CHAPTER 9

# Ethical Considerations Regarding the Use of Smart Home Technologies for Older Adults

## *An Integrative Review*

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**ABSTRACT**

Problem: With the wide adoption and use of smart home applications, there is a need for examining ethical issues regarding smart home use at the intersection of aging, technology, and home environment. Purpose: The purpose of this review is to provide an overview of ethical considerations and the evidence on these ethical issues based on an integrative literature review with regard to the utilization of smart home technologies by older adults and their family members. Review Design and Methods: We conducted an integrative literature review of the scientific literature from indexed databases (e.g., MEDLINE, CINAHL, and PsycINFO). The framework guiding this review is derived from previous work on ethical considerations related to telehealth use for older adults and smart homes for palliative care. Key ethical issues of the framework include privacy, informed consent, autonomy, obtrusiveness, equal access, reduction in human touch, and usability. Results: Six hundred and thirty-five candidate articles were identified between the years 1990 and


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2014. Sixteen articles were included in the review. Privacy and obtrusiveness issues appear to be the most important factors that can affect smart home technology adoption. In addition, this article recommends that stigmatization and reliability and maintenance of the system are additional factors to consider. Implications: When smart home technology is used appropriately, it has the potential to improve quality of life and maintain safety among older adults, ultimately supporting the desire of older adults for aging in place. The ability to respond to potential ethical concerns will be critical to the future development and application of smart home technologies that aim to enhance safety and independence.

## INTRODUCTION

There is a rapid growth in the number of older adults worldwide. According to projections by the U.S. Census Bureau (2014), the population of adults age 65 years and older will account for 15% in 2015 and is expected to reach about 24% by 2060 due to longer life spans and the aging baby boom generation. This situation presents many challenges for our health-care system due to conditions that come with aging, such as chronic diseases, sensory and cognitive impairments, physical disabilities, and isolation. These health challenges then place substantial social, psychological, and financial burden on older adults, their family caregivers, and society. As a result, there is increased need for high-quality, efficient, and accessible care. Especially critical are community-based solutions, as older adults have a desire to remain independent in their homes or in the community setting (Rantz et al., 2010; Rantz et al., 2013; Vasunilashorn, Steinman, Liebig, & Pynoos, 2012; Wild, Boise, Lundell, & Foucek, 2008). The use of technology applications in the home setting can be one of these solutions; yet there are ethical issues to be considered regarding their use. This article discusses ethical considerations and dilemmas arising from smart home implementations to support older adults and their family caregivers at home. Also we provide an integrative review of the literature on ethical issues regarding smart home technologies by analyzing and synthesizing the current state of smart home technology ethics. An ethical framework derived from the previous literature guides the review.

## BACKGROUND

The emergence of novel home-based sensor technologies has introduced a new way of providing care for older adults and assistance to their family caregivers. Personal living spaces of older adults with embedded sensor technologies

to promote independence and wellness are termed *smart homes* (Reeder, Meyer, et al., 2013). Smart home technologies are designed to support older adults or people with disabilities by monitoring their health and facilitating prevention of undesirable events. These technologies may allow for functional independence by assisting the elderly population to cope with various health issues such as falls, mobility limitations, cognitive impairment, or social isolation (Berke, Choudhury, Ali, & Rabbi, 2011; Scanaill, Garattini, Greene, & McGrath, 2011). Also, smart home applications have the potential to enable real-time, accessible, and minimally intrusive ways of monitoring health and delivering care to individuals who are in need.

There are two distinct smart home approaches, *distributed direct sensing* (DDS) and *infrastructure-mediated sensing* (IMS; Demiris, 2009). DDS refers to infrastructure with a new sensing network physically installed in the home to sense motion, presence, or other behavioral indicators. On the other hand, IMS indicates existing sensor-based residences through electrical or air conditioning systems with the aim of monitoring activities of the individual. There are various types of smart home applications, including, but not limited to, (a) activity monitoring system employing wireless motion sensors, refrigerator door sensor, toilet flush sensor, water consumption sensor, bed sensor, or pressure mats, (b) video monitoring system, or (c) home-based sensors for enhancing safety such as smoke detector, temperature sensor, door security system, and so forth (Alwan, 2009; Bruce, 2012; Kang et al., 2010). A smart home is viewed as a holistic and centrally controlled environment that enables interpretation of resident health needs and proactively responds to changes in health (Johnson, Davenport, Mann, & Otr, 2007). Passive monitoring features of smart homes do not require older adults to operate the device or use a computer. Therefore, these can benefit various populations of older adults with limited technological knowledge or those with cognitive impairment, while avoiding problems caused by incorrect or nonuse of a system (Alwan, 2009; Mahoney, 2011). Smart home applications were found to be useful for individuals with chronic conditions because the systems can be further applied to examination, diagnosis, and consultation of the person being monitored (Chan, Estève, Escriba, & Campo, 2008). However, the monitoring function depends on complex algorithms to interpret the data generated by the sensors.

Multiple forms of smart home applications are being developed and applied in the health-care sector to support aging in place (Figure 9.1). The pervasive use of smart home technologies requires thoughtful considerations on the complexity of ethical issues. Although smart homes have positively impacted patients, family caregivers, and health-care providers, there is a potential for harm and abuse that may result from privacy invasion, the breach of confidentiality, loss of

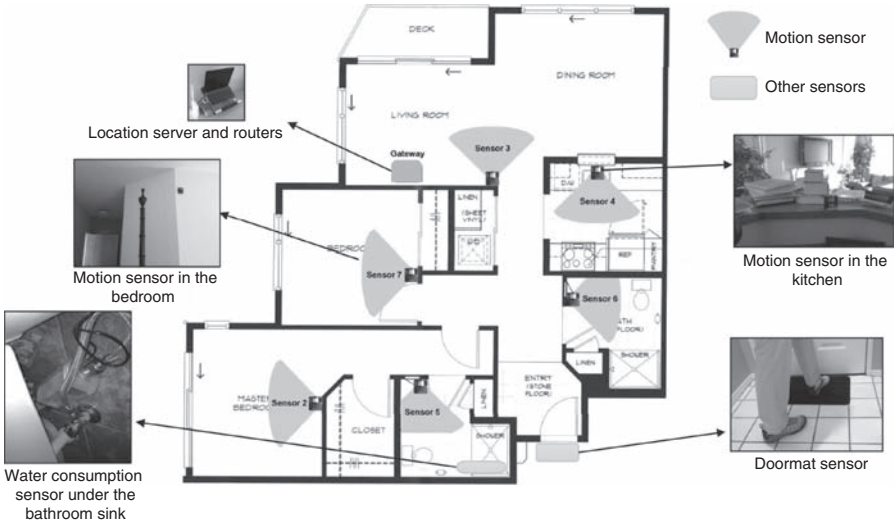


**FIGURE 9.1** A sample floor plan and its sensor network. The simulated smart home system in this diagram consists of various types of home-based wireless sensors and a location server. These sensors are designed to monitor different types of activities such as movement from one location to another, water use, stepping out of the house, and so forth. Each sensor sends the signal to the local server, and the server sends the data to a central server so that engineers or data personnel download and analyze the data. Please note that there are different types of smart home applications and system architectures.

touch, or dehumanization. Also, ethical considerations arising for older adults may not be the same as ethical concerns for other age groups. They may have difficulty in technical understanding of the information they receive due to lack of technology experience or instruction as well as age-related capabilities. In order to ensure the optimal use of smart home applications, it is necessary to adequately address the ethical issues at the intersection of aging, technology, and home environment when considering the adoption of smart homes for supporting aging in place (Lorenzen-Huber, Boutain, Camp, Shankar, & Connelly, 2011). Addressing these issues can guide better design and help predict successful implementation of the technology.

## METHODS

Whittemore and Knafl's methodology (2005) was used to guide the current review. Two researchers (JC & GD) discussed which ethical categories should be included for this review based on the previous studies on telehealth

and smart home ethics. This integrative review includes qualitative, quantitative, and mixed methods studies and uses studies published in English between 1990 and August 2014. Computerized database searches were conducted by the first author (JC) using PubMed, CINAHL, and PsycINFO. Search terms included "smart home," "sensor," "sensor technology," "home-based health monitoring," "home-based health technology," "gerontechnology," and "gerotechnology" combined with "older adults," "elderly," and "community-dwelling."

Inclusion and exclusion criteria were developed by two authors (JC & GD). We did not exclude any studies based on study design or methodology because we wanted to cover all studies that examined ethical issues with actual or potential end users of smart home technologies. Titles and abstracts were reviewed by the first author (JC) and included if they met the following criteria: (a) The study examined ethical concerns of older adults or caregivers with regard to the utilization of smart homes using either a survey or an interview, (b) the study focused on home-based technologies to support older adults in residential settings with an aim of either monitoring activities or preventing adverse health outcomes, (c) the study sample included older adults or their informal or formal caregivers, and (d) the study was a quantitative or qualitative analysis of data. Studies were excluded if they focused on remote monitoring of health among older adults with a specific disease (e.g., diabetes). In total, 635 articles were returned from database searches and reference list reviews. During the full-text article review, another researcher (HT) independently reviewed three randomly selected articles from the downloaded full-text results and applied the inclusion and exclusion criteria for testing interrater reliability. The two researchers (JC & HT) discussed differences until agreement was reached about application of the inclusion and exclusion criteria. Initial agreement before reconciliation was 67%, and agreement after reconciliation was 100%. Figure 9.2 shows literature identification and screening processes, indicating that from the initial 635 publications, finally, 16 articles were selected for this review.

## ETHICAL FRAMEWORK GUIDING THE REVIEW

In order to successfully implement smart sensor projects for older adults, an ethical framework is important to guide the design, development, and evaluation of smart home technologies. Such a framework better informs the application of smart home technologies and delivery of care through those technologies. The framework for ethical dimensions in this review is based on previous

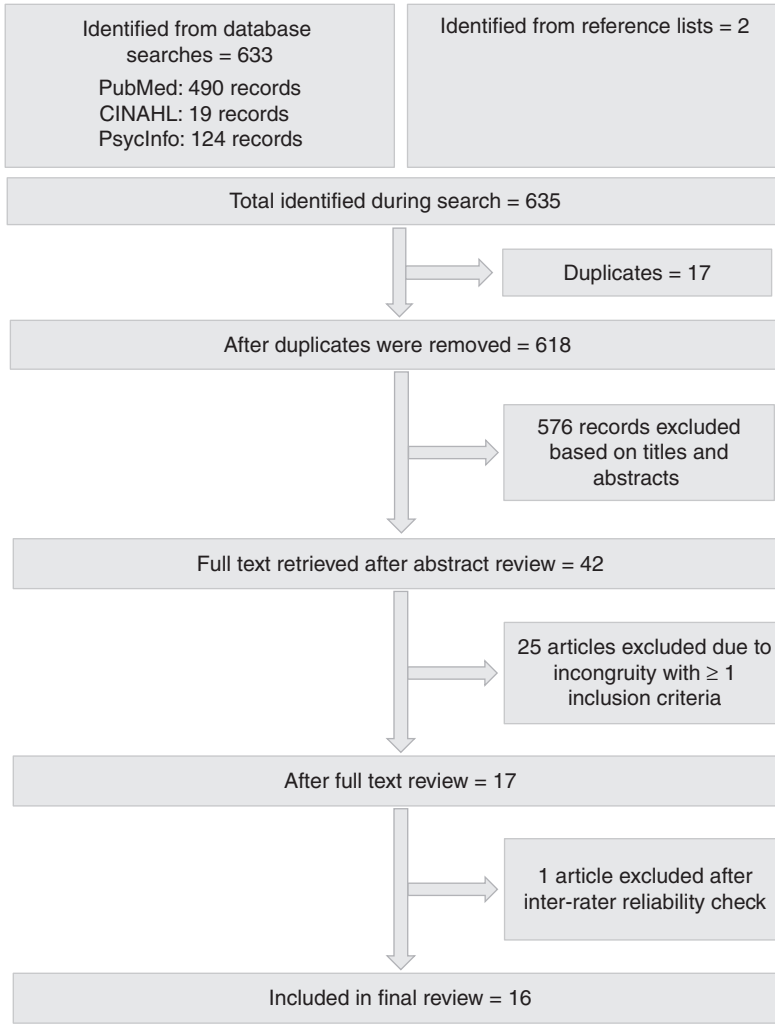


**FIGURE 9.2** Flow chart of selection process with search results.

work on ethical considerations in the use of telehealth technologies for older adults (Demiris, Doorenbos, & Towle, 2009) and smart homes for palliative care (Demiris & Hensel, 2009). Key ethical factors that form the framework in this chapter include privacy, informed consent, autonomy, obtrusiveness, equal access, reduction in human contact, and usability (Table 9.1).

**TABLE 9.1**

*Categories of an Ethical Framework for the Use of Smart Home Technologies and Their Theoretical and Operational Definitions*

| Category | Theoretical Definition | Operational Definition |
|---|---|---|
| Privacy | The control and management of personal space around one's body (physical), cognitive and affective processes related to formation of values, personal identity, self-esteem, or agency (psychological), social contacts (social), and personal information use and dissemination (informational) (Hughes, 2004) | In the context of smart homes, the concept of privacy is discussed primarily in terms of *informational privacy* that refers to an individual's right to control the access to personal data (Demiris, Oliver, & Courtney, 2006). On the other hand, *confidentiality* is an act of respecting an individual's right to make a decision with regard to sharing information with others (Fleming, Edison, & Pak, 2009). |
| Informed consent | An individual's agreement to give permission for a medical procedure or participation in a clinical intervention or research (Demiris & Hensel, 2009) | A formal statement that describes the purposes of the research, procedures to be followed, and all potential benefits and risks related to the in-home use of technologies. Informed consent could be used in a way that assists an individual to comprehend and evaluate information to make an informed choice about what information will be disseminated or kept private (Bruce, 2012). |
| Autonomy | The capacity of an individual to make a choice without coercion or external influence (Le, Di Mascolo, Gouin, & Noury, 2007; Mallers, Claver, & Lares, 2014) | A sense of empowerment and independence obtained by becoming involved in the health-care plan based on the automation of the technology (Demiris et al., 2006) |

(*Continued*)

**TABLE 9.1**

*Categories of an Ethical Framework for the Use of Smart Home Technologies and Their Theoretical and Operational Definitions (Continued)*

| Category | Theoretical Definition | Operational Definition |
|---|---|---|
| Obtrusiveness | The characteristic of being prominent or noticeable in an unpleasant way (Hensel, Demiris, & Courtney, 2006) | A user's evaluation based on features of the technology that are perceived as physically and psychologically noticeable (Hensel et al., 2006) |
| Equity of access | Equal and fair access to information and necessary resources (Fleming et al., 2009) | Universal access to necessary health information and means for monitoring of health and safety (Demiris et al., 2006) |
| Reduction in human contact | Deprivation of the chance to have therapeutic human touch (Demiris et al., 2009) | An individual's dependence on virtual visits or remote monitoring without meaningful interaction between an individual and health-care provider (Chan et al., 2008) |
| Usability | An attribute of products or systems that is assessed by the degree of ease and usefulness (Nielsen, 2012) | The extent to which the technology is used by specified users to perform tasks in a defined environment (Yen & Bakken, 2012) |

## RESULTS

### Study Characteristics

Among the 16 articles included in this review, 8 were part of a technology trial where participants were involved in smart home projects while 8 studies were conducted to form evidence related to ethical issue identification (Table 9.2). Typically, an interview approach to data collection was used ($n$ = 15) to explore attitudes and perceptions concerning the ethical use of smart home applications among older adults or stakeholders (caregivers, service managers, or policy advocates). The number of study participants ranged from 7 to 119. Types of smart home technologies included for field test or inquiry were various sensors (motion, bed, stove, door, etc.). The majority of the studies were conducted in the United States ($n$ = 14), while one study was performed in the Netherlands (Nijhof, van Gemert-Pijnen, Woolrych, & Sixsmith, 2013) and another in Canada (Mihailidis, Cockburn, Longley, & Boger, 2008).

### Ethical Issues Addressed in the Reviewed Studies

We discuss ethical considerations according to the framework and then provide the evidence for each ethical issue from the selected studies on the use of smart home technologies.

#### Privacy

Technological advances in the health-care sector have brought a widespread concern about the privacy of the health information of patients. Especially, with the implementation and evaluation of smart home technologies, the right to privacy is recognized as a core issue that should be discussed in order to appropriately perform gerontechnology research and practice. The violation of privacy can be manifested in two ways: sharing one's information without permission and obtaining personal information against one's will (Leino-Kilpi et al., 2001). Smart home applications are designed to collect information about resident health in the *home* setting to enhance functional health, quality of life, security, and safety. However, information about the home environment may also be accessible, so technologies installed at home can be a challenge to the perception of privacy in many ways.

There should be a precaution to ensure that personal data recorded through home monitoring sensors are protected in every step, for instance, gathering, storage, and retrieval of files, tapes, or images on behavioral or physiological data (Demiris, Oliver et al., 2006; Mahoney et al., 2007). There are other possible sources of privacy violations with regard to electronic transmission of information such as communication over phone lines, satellite, or wireless Internet. Confidentiality often cannot be ensured with the presence of technical staff who

**TABLE 9.2**
*Description of All Identified Studies*

| Author (Year) | Study Design | Technologies | Participants | Purpose of the Study |
|---|---|---|---|---|
| Boise et al. (2013) | Descriptive study, technology trial | Motion sensor, door sensor, and refrigerator sensor | 119 older adults | Evaluated participant willingness to share sensor data with others and privacy or security concerns of monitoring technology implemented over 1 year in community settings |
| Chung et al. (2014) | Descriptive study, technology trial | Motion sensor–based monitoring technology | 7 older adults | Explored older adults' perceptions of informed decision making regarding sensors installed in their homes |
| Coughlin, D'Ambrosio, Reimer, and Pratt (2007) | Descriptive study | Smart home technologies | 30 aging services leaders and policy advocates | Assessed participant perceptions of smart home technology to better inform the design of the technology |
| Courtney (2008) | Descriptive study | Bed sensor, motion sensor, kitchen sensor, and fall detection sensor | 14 older adults | Explored factors affecting the decision to adopt a smart home technology among community-dwelling older adults |
| Courtney Demiris, Rantz, and Skubic (2008) | Descriptive study | Smart home technologies | 14 older adults | Assessed older adults' willingness to accept smart home technology |

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|---|---|---|---|---|
| Demiris et al. (2004) | Descriptive study, technology trial | Smart home technologies | 15 older adults | Evaluated participant perceptions of smart home technologies installed in a retirement community for older adults |
| Demiris, Hensel, Skubic, and Rantz (2008) | Descriptive study, technology trial | Motion sensor, bed sensor, gait monitor, stove temperature sensor, and video sensor | 14 older adults | Evaluated smart home residents' perceptions of in-home sensors from an ongoing longitudinal study |
| Demiris, Oliver, Dickey, Skubic, and Rantz (2008) | Descriptive study, technology trial | Motion sensor, sensor mat, stove temperature sensor, door sensor, gait monitor, and bed sensor | 9 older adults | Assessed participants' perceptions of smart home applications installed in their homes |
| Demiris (2009) | Descriptive study | Two smart home approaches (distributed direct sensing vs. infrastructure-mediated sensing) | 20 older adults and 14 informal caregivers | Assessed older adults' and caregivers' acceptance of two smart home approaches |
| Johnson et al. (2007) | Descriptive study | Tracking system, remote monitoring, voice activation, smart wave, smart mailbox, smart front door, cueing system to remind washing hands, and security system | 18 older adults | Assessed older adult perceptions of smart home applications among participants who received demonstration of a lab-based single-family smart home |

(*Continued*)

**TABLE 9.2**
*Description of All Identified Studies (Continued)*

| Author (Year) | Study Design | Technologies | Participants | Purpose of the Study |
|---|---|---|---|---|
| Mihailidis et al. (2008) | Descriptive study | Home-based monitoring technologies | 15 baby boomers and 15 older adults | Evaluated participant willingness to accept home monitoring technologies |
| Nijhof et al. (2013) | Descriptive study, technology trial, feasibility testing | ADLife comprising a gateway and sensors | 14 older adults with dementia and 14 caregivers (formal/informal) | Evaluated the feasibility of home-based sensor system for activity monitoring over 9 months |
| Reder, Ambler, Philipose, and Hedrick (2010) | Descriptive study, technology trial, feasibility testing | Wireless shake sensors | 12 older adults, 12 family and/or paid caregivers, and 2 service managers | Pilot study implemented over 1 year to test sensor technology for remote monitoring of activities |
| Reeder, Meyer, et al. (2013) | Descriptive study, technology trial, feasibility testing | Motion sensors for monitoring mobility | 8 older adults | Evaluated participant perceptions of home-based sensor technology installed for 6 months in a retirement community |

| | | | | |
|---|---|---|---|---|
| Steggell, Hooker, Bowman, Choun, and Kim (2010) | Descriptive study | Video communication device, emergency-monitoring device, sleep monitor, and medication reminder/dispenser | 32 older women | Investigated perceptions of Korean and Hispanic older women living in the United States regarding monitoring technology designed to promote aging in place |
| Wild et al. (2008) | Descriptive study | Home monitoring technologies | 23 older adults and 16 family members/friends | Explored attitudes and concerns of older adults and their family members or friends regarding unobtrusive home monitoring technologies |

provide assistance in transmitting data from one site to another and maintaining Web portals containing individual health information (Demiris et al., 2006). It is necessary to ensure safe and secure communication to safeguard access to data obtained from home monitoring technologies. To do so, encryption or security systems must be in place for transmitting messages or identifiable patient information especially through the Internet (Chan et al., 2008; Fleming et al., 2009).

*Review Results.* Based on the review, it became apparent that privacy is the most critical factor affecting older adults' willingness to participate in smart home projects. Twelve out of 16 studies address the issues of privacy and confidentiality (Table 9.3). This is the case for smart home residents as well as individuals who have not been exposed to smart home applications. For example, older adults were concerned about potential judgment of their activity patterns through sensor data, or they simply did not want others to know when specific activities were done, such as toilet use (Demiris et al., 2008; Reeder, Chung, Lazar, Demiris, & Thompson, 2013). Also the perception of privacy invasion was related to the extent of detailed data the technology collects, for example, motion detection as compared to sound or image capturing. However, as long as technology meets the needs of older adults for maintaining independence in their homes, privacy issue is no longer an important concern for older adults (Courtney et al., 2008; Steggell et al., 2010; Wild et al., 2008).

**Informed Consent**

Informed consent is an important tool for protecting the autonomy, dignity, and well-being of older adults (Fleming et al., 2009). Informed consent emphasizes three bioethics principles: (a) nonmaleficence (prohibition of doing harm to an individual), (b) beneficence (an act of doing good), and (c) autonomy (a person's own right of making a decision) (Beauchamp & Childress, 2012). Despite potential benefits of smart home technologies, it is often difficult for older adults to make a decision about accepting or refusing smart home technologies, especially if they do not have sufficient information (Bruce, 2012). If an older adult faces cognitive decline related to dementia or other neurodegenerative diseases, this individual's ability to comprehend and evaluate information and to make a reasonable choice may be compromised.

Effective clinical interactions rely largely upon respect and trust in a patient–provider relationship. The provider's respect for patient rights can be manifested through informed consent. The use of consent allows an opportunity through which older adults can make an informed decision whether or not to participate in a technology trial. In the context of smart home technologies, informed consent needs to be pursued during the process of technology interventions, because clinical interactions are presented continuously through

**TABLE 9.3**
*Ethical Issues Identified in the Reviewed Studies*

| Author (Year) | Method for Addressing Ethical Issues | Ethical Framework | | | | | | | Other Ethical Issues |
|---|---|---|---|---|---|---|---|---|---|
| | | Privacy | Informed Consent | Autonomy | Obtrusiveness | Equal Access | Reduction in Human Contact | Usability | |
| Boise et al. (2013) | Survey | X | | X | | | | | Security risks |
| Chung et al. (2014) | Semistructured individual interviews | X | X | | X | | | | |
| Coughlin et al. (2007) | Focus group interviews | X | | | | X | | X | Reliability of technology |
| Courtney (2008) | Focus group and individual interviews | X | | X | | | | | |
| Courtney et al. (2008) | Focus group and individual interviews | X | | | | | | | |
| Demiris et al. (2004) | Focus group interviews | X | | | X | X | | X | |

(*Continued*)

**TABLE 9.3**
*Ethical Issues Identified in the Reviewed Studies (Continued)*

| Author (Year) | Method for Addressing Ethical Issues | Ethical Framework | | | | | | | Other Ethical Issues |
|---|---|---|---|---|---|---|---|---|---|
| | | Privacy | Informed Consent | Autonomy | Obtrusiveness | Equal Access | Reduction in Human Contact | Usability | |
| Demiris, Hensel et al. (2008) | Focus group interviews | X | | X | | | | | Stigmatization, reliability of technology |
| Demiris, Oliver, et al. (2008) | Individual interviews | | | | X | | | | |
| Demiris (2009) | Individual interviews | X | | X | X | | | | Stigmatization |
| Johnson et al. (2007) | Focus group interviews | | | X | | X | | | |
| Mihailidis et al. (2008) | Survey and interviews | X | | | | | X | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nijhof et al. (2013) | Semistructured individual interview | | | | X | | | | X | Reliability and accuracy of technology |
| Reder et al. (2010) | Individual interviews | | | X | | X | X | | | Reliability of technology |
| Reeder, Chung, et al. (2013) | Semistructured individual interviews | X | X | X | | | | | | Data security |
| Steggell et al. (2010) | Focus group interviews | X | | X | | X | | | X | Maintenance of the system |
| Wild et al. (2008) | Focus group interviews | X | | X | | | | | | |

ongoing monitoring or communications via technology applications (Demiris et al., 2009; Fleming et al., 2009). Also, consenting as a procedural tool provides older adults with an opportunity to discuss their preferences, lifestyles, and any changes in health status.

Some people may argue that there is not a significant difference in ethical considerations regarding the use of technologies between older and younger adults. However, because many older adults are not familiar with the mechanism of information gathering and sharing through technologies and may have a lack of technical understanding, they might not be well aware of the importance of protecting private information (Lorenzen-Huber et al., 2011). There is also a possibility that potential risks or discomforts related to the use of technology are not fully explained to older adult participants. This may hinder older adults from making an appropriate decision.

According to gerontechnology research, all families or informal caregivers residing with the older adults should be aware of all possible impacts of the technology on themselves as well as their own exposure to the technology. Multiple consents in this case should be obtained from all stakeholders who are involved in the use of technology, such as an individual's family or legal guardian. Then they should be given an opportunity to approve the installation (Demiris et al., 2009).

*Review Results.* The importance of informed consent or informed decision making was addressed in two studies. One study reported that despite the information provided during the recruitment as well as study enrollment sessions, misperceptions were found among a few participants regarding technology functionality (Reeder, Chung, et al., 2013). In a study by Chung et al. (2014), older adults expressed a need for information about potential benefits and harms of smart home technologies in order to ensure voluntary participation in smart home projects. However, unlike literature findings, older adults were less interested in system functionality than in the purpose of the technology. Importantly, there was an emphasis on the role of health-care professionals in conveying knowledge and information about smart home applications to older adults in order to facilitate their understanding of the technology as part of encouraging informed decision making.

**Autonomy**

The aims of smart home technologies are extended to generating datasets that enable detection of abnormal patterns and proactively responding to potential risks beyond monitoring of residents. Therefore, smart homes can contribute to gaining a sense of empowerment and independence among older adults and family caregivers (Demiris et al., 2006). However, despite the focus on enhancing

autonomy, some people are concerned about the possibility that they might become overly dependent on those technologies (Bruce, 2012). Such a situation may result in human touch being traded for technology-based interactions (Demiris & Hensel, 2009). Moreover, the passive monitoring feature may keep end users away from being actively involved in operation and management of the system. Physicians, nurses, social workers, or case managers need to provide older individuals and their families with practical recommendations in order to engage them in care process planning based on data collected by smart home applications.

*Review Results.* The desire of older adults to have control over who will be granted access to data was identified in several studies with regard to potential privacy concerns. Generally, older adults are willing to share information collected through technology with family, friends, or health-care providers, but at different levels of sharing. For example, participants were not concerned if activity data could be viewed by anyone (Boise et al., 2013), while reluctance was observed with regard to information sharing with anyone other than health-care providers (Wild et al., 2008) or unauthorized third parties (Demiris, 2009). This was further amplified by individuals who indicated the need for control over the amount and frequency of information sharing (Demiris, Hensel, et al., 2008). On the other hand, Johnson et al. (2007) reported participant concern about losing control. Study participants had a tour of a smart home equipped with smart floor, voice activation, smart microwave, smart mailbox, smart front door, cueing system, and security system, and were encouraged to express their expectations and concerns about living in a smart home environment. While older adults had a desire that the technology performs tasks they cannot do, they did not want the system to take over the role for fear that they would be overly relying on the system.

**Obtrusiveness**

The perception of obtrusiveness is subjective and varies from person to person (Courtney, Demiris, & Hensel, 2007). Eight dimensions of user perception of obtrusiveness were identified with regard to technologies installed in the home setting, such as physical, usability, privacy, function, human interaction, self-concept, routine, and sustainability (Hensel et al., 2006). For example, physical considerations such as physical discomfort or strain, excessive noise, and aesthetic incongruence associated with the technology, or functional factors including malfunction or inaccurate measurement may contribute to users' perception of obtrusiveness. Because smart home technologies are installed in private residences, researchers should be aware of the possibility of obtrusiveness concerns associated with the technology. It is also essential to develop nonobtrusive technologies to maximize technology adoption among older adults.

*Review Results.* In reviewed studies, smart home residents indicated the importance of nonobtrusive technology because of the effect on their privacy concerns (Chung et al., 2014; Demiris, Oliver, et al., 2008), but this was not observed among participants of the studies that did not involve technology installation. Also obtrusiveness issues were associated with installation locations (e.g., bedroom or bathroom) or types and size of technologies. For instance, older adults perceive that a video camera installed in a home would become a major source of privacy violation (Demiris, 2009; Demiris et al., 2004). Importantly, physical aspects of sensors, such as noises or flickering lights from the system, would become a nuisance or even a source of anxiety among smart home residents and caregivers (Nijhof et al., 2013).

**Equal Access**

Universal access to necessary health information technologies is the first step to supporting older adults to benefit from those technologies. The term *digital divide* refers to the gap in access to and usage of information and communication technologies between those who have access to the technology and those who do not, because of age, income, education, community type, disability, or other factors (Pew Research Center, 2013; Shrewsbury, 2002). Despite the fact that the population of older adults is the fastest growing group using the Internet, those who are older, who are in low socioeconomic status, or who live in rural or urban underserved areas are more likely to lag behind in technology use (Olson, O'Brien, Rogers, & Charness, 2011; Pew Research Center, 2014). Moreover, lack of access to appropriate health care among ethnic minority older adults is becoming a central issue in the U.S. health-care delivery system, which also has implications for the deployment of smart home technologies. Considering longstanding mistrust of the health-care system among individuals from underserved groups, it may be challenging to develop specifics of home-based technologies tailored to the needs of older adults in low-access settings (Fleming et al., 2009).

In addition to efforts to extend access to infrastructure such as computers, wireless Internet, or even electricity, there is an ongoing challenge revolving around the issue of health literacy and customized Web content for the elderly with low literacy and sociocultural barriers.

The cost of implementing technology is another of the widely recognized barriers to health resources and opportunities for innovative technologies. In most cases, technology installation at the initial stage should require expenditure to acquire or purchase equipment, which is often charged to the user or provider, rather than the insurer (Goldwater & Harris, 2011). If the technology needs to be connected to the Internet or Web portal, then the user may be required to pay for a monthly fee or subscription. Because insurance companies usually do not

cover the cost, and only a small number of older adults can afford the devices and services, these fees can be a barrier to the access to the technology. If family caregivers are responsible for monetary support for the elderly, the perceived cost of technology for the family should be discussed because it depends on the family's income and resources.

*Review Results.* In five studies (Coughlin et al., 2007; Demiris et al., 2004; Johnson et al., 2007; Reder et al., 2010; Steggell et al., 2010), older adults were concerned about the cost of purchasing and maintaining the device, which could be a potential barrier to technology adoption. Also, among a group of older adults who have limited English proficiency, instructions written only in English were found to prevent them from accessing necessary technology solutions (Steggell et al., 2010).

**Reduction in Human Contact**

The loss of human touch resulting from smart sensor adoption is a significant concern among older adults, because the technology may be used in ways that replace face-to-face contact. Technology may deprive the chance of therapeutic interactions between older adults and their formal caregivers or clinicians, while making older adults solely dependent on virtual visits or remote monitoring (Chan et al., 2008). Therefore, reduced number of actual visits is often expected as a main outcome of the technology use. Older adults and their families who agree to live in smart homes should be aware of such possibilities.

Cost reduction is one of the main interests among patients, families, and health-care managers. Many home-based monitoring technologies are being adopted in the hope of achieving cost-effectiveness resulting from saving of time and avoidance of travel (Ratliff & Forch, 2005). However, if the focus of utilizing technologies is solely on cost cutting, the importance of the therapeutic touch in patient–provider relationship might be ignored. Thus, it is necessary to emphasize that technology is not a substitute for skilled health-care professionals or caregivers but a supplement to traditional face-to-face care (Demiris et al., 2006; Fleming et al., 2009; Kang et al., 2010).

*Review Results.* In a sensor-based monitoring technology implementation, Reder et al. (2010) found that older adults did not want a situation in which technology could replace human touch when they are in need of social interaction. Similarly, in a study by Mihailidis et al. (2008), older adults preferred a sensor system that encourages human contact, which ultimately leads to a high adoption rate.

**Usability**

There has been increasing attention to the usability issue related to home-based health information technologies. Usability influences people's decision as to

whether the technology is useful and acceptable to them. While usability is a critical factor in the adoption and use of technologies, the issues of usability have not been fully addressed in the context of smart home environments for older adults. Technologies that are designed poorly and do not meet the needs of older adults are likely to be refused. So far, heuristics and cognitive functioning associated with human-technology interaction have been largely discussed for a wide range of consumer groups of health information technologies, but it has not been fully discussed for the population of older adults. Often the design of technology fails to address age-related constraints and lack of experience in using technology among seniors (Joe, Chaudhuri, Chung, Thompson, & Demiris, 2014). Specifically, reduced sensory function associated with normal aging as well as possible cognitive impairment or mobility limitations may cause older adults to be less adept at fully implementing smart home environments (Cashen, Dykes, & Gerber, 2004; Demiris et al., 2009). For instance, even simply switching the system on or off is challenging, especially if the individual experiences vision loss or cognitive decline. Therefore, it is necessary to examine important usability aspects of smart homes and home-based sensor technologies. Also training and user education need to be developed to meet older adults' needs in order to maximize the usability that ultimately leads to the increased acceptance of technology among older adults (Mei, Marquard, Jacelon, & Defeo, 2013).

*Review results.* In four studies, older adults and their caregivers voiced the opinion that the user-friendly feature of technologies is critical for wide adoption and use. There were some suggestions for improving usability in terms of training sessions, manuals, readability, and data visualization techniques (Coughlin et al., 2007; Demiris et al., 2004; Nijhof et al., 2013; Steggell et al., 2010), all of which can contribute to the perceived ease of use of the technologies and data for both older adults and their families. Also, it becomes apparent that the design of interface or manuals should meet the needs of older adults who have not been exposed to technologies previously or who have difficulty comprehending information.

## DISCUSSION

The use of smart homes and home-based sensors is becoming prevalent in health-care service and delivery for older adults to support independence, safety, and security. Technology development and advances should be beneficial to end users and useful for stakeholders. However, the introduction of technology in the home setting inevitably brings challenges and ethical issues. This article provides the first integrative review on ethical issues with regard to the adoption and use of smart home technologies for older adults. The majority were qualitative studies that examined older adults' attitudes and perceptions about smart home

applications in the preimplementation stage or in small-sized feasibility testing. Among them, only four studies had a main purpose of examining ethical issues related to smart home applications, such as privacy and informed decision-making (Boise et al., 2013; Chung et al., 2014; Courtney, 2008; Demiris, 2009), while others were originally focused on the acceptability of smart sensor systems.

The current ethical review suggests that technologies should be accessible, affordable, easy to use, and helpful for maintaining autonomy in order to increase adoption. More importantly, studies have shown that older adults want to live in smart homes in which their privacy is not invaded and which are not intrusive. However, privacy was not a major concern in some older adults or they were willing to use the technology in spite of a privacy risk if the technology provided a critical function (Demiris, Oliver et al., 2008; Reder et al., 2010; Wild et al., 2008). Similarly, in three studies, participants mentioned obtrusiveness issues related to technologies installed in homes, but it worked for older adults in a positive way (e.g., avoiding a lazy lifestyle or increasing physical activity) or was simply not a significant concern (Reder et al., 2010; Reeder, Chung, et al., 2013; Wild et al., 2008).

Besides the seven dimensions of the framework, we identified two other ethical issues that need further attention. First, older adults were concerned about social stigma after adopting the system because living in smart homes may be viewed as a loss of the ability to be independent (Demiris, Hensel, et al., 2008; Demiris, 2009). Kang et al. (2010) provides recommendations in order to prevent a situation in which older adults feel stigmatized, such as using invisible sensors or employing technology before the onset of functional decline. Second, older adults were favorable to devices that are reliable and do not require maintenance efforts to have a greater sense of security. When considering adoption of technology solutions into older adults' residences, reliability or maintenance issues of the technology may be overlooked including hardware or software glitches, incompatibility, power outages, or abrupt shutdown (Kang et al., 2010). Therefore, when home-based technology is introduced, researchers or clinicians must rigorously validate and test the system whether it is robust and secure. Technical staff should be ready in case of a need for troubleshooting, and the question of who will pay for the maintenance and service costs should be discussed prior to the technology implementation (Scanaill et al., 2011). Moreover, end users should be well informed about the possibility of technical problems in order to avoid excessive dependence on such technology (Mahoney et al., 2007).

When smart home technology is correctly used, it can increase the sense of well-being and quality of life and ultimately support older adults' desire for remaining in their homes as long as possible. To effectively employ the benefits of the technology and to support the successful integration of the technology with

traditional care, the development and applications of technology innovations for older adults should be carried out with strict ethical standards that aim to ensure an individual's safety and independence. Professionals who are interested in the application of technology are required to have moral principles that lead to efforts to mitigate all possible risks and to maximize benefits for older adults. Ethical issues identified in this review need to be thoroughly examined by professional groups who consider using smart home technologies.

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