Smart Living for Elderly: Design and Human-Computer Interaction Considerations

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Abstract. To address aging challenges, we examine the concept of smart living and its applications for the elderly. Smart living refers to improving quality of life by transforming environments to become more intelligent and adaptable to users. In this paper, we discuss how smart living applications can help to address the needs of the elderly, as well as the design and human-computer interaction considerations for such applications.

Keywords: Smart living · Elderly · Design · Human-computer interaction

1 Introduction

Smart living refers to improving quality of life by transforming environments, such as home, workplace, and transportation, to become more intelligent and adaptable to users [1]. Smart living has important implications for the elderly because of the increased needs and demands in their daily lives. In this paper, we will examine cognitive problems faced by the elderly, how these problems affect their daily living activities and appropriation of technology from the design and human-computer interaction (HCI) perspective, and the role of smart living for the elderly.

Over the last century, high healthcare standards and high birth rates have contributed positively toward the world population [2]. Access to high standards of healthcare has increased the average life expectancy, giving rise to a relatively larger elderly world population. According to a report by United Nations [3], people who were 60 year old and above constituted 11.7 % of the world population, which was an increase of 2.5 % from 1990 to 2013. The percentage of elderly people in the world is expected to continue to increase [3]. Given the global aging population trend, providing daily living assistance and support to the elderly to maintain or improve their quality of life is critical.

Daily living activities of the elderly can be categorized into: (i) activities of daily living (ADL), (ii) instrumental activities of daily living (IADL), and (iii) enhanced activities of daily living (EADL) [4]. ADL are personal activities of daily living with focus on self-care tasks such as bathing, dressing, eating/cooking, transfer, and hygiene [5]. Functional

J. Zhou and G. Salvendy (Eds.): ITAP 2016, Part II, LNCS 9755, pp. 112–122, 2016.
DOI: 10.1007/978-3-319-39949-2_11

mobility and physical strength are prime requirements for ADL [4, 6]. IADL are activities that enable an individual to live independently within a community [7]. These activities involve cognitive and physical activities such as shopping, laundry, managing finances, and monitoring health related activities [8]. Active elders also carry out EADL to adapt to the ever changing environment that requires them to be willing to accept challenges and engage in learning experiences [8]. Examples of such activities are leisure activities, learning new technologies, and communicating with family and friends [8]. EADL are primarily cognitive oriented, and they contribute to quality of life [4].

Technologies facilitating smart living have the potential to address issues of the elderly by assisting them with their daily life activities [9]. Chen et al. [10] defined the pursuit of smart living technologies in terms of increasing efficiency, affordability, and sustainability in everyday lives. Devices of smart living technologies can help the elderly to achieve greater independence while enhancing safety, health, and social interaction [11]. In terms of user driven concepts, these technologies aim to palliate day-to-day activities such as mobility, communication, medication, and environmental controls [9, 12].

Performing specific activities of daily living can be difficult for the elderly, as their cognitive and physical abilities deteriorate due to the aging process. The aging process also affects their social life by limiting their social activities and interactions [13] and increases their need for a safe and secure living environment [14]. Furthermore, most elderly people prefer to live independently at their home rather than in institutional care [14], and they face various issues due to the aging process.

The next section will discuss the needs of the elderly and provide examples of smart living applications that can assist them with their needs.

2 Smart Living for Elderly

Dohr et al. [15] have identified six needs of elderly people: health, safety/security, peace of mind, independence, mobility, and social contact. In this section, we offer perspectives on how technology interventions can support the daily needs of the elderly in these areas. These needs are not mutually exclusive but are overlapping; for example, it is possible for an application to offer mobility as well as reduce dependency on others.

2.1 Health

The aging population has posed a challenge to the healthcare industry in providing better care aiding facilities to the elderly at a viable cost that could fit their budget [16]. One way to address this challenge is to develop applications of ubiquitous healthcare solutions by creating an intelligent environment in the homes of the elderly [16]. Such ideas and applications have been termed a smart home, which refers to a living environment that is well equipped with technology to complement its occupants by predicting their activities and responding accordingly [17]. There are benefits of offering telemedicine services to elderly people in their homes, where the elderly can consult remote doctors

through such services [18]. The concept of HomeADL (i.e., home activities of daily living) highlights the application of adaptive monitoring of ADL within smart homes based on the confluence of sensor technologies and wearable devices [19]. Under the umbrella of smart health, sensor embedded fitness trackers (e.g., Fitbit One, Vivo), and smartphone apps that monitor and maintain a log of daily activities such as walking, jogging, and sitting are also gaining popularity [20].

Le et al. [21] noted six categories of health-related smart home technologies identified by Demiris and Hensel [22]: (i) physiological monitoring (e.g., measurements of blood pressure, respiration, and pulse rates); (ii) functional monitoring (e.g., measurements of various daily activities and meal intakes); (iii) safety monitoring and assistance (e.g., automatic lighting, accident prevention, hazard detection and warnings, and personal alarms); (iv) security monitoring (e.g., identification of intruders versus familiar people in one's social network); (v) social interaction monitoring and assistance (e.g., phone and conference calls); (vi) cognitive/sensory assistance (e.g., medication reminders).

2.2 Safety/Security

Availability, accessibility, and affordability of in-home monitoring technologies have provided friends, family members, and caregivers with the convenience of tracking the activities of older people [23]. Monitoring of ADL of the elderly is also important to measure safety conditions of the elderly [24]. Smart homes are equipped with devices that allow monitoring of the elderly people and communication of real-time data/information to the stakeholders [25]. The combination of smart homes and in-home monitoring applications can not only provide the elderly with greater control of their home environment but also enhance the elderly's safety and security of being cared for [12, 23]. Besides safety, interrelated functionalities of in-home monitoring systems cover health care needs, security, and social connectedness [23]. Applications of smart technologies, such as motion and position detection, sensor based wearable systems, and automated monitoring, offer safety precautions to the elderly while performing their daily activities [26, 27].

2.3 Peace of Mind

Advancements of technology have allowed family, friends, and caregivers to take care of the elderly who live at a distance by facilitating face-to-face interaction, which in turn gives them peace of mind [23]. Mynatt et al. [28] have identified the following prime contributing factors to peace of mind: health related information, environment inside the house, social interaction, physical activity, and planned as well as unplanned events. Monitoring of these activities, events, and information, and alerting stakeholders to any deviations from expectations can contribute to peace of mind.

2.4 Independence and Mobility

One of the best ways to support the elderly is by maintaining and maximizing their independence with the support of applications related to the social, personal, and health dimensions [29]. Applications of smart living that support physical and cognitive issues related to the elderly and allow them to live independently include assistive robotics such as the Wheelchair Mounted Robotic Arm, feeding robots, and robotic workstations [30], as well as handheld computers such as smartphones [31] and wearable devices such as ECG monitoring systems [32]. Likewise, assistive technology (e.g., voice/activation commands), telemedicine applications that connect the elderly to their caregivers via television and the Internet, and medication adherence applications (e.g., a reminder system for medication) assist the elderly in performing ADL and IADL without compromising their independence [11].

Smart wheelchairs and smart walkers, along with navigation systems, are helpful to the elderly suffering from visual impairment and mobility restrictions [12]. For those who are not able to operate conventional powered wheelchairs, the smart wheelchair is a feasible alternative [33]. Smart wheelchairs can be equipped with sensors, software, and hardware which could be fitted aesthetically to avoid unnecessary attention [33]. Manipulation aids offered by the Wheelchair Mounted Robotic Arm can provide independence to the elderly in performing ADL such as moving objects, eating, drinking, and controlling devices in the environment [12].

2.5 Social Contact

Smart homes are typically equipped with communication technologies that allow the elderly to stay in touch with family and friends [12]. Communication applications and technologies, such as Skype and telepresence, also play a key role in this regard. The need for sociability and accessibility goes hand in hand in enabling the elderly to utilize technologies for social networking. Advanced technologies such as the 3D virtual worlds and Microsoft HoloLens also show promise in creating more options and flexibility for extending the elderly's social networks. Availability of elderly friendly communication devices, such as cell phones, video phones, e-mail, and the Web, has helped to reduce the virtual distance between the elderly and their friends/family as these applications facilitate daily audio and video communications [11]. Active social interaction offers positive fulfillment of EADL for the elderly.

3 Design and HCI Challenges of Smart Living for Elderly

Technology is ubiquitous and can help to overcome motor and cognitive barriers [34]. Elderly people face more challenges in utilizing technology, and hence, it is important to design and develop usable and accessible interfaces for them [35]. We discuss key considerations in interface design, adaptive design, complexity, affect, aesthetics, and privacy.

The elderly's cognitive and sensory capabilities, as well as motor skills, decline over time due to the aging process which affects their sensitivity toward defective design and

their need for elderly friendly interfaces [31]. There are unique challenges in designing for the elderly. Elderly users are less able to block out distractions or irrelevant stimuli on the interface [36] and they tend to focus their attention on the center of the interface due to their reduced width of visual field [37]. They need bigger text on their screen, greater spacing between keys and buttons/icons, more color contrast, loud ringtones, prolonged backlight, and strong feedback (i.e., low frequency if it is an audio feedback) [37]. Kurniawan and Zaphiris [38] provided a list of research-derived web design guidelines for the elderly and it covers 11 categories ranging from navigation and use of graphics to use of color/background and text design. These guidelines include avoiding a deep menu structure, providing a site map, avoiding moving text, providing the location of the current page, avoiding scroll bars, and maintaining consistency in screen layout.

Although smart technologies have been in use by the elderly, their full potential has not been realized [10]. The lack of adaptable design for people with impairments is one of the reasons that has prohibited them from adopting wireless devices in their daily life [39, 40]. Research and development efforts in mobility-based smart devices for the elderly are striving to deliver a localized, context-dependent, and user adaptable design that will suit every user given their characteristics and conditions [33]. Adaptive design is an important aspect of smart living applications.

There are challenges in using restricted screen space of mobile devices for enhanced data access, particularly for elderly people. Moreover, the increased diversity of functions on these gadgets are creating huge psychological burdens for the elderly. Interfaces of systems and applications that are designed for the elderly should be simple, clear, consistent and straight-forward. In order to exploit the capability of mobile and wireless innovations, research needs to consider the effect of visual density and cognitive capacity of the users to avoid confusion and information overload [41]. Managing complexity is an important aspect of design for the elderly.

Design of technology should consider the emotional or affective aspects in terms of feel, value, sensitivity, and appeal [13]. Smart technologies allow the elderly to be self-reliant and can enhance their self-efficacy and confidence to live on their own with personal freedom and individuality [42]. However, the utilization of assistive technologies may intimidate individuality of the users because of concerns associated with how others might view them and their associations with others. Perceived disgrace and awkwardness might discourage elderly people from utilizing certain assistive technology systems [43].

Though numerous systems could be helpful to the elderly, acceptance might be hindered if they look awkward or unpleasant despite the benefits that can be gained from them [42]. If a wheelchair resembles a tank, we cannot expect the elderly to accept it with enthusiasm despite the fact that it could be helpful to them [44]. Sometimes, even wearable devices are not acceptable to the elderly due to their appearance [42]. Elderly people like to use assistive systems that not only provide support for practical necessities, but are also aesthetically pleasing [42]. Hence, aesthetic is an important design consideration for the elderly.

The safeguarding of users' identities, personal information, and information about their daily activities is another important design consideration in autonomous living.

A trade-off between privacy risk and utility needs to be made, and the users should be able to determine the desired trade-offs. Based on privacy calculus theory [45], users are expected to be willing to give up some degree of privacy (e.g., personal information) for the benefits received (e.g., personalization of services). In order to safeguard the privacy of the elderly (some of whom might be living alone), the Privacy by Design (PbD) approach is recommended in order to embed privacy preferences into the design of technologies and business practices for the elderly [46].

4 Future of Smart Living for Elderly

Frisardi and Imbimbo [47] described a smart home as a living arrangement outfitted with technology that enables the occupants to enhance their living standard, increase their physical freedom, and reduce their dependence on caregivers. Demiris [48] characterized smart home innovation as an evolving multidisciplinary arena that expands on the utilization of innovation to bolster aging. Le et al. [21] have examined innovative ways to design a smart home to augment the autonomy, security, and personal satisfaction of elderly people. According to them, smart homes should have the following five basic features: automation, multi-functionality, adaptability, interactivity, and efficiency [21]. Automation can help to overcome cognitive limitations and assist with motor limitations of the elderly. Multi-functionality of the smart homes can help with various aspects of their daily living activities. Adaptability, or the ability to adjust to the needs of the user, is essential for meeting the diverse needs of the elderly. Interactivity refers to the ability to communicate or interact with smart devices and other users, and efficiency refers to the ability to deliver convenient services or help users to save time or money.

Artificial intelligence (AI) can be used to augment the living standard of elderly people [44]. For example, a remote robot such as Sony Qrio can perceive people by their countenances and discourse, interact with them, and recollect particular people and past discussions. Qrio has a lot to offer in terms of emotional and practical necessities [44]. Such autonomous remote robots can be utilized to enhance the living standards of the elderly by contributing towards EADL. Other AI techniques such as neural networks can be used to learn or recognize the behaviors of the elderly and identify any abnormalities that may need attention.

As robots become more economical, adaptable and common, they can be used to accomplish a variety of tasks. Robots may soon be a regular face all over the globe. For example, telepresence robots [49] can offer mobility to the elderly, whereas Care-O-bot [50] can be an assistant to the elderly for accomplishing daily activities. The mobility of the elderly can be extended through the use of smart wheelchairs [42] such as those that can self navigate and avoid obstacles [51]. Toyota introduced a concept vehicle 'i-unit' that might help in enhancing the mobility of elderly people. The vehicle is very compact and is incorporated with an intelligent technology for avoiding mishaps [52]. If a voice-enabled intelligent navigation device is integrated into the vehicle, it can offer further extensions to the vehicle's capabilities in transporting elderly people to destinations of their choice. Robotic solutions, however, are still in development and much research is still needed to understand their effectiveness for the elderly, especially with

regard to their social and unintended consequences. Usability and user acceptance are important for success. Various evaluation studies questioned the efficiency, effectiveness, user satisfaction, and level of autonomy of these robots, and the results are not satisfactory, which is a clear indication that there is a lot of scope for improvement.

An important aspect of smart living is Internet of Things (IoT), where objects interact with one another through the networks that interconnect them to provide adaptable and intelligent applications to users. Three important concepts related to IoT are: Ubiquitous Communications, Pervasive Computing, and Ambient Intelligence. Ubiquitous Communications refer to the interaction among the objects whereas Pervasive Computing refers to incorporating these objects with processing power. Ambient Intelligence is the capability of these objects to recognize and record the physical changes around them. Integration of these concepts leads to dynamic networks termed IoT [15].

Based on IoT, Ambience Assisted Living (AAL) refers to "technical systems that support elderly people and people with special needs in their daily routine" [15, p. 805]. The goal of AAL is to offer autonomy to the elderly and increase the safety of their lifestyle and environments. AAL can be helpful in fulfilling the needs of the elderly from the perspective of health, safety/security, peace of mind, independence, mobility and social contact.

IoT can incorporate various technologies such as sensors, robotics, and brain-computer interaction (BCI). Recent advances in sensor technologies give rise to the emergence of the smart home concept. Sensor technologies are used for mobility assistance and disease prevention, and they can be deployed to reduce manual labor and potentially eliminate the problem of social isolation that elderly face [53]. These sensor technologies, integrated with monitoring technologies, are useful for detecting the daily activities of elderly people in their homes. Five types of monitoring technologies have been identified [54]: Passive infrared motion sensors, body worn sensors, pressure sensors, video monitoring, and sound recognition. A combination of these technologies can be used in smart homes to monitor the activities of the elderly.

BCI is a new communication method that replaces existing augmentative and alternative communication methods. It involves analyzing physiological data with considerable accuracy. Invasive techniques are more efficient than non-invasive techniques, but they may not be the right option for the elderly unless the problem is severe. Electroencephalography (EEG) is one of the non-invasive techniques to collect data and it includes processes such as signal acquisition, signal preprocessing, signal classification, and computer interaction. BCI technologies are being used immensely in medicine, especially for people with disabilities. They can provide users with basic communication capabilities such as express wishes to caregivers, operate devices, and manipulate objects independently. In a smart home context, BCI can be implemented by arranging alphabets and/or numbers in a matrix form where users can then be asked to concentrate on a specific character in order to perform a specific task. The associations between characters and tasks can be coded and integrated with robotic technologies to accomplish specific tasks. However, elderly people may require extensive training to operate these technologies successfully.

5 Conclusions

Technology facilitating smart living applications should be marketed and distributed through appropriate channels such as health magazines, video display/demonstrations in hospitals or elder care, or recommendations by doctors. Appropriate distribution channels such as home delivery, e-commerce websites, or dedicated areas in frequently visited stores like Costco and Walmart can be used to reach targeted audiences such as the elderly and their family and friends. Moreover, a smart living application should be affordable and sensitive toward economic conditions of the elderly. Subsidized rate or insurance policy coverage for a wide range of smart living applications may motivate the older generation to adopt these products to support their day to day activities.

The aforementioned criteria are easier to achieve through policy intervention and strategies; however, adaptable smart living applications for the elderly are still at a very nascent stage. A standard design may not suit the requirements of all elderly alike. In dearth of literature, we would recommend relevant institutes to pursue research projects to develop prototypes of smart living applications tailored to the elderly needs and requirements. The prototype should be flexible and be subjected to improvisations and adjustments based on the geographical area, localized needs, cultural dimensions, and privacy protocols.

A smart living application should be able to sense its environment and respond effectively. It should be aesthetically pleasing and utilize modern technologies to offer the best value to its users. Elderly users should feel the betterment in quality of life and ease of performing daily activities by utilizing or interacting with the smart application. In conclusion, a smart living application for the elderly should be **(S)**ensible, **(M)**odern, **(A)**daptable, **(R)**esponsive, and **(T)**angible in delivering value to the elderly users through careful design and HCI considerations.

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