Emerging Smart Home Technologies to Facilitate Engaging With Aging

ABSTRACT

Engaging with aging (EWA), the ongoing process of an individual to identify resources and implement adaptive strategies to maximize quality of life, may be enhanced by advances in information technology and adaptive upgrades to the built environment. Smart home technologies (SmHT) introduce passive monitoring features into the residential infrastructure to promote older adults' ability to manage day-to-day living and age in place. This article provides an overview of current and emerging SmHT and discusses opportunities to leverage this technology for enhancing the capacity of older adults to engage with their own aging. There are opportunities to create smart homes that enhance physical and cognitive capacity for older adults, but there are also ethical and practical challenges that will inform the design of future smart home systems. [*Journal of Gerontological Nursing, 45*(12), 41-48.]

Advances in sensor technology and artificial intelligence (AI)–powered data analytics have made a significant impact in smart home technologies (SmHT), namely home-based systems that can be integrated into the residential infrastructure to facilitate monitoring of residents and provide tailored support. These advances have been bolstered with the introduction of the *Internet-of-Things*, a term that refers to the interconnectedness of devices and sensors over the internet. As a result, SmHT have been further developed to not only provide convenient functionalities (e.g., automated lights), but also a variety of health-related services. In this regard, there has been substantial development

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in SmHT designed to assist older adults' aging and independence (Wang, 2018). As individual older adults have differing strengths and needs—indeed, these often change within individuals over time—it is critical for nurses to assist older adults and their families in the identification of SmHT tools that have the capacity to support healthy aging.

Engaging with aging (EWA), as defined by Carnevali (Primomo & Belza, 2019), refers to an ongoing process whereby an individual identifies resources and implements adaptive strategies to maximize quality of life. The built environment, along with SmHT installed in the residential setting, can moderate this process. As technologies embedded in the residential infrastructure emerge with the goal to facilitate independence and improve quality of life, they have the potential to promote older adults' ability to manage day-to-day living. The current article provides an overview of emerging SmHT and discusses opportunities for these technologies to enhance capacity of older adults to engage with their own aging as they adapt to ongoing changes and seek to attain higher level needs (e.g., self-actualization).

OVERVIEW OF SMART HOME TECHNOLOGIES

Monitoring Technologies

One of the prominent focal areas of SmHT to support aging is monitoring the health and wellness of older adults. This monitoring may be achieved through embedded sensors in the home environment as well as wearables or body-worn sensors. Such a multimodal sensor system that consists of passive and active monitoring allows holistic monitoring of older adults' health parameters, daily activities, and behavioral patterns in their home environment. Researchers have studied novel machine learning algorithms to analyze data from multiple sensors to correctly classify and categorize older adults' activities of daily living (ADLs) to assess their functional capacity (Ghayvat, Mukhopadhyay, Gui, & Suryadevara, 2015; Suryadevara, Mukhopadhyay, Wang, & Rayudu, 2013). One area of focus is systems for automatic fall detection. Several different approaches using wearables (Wang, Zhang, Li, Lee, & Sherratt, 2014), acoustics (Salman Khan, Yu, Feng, Wang, & Chambers, 2015), or privacy-preserving motion capture images (De Miguel, Brunete, Hernando, & Gambao, 2017) have been studied to prevent fall-related injuries among older adults. In addition, several studies have looked at how to use physiological and behavioral data collected through sensors to assess short- and long-term health patterns, detect anomalous activities, and respond to emergencies (Helal et al., 2005; Rantz et al., 2008).

Smart home systems have the potential to assist with chronic disease management. Affordable sensors and devices are becoming readily available that can accurately capture health parameters such as blood pressure and heart rate in the home setting. To increase medication adherence, smart monitoring systems have also been examined among older adults (Aldeer, Javanmard, & Martin, 2018). Furthermore, home furniture equipped with sensors to measure physiological and behavioral data are becoming available to consumers. One example is smart beds and mattresses that can monitor sleep patterns and provide nightly sleep quality data.

Home Automation and Artificial Intelligence Digital Assistants

Home automation can create convenient, efficient, and safe environments for older adults. The concept has evolved from a resident being able to simply control light switches to controlling a wide range of devices at home, including door locks, thermostats, and even appliances (e.g., stove). The ability to control appliances and automate common tasks in homes can decrease the burden for individuals with physical or cognitive disabilities, which are more common as one ages.

Advances in natural language processing and AI have significantly improved home automation experience through integration of smart speakers. Smart speakers (e.g., Amazon Echo, Google Home) are equipped with an AI digital assistant and allow users to interact with smart home devices with voice commands. Hands-free voice control could improve the accessibility and usability of SmHT for older adults, particularly for individuals with general mobility disability or upper extremity dexterity issues due to conditions such as arthritis or tremor, who may have found the manual operation of hardware systems more challenging.

Virtual Reality and Augmented Reality

Virtual reality (VR) and augmented reality (AR) applications have originated from the video gaming industry; however, they have more recently been explored in the context of health care. Some early research in this area has investigated the use of VR applications for gait recovery for older adults and proposed that VR applications could potentially help older adults improve their static and dynamic balance and reduce fall risks (Kamínska, Miller, Rotter, Szylínska, & Grochans, 2018; Rendon et al., 2012). Studies have explored the use of VR systems to help older adults with pain management (Benham, Kang, & Grampurohit, 2018), depression, and social isolation (Lin, Lee, Lally, & Choughlin, 2018). As many older adults experience pain, decreased mobility, and decreased social connections, VR applications could provide strategies to reduce pain in a nonpharmacological manner, minimize mobility barriers, and enhance older adults' enjoyment of various social adventures in the convenience of their home.

TABLE 1

EXAMPLES OF ADAPTIVE STRATEGIES USING SMART HOME TECHNOLOGIES

Risk Factors Associated With Aging	Age-Related Change Impact Areas	Examples of Smart Home Adaptations for Assessment or Intervention
Short-term memory problems	Medication adherence	Smart pill dispenser with automated reminders
	Safety in cooking	Smart stove that automatically shuts off when left unattended
Long-term memory problems	Forgetting names and past events	Artificial intelligence smart assistants with access to personal memory database
Sleep quality	Sleep interruptions, insomnia	Smart mattress to monitor sleep duration, body movement, and sleep cycles
Sedentary lifestyle	Too much time spent sitting down	Sensors to detect sitting time and prompt timely notification to promote physical activity
Hand dexterity	Decrease in hand dexterity to use digital devices	Smart speaker voice interaction technology (e.g., natural language voice commands to execute commands and log and retrieve information from the internet)
Social isolation	Decrease in social connection	Virtual reality social gatherings with distant family members and friends

Although a recent review concluded that evidence was insufficient for the clinical value of VR compared to conventional therapies, its' potential warrants further development and research (Laver et al., 2017).

ENGAGING WITH AGING USING SMART HOME TECHNOLOGIES

Understanding Aging in the Personal Context

As SmHT become more affordable and diverse, older adults can use these tools to address their unique needs and challenges associated with aging. A critical element in this process involves older adults becoming more aware of the manifestations related to their unique aging-related changes and understanding them in a personal context. The self-awareness of age-related changes and how they impact ADLs is especially important to develop appropriate adaptive strategies to cope with them. SmHT with a specific focus on aging support generate objective physiological, behavioral, and environmental data about older adult users and their home environment. Such data could objectively depict areas impacted by age-related changes within older adults and their living environment and could serve as an insightful resource when making health-related decisions. For example, a sedentary lifestyle is a well-known age-related change prevalent among many older adults. Past research has linked sedentary behaviors with adverse health effects (de Rezende, Lopes, Rey-Lopez, Matsudo, & Luiz, 2014). Assessment of sedentary behaviors has traditionally relied on self-report data. Results from subjective measures may not accurately reflect older adults' actual behaviors and are often uninformative in generating actionable insights for older adults to make positive changes.

SmHT that incorporate on-body sensors and other types of sensing devices with advanced data analytics could objectively and accurately identify ADLs and provide detailed analysis of sedentary lifestyles. Older adults could review their activity data and learn more about the specific context of how sedentary behaviors occur (e.g., time spent sitting watching television, reading books, using a computer) and consider adaptive strategies. In addition, older adults can agree to receive timely reminders to promote physical activity to help them stay active. **Table 1** provides some common examples of risk factors associated with aging, the impact of age-related changes, and adaptive strategies using SmHT.

System designers should also consider how to deliver the data generated by SmHT in easy to understand and intuitive formats. Providing the means for older adults to easily access their data and facilitating insight about individual health status and ADLs is an important element of how SmHT could assist in EWA. Previous studies have shown that older adults are interested in receiving smart home data that help them better understand their health status (Reeder et al., 2013). However, such

data that are difficult to access or presented in poorly designed graphs or other data visualization formats will have limited value and may even lead to misinterpretation of data. Therefore, web portals that give continuous access to relevant and useful smart home data must be provided to users. Older adults may want to use interactive data visualizations of their health data and identify longitudinal trends and patterns related to age-related changes. A portal might also use a smart speaker and its embedded AI assistant to allow older adults to dynamically explore their data using natural voice commands. By having access to their detailed health data and behavioral patterns, older adults can make timely adjustments in health behaviors themselves or present the data to health care providers and family caregivers to develop personalized adaptive strategies together, which could be reinforced by the AI assistant.

As SmHT to support aging inevitably collect multitudes of data, it is essential to consider potential negative impacts of data fatigue and context-insensitive alarms (e.g., notifications to exercise when visitors are present, false alarms in fall detection). The risk of context-insensitive alarms may render potentially good solutions ineffective, cause emotional discomfort, and negatively impact long-term adoption of the technology. Therefore, SmHT must be able to integrate with other devices to deliver appropriate notifications. Data analytic algorithms must also preserve a high degree of precision with adequate levels of sensitivity and specificity to minimize the risks of false alarms. Even if started with strong motivation to use smart home data to engage with aging, older adults may quickly find themselves overwhelmed by vast amounts of data and puzzled as to how to access, control, and use the data. To avoid this problem, older adults should be adequately oriented to the smart home environment. This orientation may involve the help of adult family or community members. Nurses or case managers equipped with technological competencies may also assist older adults. Finally, SmHT to support aging should place older adults at the center of design and implementation (Huber & Camp, 2017).

Smart homes have the potential to serve as environments that enhance, or support, cognitive capacity.

Enhancing Capacity: Agency and the Smart Home

An implicit element of EWA involves the ability of older adults to make decisions based on their needs, preferences, and priorities. Some science and technology researchers note that agency, or the ability to act, is not located solely within an individual (Suchman, 2009). Rather, the ability to act is tied to the social and material resources in one's environment (Suchman, 2009). And one's home and the technologies in it constitute some of these material resources. For example, a smart light that turns on when one is walking to the bathroom at night can be a supportive resource, whereas an individual might not be able to complete that same activity without the light. In this example, one's physical ability to complete a task is tied to the technology in one's home. But SmHT, particularly those supporting aging in place, may also hinder agency. Mort, Roberts, and Callén (2013) argue that aging in place technologies can actually be coercive, potentially hindering people's ability to act according to their preferences. SmHT can be coercive when they are presented as older adults only opportunity to continue living alone (replacing in-person consultation with nurses and other practitioners) or when they intensely monitor people and share private data that invite unwelcome responses or actions from caregivers or family members (Mort et al., 2013).

As research and practice move toward SmHT, near-future dystopian possibilities must be carefully considered: people being compelled to act against their wishes by their home infrastructure (e.g., insurance costs tied to daily exercise, smart refrigerators locking when one has achieved the optimal number of calories). One way of addressing this concern is to ensure that technologies are adaptable and permit non-use (Mort et al., 2013), which requires a range of settings that must be determined in consultation with older adult users. To ensure that older adults play an active role in the use and configuration of these devices, rather than being passive recipients of alerts or directives, an important area in research and practice is supporting digital literacy as technologies evolve.

Cognitive Capacity. In considering one's ability to act according to his/her preferences, it becomes important to discuss cognitive capacity. Although many older adults do not experience cognitive impairment such as dementia, it is a condition that becomes more prevalent as

people age (Plassman et al., 2007). A diagnosis of dementia is no longer viewed as the end to one's ability to make decisions (Kelly & Innes, 2013). Thus, consideration should be given to supporting people at varying levels of cognitive abilities to evaluate tradeoffs and make decisions. This support includes big picture decisions such as health care priorities and end-of-life considerations, but also the mundane day-to-day choices, such as when to go to bed. When thinking about capacity to make decisions, legal capacity, which includes the ability to understand and appreciate the consequences of one's actions, should be considered. According to some frameworks, capacity is not something that someone globally "has" or "does not have," but is something that should be evaluated on a case-by-case basis (e.g., capacity to consent to treatment) (Appelbaum, 2007). Capacity, like agency, is tied to the socio-material environment—someone may have less capacity when there are many distractions present or when questions are delivered in dense language or jargon. In some countries, individuals who assess capacity (i.e., physicians, nurses, social workers, occupational therapists, health care assistants, support staff) are required to optimize the environment accordingly for people with dementia, yet it is not currently clear how technological platforms can support these efforts (Batchelor, Bobrowicz, Mackenzie, & Milne, 2012).

Smart homes have the potential to serve as environments that enhance, or support, cognitive capacity. First, seeing cognitive capacity as something that fluctuates over time, particularly for persons with dementia (e.g., sun-downing), a smart home could learn the times when someone has the most capacity and present decisions to them at that time. This approach could draw on the algorithms and sensors being developed to detect decline and orient outcomes toward supporting action by people with dementia rather than primarily as information to be used by others. A second approach could be to use prompting to support action. Past research shows that with support and prompting, people with dementia can do more than their scores on dementia rating instruments may indicate (Perry, Galloway, Bottorff, & Nixon, 2005). A smart home might draw on advances in machine learning to provide prompts (e.g., steps to complete making tea) or even remote communication that supports a simulated presence, such as social VR where a family member might guide someone through an everyday routine.

Addressing Risks. When discussing any kind of digital networked technology, it is essential to consider the potential for scams and security risks. Elder abuse includes exploitation, including financial exploitation. Older adults are targeted for exploitation and scams, yet elder abuse is a significantly underaddressed area (Daly, 2011). Being a victim of these crimes impedes one's ability to engage with aging in many ways: it reduces one's resources and may cause others to step in and begin to make decisions on the behalf of an individual. SmHT might play a role in preventing some of these crimes. For example, showing someone who is at the door or inviting family members who may have input into older adults' decisions (Rowles & High, 1996) to have more insight into what is happening in an older adult's life may provide preventive measures or the ability to step in to avoid what seems to be a scam. At the same time, SmHT must not invite potential for security risk. Many smart devices on the market are "hackable" on the device level and through higher-level security breaches, where many individuals' private data are stolen. Further, data collected by these devices may not be protected by HIPAA, and companies might share or sell the data with other parties. Even when medical data are protected, it might be shared with insurance companies without older adults' awareness. Devices used by older adults, and particularly those marketed to them, should be held to a high standard of security as well as transparency.

As another factor to consider, elder abuse is not only perpetrated by strangers, but also by family members and caregivers (Daly, 2011). Therefore, how SmHT might inadvertently provide opportunities for abuse must be considered: for example, extreme monitoring or even executing domestic violence enabled through technology (e.g., stalking via GPS) has been noted with other populations (Freed et al., 2017). There should be ways that inappropriate use of SmHT can be tracked, documented, and prosecuted when officials become concerned about possible abuse.

Engaging With Higher Level Needs in Aging

Technologies designed for aging often focus on physical and cognitive factors, such as detecting acute events (e.g., falls). However, "higher level needs," such as self-esteem and self-actualization, are rarely addressed in technology design. These needs, which include factors such as confidence, achievement, and respect, as well as morality, creativity, and acceptance, respectively, may be unmet in many existing technologies and thereby explain some older adults' lack of adoption of technology (Thielke et al., 2012). Beyond technology design, these needs are often neglected in ways of conceptualizing older adulthood and definitions of successful aging (McCarthy, Ling, & Carini, 2013). EWA to its fullest extent means that higher purposes should be considered and supported (Carnevali, 2019). What might it mean for a smart home to support higher purpose?

For many, engaging with a higher purpose is centered around religion. In beginning to attend to religion

TABLE 2

SUMMARY TABLE

Key Takeaways for Nurses
Smart home technologies (SmHT) provide opportunities to enhance physical and cognitive capacity of older adults and engage them in managing ongoing aging-related changes.
SmHT that maximize engagement with aging should be aging-friendly in design and implementation and not coercive (i.e., should not diminish older adults' agency).
Nurses need to be aware of available SmHT tools that have the capacity to support healthy aging to assist older adults and families.
Facilitators and barriers, such as digital literacy, privacy, and accessibility to technology, should be considered for successful adoption of smart home tools.
Resource
AARP Series on Caregiving and Technology (https://www.aarp.org/caregiving/home-care/info-2018/technology-helps-remote-monitoring.html)

with technology, the diversity of religions and factions that older adults practice is one important component of the heterogeneity of the population of which to take note. Considering religion in the design of smart homes might involve smart homes that support the observation of Sabbath directives, the telepresence of church services for those who face mobility restrictions, include Buddhist soundscapes, and take into account dietary needs around Ramadan for smart refrigerators.

For others, higher purpose may be about contributing to one's community or to society more broadly. Volunteering is something that benefits older adults who engage in it (Morrow-Howell, Hinterlong, Rozario, & Tang, 2003) and the community around them. Some may gain a sense of contribution from continuing to work full or part time. Gig (i.e., temporary) and crowd-work may open new opportunities for people to work from home (Brewer, Ringel Morris, & Piper, 2016) should that be their preference. Finally, opportunities to engage in life-long learning are essential for continued work and may be a way people find meaning. To support volunteering, paid employment, and lifelong learning as fundamental components of EWA, a smart home would need to consider making space for work and learning, including workplace technology, such as remote communication and collaboration technologies, as well as opportunities to access information and online courses.

CONCLUSION

The current article discusses opportunities to leverage SmHT to facilitate and adapt to ongoing aging-related changes and higher-level needs. SmHT provide opportunities to enhance physical and cognitive capacity, thereby increasing older adults' ability to engage with aging. Nurses need to be aware of available and emerging SmHT to assist older adults and families in the identification and selection of appropriate, versatile, and adaptable tools. Such tools can support age-related changes and maximize an individual's ability to engage with aging. Context-rich information gathered from SmHT has the potential to assist older adults and clinicians in identifying patterns that may precipitate or exacerbate age-related changes. This information can be used to activate older adults to change health-related behaviors, with ongoing feedback through the SmHT, supported by clinicians. However, nurses must also ensure that SmHT do not diminish older adults' agency by overly regimenting their lives or providing unwanted or unneeded support. SmHT that maximize engagement with aging need to place older adults at the center of their ideation, design, implementation, and evaluation.

A need to support digital literacy of clinicians and older adults remains as technology evolves, and strategies to best accomplish this are active areas of research and practice. Some individuals erroneously assume that older adults do not use or want to adapt to new technologies. However, the digital divide is narrowing with the growth of the aging population (Anderson & Perrin, 2017). Yet, the cost of and access to new technology can create or widen health disparities. For example, persons living in rural areas are less likely to have broadband internet. This lack of access can, in turn, reduce ability to use SmHT for health information or telehealth services, which can impact overall health (Federal Communications Commission, 2016). Lack of previous experience with technology and limited familiarity with technical terms may also affect older adults' ability to

fully understand risks and benefits of SmHT when consenting to their use. Nurses can advocate for policies that support improved access to high-speed internet or more generally advanced digital infrastructure in these communities and educational resources and tailored consent tools with the goal of supporting health equity. **Table 2** highlights key takeaway points for nurses who provide care and support for older adults and their families.

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