd TIDE Congress: Technology for Inclusive Design and Equality Improving the Quality of Life for the European Citizen; 1998; Helsinki, Finland; 1998.

[2]   Marek KD, Rantz MJ. Aging in Place: A new model for long-term care. Nurs Adm Q. 2000;24(3):1-11.

[3]   Rantz MJ. Aging in place. Nurseweek, Midwest/Heartland Edition. 2003 7(4):2.

[4]   Demiris G, Rantz MJ, Aud MA, Marek KD, Tyrer HW, Skubic M, et al. Older adults' attitudes towards and perceptions of "smart home" technologies: A pilot study. Med Inform Internet Med. 2004;29(2):87-94.

[5]   Dewsbury G, Taylor B, Edge M. The process of designing appropriate smart homes: Including the user in the design. Equator IRC Workshop on Ubiquitous Computing in Domestic Environments; 2001; University of Nottingham, UK; 2001. p. 131-46.

[6]   Rogers E. Diffusion of Innovations. 5th ed. New York: The Free Press; 2003.

[7]   Edge HM, Milner J. Universal Design: A social agenda within the ecological designed built environment. Shifting Balance: Changing Roles in Policy, Research and Design, IPAS Conference; 1998; Netherlands; 1998.