

Article

Smart Homes for Older People: Positive Aging in a Digital World

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Received: 18 April 2012; in revised form: 15 June 2012 / Accepted: 18 June 2012 /

Published: 19 June 2012

Abstract: Smart homes are homes with technologically advanced systems to enable domestic task automation, easier communication, and higher security. As an enabler of health and well-being enhancement, smart homes have been geared to accommodate people with special needs, especially older people. This paper examines the concept of “smart home” in a technologically driven society and its multi-functional contribution to the enhancement of older people’s lives. Discussion then focuses on the challenges in the use of smart homes among older people such as accessibility and ethical issues. Finally, some implications and recommendations are provided.

Keywords: smart home; older people; positive aging; health and wellbeing; accessibility; ethics; acceptance of technology

1. Introduction

Layzell, Manning and Benton [1] use the terms “the elderly demographic time bomb” to alert us to the aging of the populations globally (p. 167). In Australia, with increased life expectancy and a pro-longed low level of fertility, a dramatic increase in the proportion of older people in the population is projected [2]. Specifically, the population aged 65 years and older is forecast to more than double by 2050, with the greatest rate of growth in the 85+ group [3]. Aging populations are more vulnerable to illness, higher hospitalization rates and prevalence of health risk factors whilst for many elderly in rural and remote areas access to existing health care is relatively limited [4]. This has resulted in a

greater need for health and disability support in the future, placing increased pressure on aged care and health services [4]. These changes have necessitated the need for strategies and policy initiatives to promote productive aging and maximize the capacity for home-based care. Within this context, smart home technologies have been suggested as a viable solution, offering new models of positive aging and empowering older adults to maintain independence, functionality, well-being and higher quality of life [3]. This paper firstly reviews the concept of “smart home” and its perceived multi-functional contribution to the enhancement of older people’s lives. It then focuses on the prominent challenges in the use of smart homes among older people such as accessibility and ethical issues. Finally, recommendations are provided for both users and providers in designing smart homes to better cater for an older population.

2. The Conceptual Framework of Smart Homes

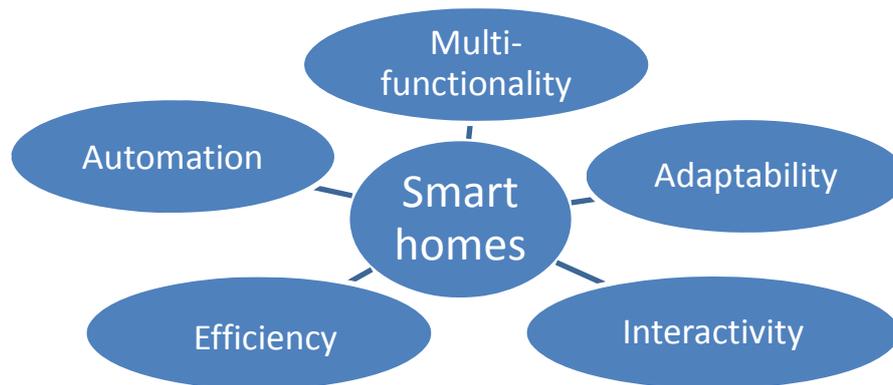
The term “smart home” is generally used to refer to a modern home which provides electronically controlled security and conveniences. Smart home technology is defined as the integration of home-based technology and services for a better quality of living [5]. Basically, smart homes are equipped with advanced automatic systems for various pre-programmed functions and tasks such as lighting, temperature control, multi-media, window and door operations, etc. This modern environment is also referred to as ambient intelligence, which is sensitive and adaptive to modern human and social needs [6]. The implementation of smart home technologies is generally meant to enhance home comfort for everyone through the automation of domestic tasks, easier communication, and higher security [7]. Smart home users are able to enhance their capacity to interact with their domestic environment, perform tasks and engage in activities that would have been previously difficult or impossible [8].

In a digitally enriched living environment, the concept “smart home” is subject to various definitions and interpretations because being “smart” can imply various characteristics of a highly advanced modern home, such as being automatic, compact, innovative, convenient, self-adjusting, responsive, or functional. With a view to generating a sound background for further discussion, a conceptual framework of smart homes has been constructed based on a review of relevant literature (Figure 1).

This proposed framework proposes that smart homes can be characterized or identified as having five basic features:

- Automation: the ability to accommodate automatic devices or perform automatic functions;
- Multi-functionality: the ability to perform various duties or generate various outcomes;
- Adaptability: the ability to adjust (or be adjusted) to meet the needs of users;
- Interactivity: the ability to interact with or allow for interaction among users; and
- Efficiency: the ability to perform functions in a time-saving, cost-saving and convenient manner.

These five features are drawn upon in the following discussion.

Figure 1. Conceptual framework of smart homes.

3. Smart Home Technologies for Older People

In Australia, exploration of the “smart home” concept has been encouraged for a number of reasons. Australia is considered a digitally orientated society where modern computer technologies permeate almost every aspect of individual and social life. It is also relatively affluent, has a stable economy and small population when compared to many of its neighbours. Arguably Australia is therefore well positioned to take advantage of advanced technology. Like many other countries across the world, Australia is ageing rapidly and is faced with challenges associated with the transition from work to retirement of the baby-boomer generation. According to Aged and Community Services—Australia [9], by 2021, close to four in every ten households will be occupied by at least one older person, the majority living alone or with only one other. Against this background, smart homes have been promoted as an emerging space for positive aging, especially with their potential to increase the ease and safety in performing domestic tasks and to improve communication. According to Stefanov, Bien and Bang [7], smart homes have recently been geared to accommodate people with special needs, including older people and those with physical disabilities and chronic illnesses.

In their discussion of dementia in the context of ageing, Frisardi and Imbimbo [10] view a smart home as “a residence equipped with technology that facilitates monitoring of residents to improve quality of life and promote physical independence, as well as to reduce caregiver burden” (p. 143). Similarly, Demiris [11] defines smart home technology as an emergent interdisciplinary field that builds on the use of technology to support aging. Innovative ways have been sought to use information technology for the enhancement of independence and quality of life for senior citizens. Cheek, Nikpour and Nowlin [12] advocate “aging well with smart technology” and provide the following justification:

Many people prefer to grow old at home, a concept known as aging-in-place. Smart home technology facilitates aging-in-place by assisting patients with emergency assistance, fall prevention/detection, reminder systems, medication administration and assistance for those with hearing, visual or cognitive impairments (p. 329).

There is no one single type of smart home for older people as actual design should vary according to users’ needs, characteristics and embrace the concept of adaptability as these change over time. Besides the general automatic systems for making domestic tasks easier, a wide range of devices have been created to provide better assistance and monitoring of both mental and physical functions of

occupants. Aged and Community Services—Australia [9] has identified the following features of smart homes for older people depending on the health and financial situation of the user:

- Personal alarms via pendants and pull cords to a response centre;
- Video door entry systems that allow the resident to see who is visiting and to then open the door remotely;
- Bed and chair occupancy sensors that provide early warning if the resident does not return in determined time;
- Lighting that can be automatically activated when a resident gets out of bed;
- Medical monitoring, such as pulse, blood pressure and soiling that can be assessed on site and information forwarded appropriately; and
- Increased use of robotics to assist around the house.

According to Demiris and Hensel [13], there are six categories of health-related smart home technologies especially developed to assist senior and disabled citizens. These categories include physiological monitoring (measurements of pulse, respiration, blood pressure), functional monitoring (measurement of general activities, motion, meal intake), safety monitoring and assistance (automatic lighting, slip and fall reduction, hazard detection), security monitoring (intruder detection), social interaction monitoring and assistance (phone calls, video mediated communication, virtual participation in groups), and cognitive/sensory assistance (medication reminder, lost key locator). Rialle *et al.* [14] use the term *health smart homes* (HSH) for those that accommodate the use of tele-med information systems and communication technologies. In their view (p. 395), technology for home-based patients, most of whom are older people, need to be advanced and complex, requiring “the use of a distributed approach and the combination of many hardware and software techniques” [14]. The functions of smart homes could be largely extended to satisfy needs of older people, who seek to live as independently as they can in the comfort of their home. This is a manifestation of the multi-functionality of smart homes, which implies diversity as well as flexibility in functions.

Numerous projects involving smart home technologies for older people have been launched worldwide, with a view to reducing the level of dependency and increasing the safety of older adults [13]. Some typical projects are the Welfare Techno-House project in Japan (1995), Assisted Interactive Dwelling House in the UK (1996), Aware Home in the US (1999), Tiger Place in the US (2003), Gator Tech Smart House in the US (2004), Health Integrated Smart Home Information System in France (2002), and ROBOCARE Domestic Environment in Italy (2007). Outcomes from these smart home projects have been reported to be positive in extending the length of community residence, enhancing physical and mental health status, delaying the onset of serious health problems and reducing the strain on family and care-givers [8]. With favourable findings on their effectiveness, smart home technologies have enabled of continuous monitoring, improved psycho-social benefits and enhanced the overall sense of well-being for older adult users [12,15–17].

One typical smart home technology for older people and home-based patients is the smart sound system. It is of particular significance in distress situations as the smart sound system in real-time operation can detect and identify sound events. Istrate, Vacher, and Serignat [18] describe the system as a combination of two components: detection and classification. The former operates in real time to detect possible alarm sounds. The latter module distinguishes between speech and sound before

launching either a speech recognition system or a sound classification between predefined classes. In this way, family and care providers can be readily informed of any changes that may warrant a response.

Despite their potential to generate many benefits for older people, smart homes as a technologically assisted lifestyle innovation, come with risks and challenges. Reported concerns are often associated with: cost, intrusiveness, privacy, user accessibility and acceptability [12,19–21].

4. Challenges

Concerns about this ambient environment for positive aging are frequently related to issues of accessibility and ethical concerns. Accessibility to smart homes for older people is defined in the context of this discussion as their financial ability to afford the cost of these technologies (financial accessibility or affordability), their ability to use them with ease (technical accessibility and user friendliness) and confidence (psychological trust and acceptance).

4.1. Financial Accessibility

A smart home includes innovative features which can be very costly to certain older users. According to Berlo [5], installing some smart home devices requires new software skills and integration of different disciplines, which renders the implementation “quite laborious and thus expensive.” (p. 84) Maintaining smart homes can incur high costs when it comes to purchasing, installing and maintaining smart devices like wireless cameras, light sensors, a central touch screen and automated systems. It is important therefore, that governments and stakeholders at various levels collaborate in planning and implementing smart homes for older people so that the divide between those who can and those who cannot afford such technology be minimized. In doing so, smart homes have the potential to bring not only technological security and comfort but also some degree of social justice. In addition to this, various organizations are encouraged to be involved. For instance, in Australia “the private sector has also developed special housing for older people as part of new developments. More compact housing with low maintenance gardens to multi-generation living in adjoining, self-contained dwellings are scattered through larger developments” [22].

4.2. Technical Accessibility

The limited familiarity of many older people with the advanced technologies of smart homes is another common concern. Unlike the younger (X,Y and Z) generations of “digital natives”, older people were not born to the age of information technology and can express less comfort with some aspects. Commenting on their experience in a Smart Home project in the Netherlands, many older residents said that it was “extra difficult” to live in a new house with different functions and that they expected a gradual introduction to the new technology [5]. Coughlin *et al.* [23] investigated perceptions of smart home technologies for older people through a workshop and focus group with 30 leaders in aging advocacy and aging services and found a variety of concerns among which usability and accessibility were highlighted. According to the participants, there was a paucity of market research and insufficient attention paid to the policy environment required to support the diffusion of these technologies. A reasonable level of familiarity and comfort with the basic aspects of 21st Century

Information Communication Technology (ICT) has huge potential to help older people in addressing these challenges, particularly in rural areas where the challenge is compounded by distance, reduced access and poor or non-existent public transport. A solution to this, is to involve end users in all stages (design, implementation and testing) of smart home development [24]. When end users are actively engaged in the design and use of the technology, their technical needs and problems become more tangible and thus can be more directly addressed. It is important not to alienate older people from their own home with the introduction of technologies which could be unfamiliar, unmanageable and even unnecessary.

4.3. Psychological Accessibility

Coupled with the financial and technical hindrances associated with the widespread introduction of smart home technologies, older people also face a number of psychological barriers. In their three-year project, Cesta *et al.* [25] found that older people's acceptance of assistive home-based technology was dependant on the complex relationships between cognitive, affective and emotional components. Resistance was the result of a combination of mistrust and uncertainty, the anxiety of being controlled and fear related to loss of privacy [19]. Compared to younger generations, older people are less tolerant to the use of technology [26]. For example, smart home sensing technologies or video monitoring systems, which are referred to as "unobtrusive" [24], may be considered by older people as intrusive to their personal lives.

To make smart home technologies more acceptable to those less familiar with its benefits and turn resistance into appreciation, it is important to raise awareness, address skepticism and cultivate trust. To this end, the Queensland Smart Home Initiative (QSHI), Australia was founded in 2007 [27]. The QSHI [28] used a model that was "established to promote independent living, improved quality of life and reduced unnecessary hospital admissions for the frail elderly, chronic illness sufferers and people with disabilities". (p. 48) QSHI initiated a Smart home demonstrator to provide an experience built around a real home-like environment with a display of assistive technologies. This provided an opportunity for people to activate the technologies and gain a greater understanding and experience how they could be applied in their own lives [27].

Apart from simulated initiation and familiarization, older people's comfort and skills are only likely to develop with routine interaction and coordination. as recommended by Birnholtz and Jones-Rounds [29], service providers and caregivers should take the time and effort to work with older people to introduce such change. The acquisition of information, initial learning and ongoing support all need to occur in the context of real interactions. To move to a point where home-based technologies become extensively integrated into the day to day lives of the majority of older people—and to fully exploit the potential of innovative smart home applications for aged care and support—more is required than just a fragmented system of mentoring.

4.4. Ethics

According to The Royal Academy of Engineering [30], the important social and ethical questions related to smart homes for older people and those who experience ill health are:

- Is the cost of the autonomy afforded by smart homes social isolation?
- How can the balance between independence and companionship be struck?
- Will vulnerable people understand the nature of the technologies in smart homes, and can we be sure that they are able to consent to their use?
- Who should control the data generated by systems that monitor people's movements and track their physical wellbeing (p.7)?

These concerns indicate that technology and ethics may not always co-exist harmoniously. Whilst innovative approaches are needed to provide support both to an active ageing population as well as the more frail or vulnerable members of society [1], there are also ethical issues to be addressed to ensure that technology supports human values and reflects socio-cultural considerations. In their report on ethical dimensions related to homecare technology and aging, Kubitschke and colleagues [31] provide a detailed account of the issues which they argue become more complex by the overlapping social, medical and technological concerns. These include transparency/informed consent, proportionality/purposefulness, privacy/dignity, information management, usability/user control, and the coordination of responsibilities and actions. As older people can be more vulnerable, these ethical concerns should be addressed within a clearly-defined framework for action. For example, Berlo [5] introduces the 3-*Ps* (Perspectives, Principles, and Paradigms) approach to respond to the ethical question of consent and concerns itself with (a) older people's perspectives about the new technology; (b) principles of autonomy, beneficence, non-maleficence and justice are applied; and (c) the paradigms or contextual situations are referenced.

In contrast, Zwijsen, Niemeijer and Hertogh [32] challenge the view that "people are, or should be, independent and self-determinant". They point out that "other ethical approaches that view people as social and reciprocal might be more applicable and shed a different light on the ethical aspects." (p.419). In a multicultural society like Australia, older people come from many different backgrounds. Their views and attitudes towards aging and caring can therefore be vastly different. For example, Vietnamese older migrants appreciate collaboration and co-existence and the idea of independent living does not fit well with a culture based on collectivism. For them, smart homes can be seen as anti-social. Thus, integrating modern technologies, such as smart homes and technical medical treatments, into the human environment needs to accommodate socio-cultural considerations and mores. Essen and Conrick [33] advise that "creating new services that exploit the capability of radical technical innovations requires organizational development and the use of many non-technology innovations and resources" (p. 679). Whether it is a smart home or a traditional home, the most essential factor is that "home is a familiar place, in a familiar location where older people know others and feel in control of their lives".

5. Implications and Recommendations

The smart home can enhance the lives of older people in a modern society where digital technologies can provide much needed solutions. Smart home innovations can however, also be associated with new or compound existing problems. Based on insights from the literature and the preceding discussion the following recommendations are offered:

1. Smart homes should be introduced in planning residences for older people with careful considerations of their strengths and potential risks. Importantly, older users need to be assured that any potential problems will be assessed, risks managed and feedback valued [30].
2. Technical and psychological accessibility can be addressed by fully investigating the views and needs of older people when implementing smart homes as spaces for aging in place. Close consultations with potential users need to take place before, during and after the construction of smart homes. The needs of older users can change during this process and should be accommodated so that a smart house can become a smart home (See for example [34]).
3. Financial accessibility or affordability should be considered. There is little point in building a smart home which is beyond the reach of its potential users. Suggestions made by The Aged and Community Services of Australia [9] provide some guidance for developing policy in this area when they recommend:
 - a. Stronger and better directed funding for public and non-profit housing;
 - b. A new incentive for private investment in low rent housing;
 - c. Expansion of the capability and contribution of the non-profit housing sector;
 - d. Better provision of residential infrastructure in high growth areas (p. 11).
4. As acknowledged by technologists, “vulnerable users may not understand what the technologies they use can and cannot do—most ethical codes for computer development assume that users are knowledgeable and sophisticated in their use of computer technologies” [30], it is recommended that some aspects of informative discussions and training should include not only the users but also their immediate social networks such as family members, friends (p. 13) and service providers.
5. A high level of public engagement associated with the introduction of smart homes can help inform the community and garner support.
6. Further research is needed around the technical and psychological accessibility to smart home technology for older users, the perceptions of caregivers, because of their direct and indirect involvement in long-term care provision.

6. Conclusion

In a digitally dominant society, the concept of a “smart home” is no longer a fanciful idea. These intelligent residential spaces have been embraced and widely introduced in some (more affluent) pockets of society, though the technical complexity of such homes varies according to the needs, views and conditions of individual users. People’s lives can be greatly enhanced by these home-based assistive technologies, especially those who may be physically or cognitively challenged. This includes older persons, who should experience the benefits of positive aging, where innovative applications facilitate higher levels of security, mobility, independence and interaction. However, accessibility, ethical and other concerns should be recognised and addressed so that the potential benefits and contributions of smart home technologies may be maximized. Fundamentally, technology is neither good nor bad: it depends on how smartly it is used to serve humanity.

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