Gerontology & Geriatric Medicine
Volume 7: 1–15

DOI: 10.1177/23337214211017340
journals.sagepub.com/home/ggm
SAGE

Safely and Actively Aging in Place: Older Adults' Attitudes and Intentions Toward Smart Home Technologies

Elif Tural, PhD[1], Danni Lu, PhD[1], and D. Austin Cole, MS[1]

Abstract

As smart technology use is growing in residential environments, research on how such technologies can provide opportunities for safely and actively aging in place by integrating physical activity into daily routines and reducing sedentariness is scarce. This study investigated older adults' intentions to use and attitudes toward currently available smart home technologies that could contribute to safe and active lives in and around home. The focus was on four representative technologies: smart lighting, smart door locks, smart fire prevention devices, and smart home systems/home automation. This paper presents the results of a sequential mixed-methods study comprised of online and in-person surveys ($n = 129$), and a focus group of community-dwelling older adults, aged 50+ ($n = 15$). Ordinal regression analyses indicated that perceived usefulness consistently predicts older adults' attitudes and willingness to use smart home products. While smart fire prevention devices were viewed most favorably due to their potential safety benefits, perceived affordability significantly influenced older adults' intentions to use them in their homes. The focus group findings underscore technology skepticism, privacy concerns and return on investment as significant determinants of attitudes toward the smart design products. The study has implications of designers and manufacturers by providing insights on how to prioritize smart home technology integrations to homes.

Keywords

aging-in-place, older people, smart home, smart home technology, technology acceptance model

Manuscript received: October 1, 2020; **final revision received:** January 31, 2021; **accepted:** April 22, 2021.

The continuing growth in the number of older adults and their desires to age in place raise significant healthcare and housing challenges. The majority of people prefer to stay in their homes as long as they can (AARP, 2018), and policy makers support this option due to high costs of institutional care. Yet most residences lack the necessary design features to support independent living in a safe, viable way. Beyond the need to modify and adapt homes of the growing senior population for basic safety reasons, such as preventing falls, residential environments could also promote active and independent living among older populations. One approach that closely relates to promoting physical activity and less sedentary behavior at home is "active living," defined as integrating any form of physical activity into daily routines, such as taking the stairs, and participating in household activities, including cooking, cleaning, or gardening (Sallis et al., 2006). For older adults, even these household physical activities can be very beneficial, as they can constitute much of an older person's total activity (Brookfield et al., 2015). Being able to actively participate in such activities would also support independence and allow the aging-in-place model to be realized.

Use of technology has been proposed and studied for its potential to support aging in place while maintaining active lifestyles at home in a safe and secure way (Berkowsky et al., 2018; Chen & Chan, 2014; Mitzner et al., 2010; Peek et al., 2014, 2016; van Hoof et al., 2011). In recent years, there is also an upsurge in interest in the applicability and acceptability of Internet of Things (IoT) or smart home technologies for safely and independently aging in place (Arthanat et al., 2019; Carnemolla, 2018; Humphreys, 2018; Liu et al., 2016; Marikyan et al., 2019; Turjamaa et al., 2019). In line with Arthanat et al. (2019) definition (p. 247), within the context of this study, our definition of smart home technologies that support safe and independent aging

[1]Virginia Tech, Blacksburg, USA

Corresponding Author:
Elif Tural, School of Architecture + Design, Virginia Tech, 201 Cowgill Hall (0205), Blacksburg, VA 24061, USA.
Email: etural@vt.edu

comprise sensor-based technologies placed in the homes of older adults that (1) monitor or gather information about the home and its residents, (2) allow device communication for automation and remote access, and (3) provide user interfaces, such as home displays, smart phones or computers to receive information and set preferences.

A recent survey by AARP on technology trends among older adults identified smart home technology as an emerging market for the 50+ age group, with many adults interested in buying smart home technology products, but only about 10% currently using them (Kakulla, 2019). The low rates of technology acceptance and adoption were also highlighted in the literature (see reviews by Liu et al., 2016; Peek et al., 2014). Several models and theories have been proposed to examine technology acceptance and use behaviors among older adults. The technology acceptance model (TAM) (Davis et al., 1989), along with the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003), is one of the most prevalent frameworks with maintained consistency and validity (Chen & Chan, 2014). The key variables of TAM models, perceived usefulness (PU) and perceived ease of use (PEOU) were shown to have significant predictive power, however, they rarely consider the unique characteristics, capabilities, and limitations of the elderly (Chen & Chan, 2011, 2014).

A significant concept that is commonly discussed for about 30 years when examining technology acceptance and adoption in later life is the digital divide (Marston et al., 2019). The digital divide refers to the gap between those who do and those who do not have access to new forms of technology (van Dijk, 2006). Several frameworks were proposed over the years to identify the factors related to the digital divide. These models primarily focused on issues of access, ability, and affordability (Marston et al., 2019; Selwyn, 2004; van Dijk, 2006; Vihera & Nurmela, 2001). Others also point to the inequality of outcomes (e.g., Wei et al., 2011). In addition to being an indication and reason of social and economic inequality, the digital divide can also be explained by individual differences, capabilities, and technology experiences (Vihera & Nurmela, 2001; Vehovar et al., 2006). Numerous empirical studies identified the factors that may play a role in the digital divide, such as gender, age, income, education, type of household, geographic location (DiMaggio et al., 2001; Loges & Jung, 2001; Marston et al., 2019; Wei et al., 2011).

Since the senior population is becoming more diverse with changing demographics and occupancy characteristics (Cisneros et al., 2015), it is significant to examine other factors that are comprised by the digital divide literature in relation to what can be explained by TAM variables. Additionally, previous research underscores that type of technology matters for older adults' attitudes and behaviors to use them (Arthanat et al., 2019; Liu et al., 2016). This relates to assessing whether that specific technology "provides specific desired utility, and the perceived difficulty of learning" to use that product (Barnard et al., 2013). While technology adoption and use behaviors are commonly studied (Macedo, 2017), more research is needed regarding the aging-in-place supportive technology (Chen & Chan, 2014, p. 246). Smart home technologies and home automation is a rapidly evolving domain with potential to support actively aging in place (Arthanat et al., 2019; Chung et al., 2016). However, as pointed out by several researchers, the current evidence on their acceptability and the influential factors is rather limited and does not fully explain why older adults are less willing to adopt them (Berkowsky et al., 2018; Humphreys, 2018; Macedo, 2017; Marikyan et al., 2019; Liu et al., 2016).

Our study contributes to the body of literature in this field by examining older adults' attitudes toward and intentions to use currently available smart home technologies across different domains that would support safely and actively aging at home. We also explored how technology access, skills, affordability, and demographic and health-related factors may influence these attitudes and intentions as these were identified in the literature as factors that may play a role in the digital divide. Utilizing the constructs from the TAM framework, we hypothesized that (1) perceived usability, perceived usefulness, and perceived affordability will be associated with more positive attitudes toward smart home products, and (2) perceived usability, perceived usefulness, perceived affordability, and more positive attitudes toward about the smart home products will be associated with higher intentions to use these products in future.

Findings from this study will add to the knowledge base in smart home technology adoption in older adults and are expected to assist design professionals who work with older adults by providing them evidence of the value of smart home technologies for their clients who prefer to age in place. The findings may also help industries that manufacture such products to improve their designs and develop efficient marketing strategies for targeting older adults.

Materials and Methods

Study Design

This sequential explanatory mixed-methods study employed a structured survey, followed by a focus group to help further explain the quantitative results with qualitative data (Creswell, 2015). In line with the characteristics of such research designs as described by Creswell and Clark (2011), this study prioritized the quantitative aspect in addressing the research objectives and relied on the qualitative strand to provide the insight and additional explanation of the overall findings. The Institution Review Board approved the study (IRB # 17-751).

Table 1. Representative Design Products Selected for the Assessment.

Product domain	Design product	Cost range
Housekeeping/safety: Products to that assist in cooking, cleaning, and other household activities as well as adapted appliances with sensors that monitor appliances	Smart stove fire prevention devices	$150–$500
Safety and security: Products to protect health and home, and to support safely leaving and returning home.	Smart door lock	$100–$300 + $50–$100 professional installation, if needed
Environmental systems: Lighting (to provide safe, programmable, sensor-based, and customizable light levels and spectrums for getting around the house), control switches.	Smart lighting	$50–$200 for a starter kit
Home automation system that would control a number of the above-mentioned products and others (thermostats, appliances, security cameras, etc.)	Home automation/ Smart Home	$500–$4,500 + installation

Note. Products were selected to represent the active living supportive domains through the Able Data database, maintained by the Department of Health & Human Services' (HHS), National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR), and its product categories. Five researchers from design and gerontology fields chose the representative products for the survey. While certain products may also represent other domains, such as lighting for safety and security, efforts were made to place them to the best representative category.

Participants

In this study, community-dwelling adults aged 50 and over were sampled from the southwestern Virginia following three different approaches. (1) Online recruitment from the [*masked for review*] Center for Gerontology Older Adult Research (OAR) registry to complete the online survey ($n=77$), (2) In-person recruitment from the local lunch program to complete the self-administered survey at community meal sites ($n=37$), and (3) Online invitation sent to residents of an independent living community to complete the same self-administered survey, attend a hands-on education session on the products, and participate in a focus group ($n=15$). The purposeful sampling from these sites allowed us to recruit community-living older adults from diverse age groups and socioeconomic backgrounds. The qualitative sample had 15 participants from the independent living community. We provided a financial incentive to the participants for their time and input.

Measures

Quantitative data collection. As part of a larger project that assessed a range of assistive designs that may support aging in place, this study focused on three smart home design products and a more comprehensive smart home/home automation system. These smart home technologies were representative of varying cost and complexity levels and target a range of products that may support integrating physical activity to daily routines. The selected products also included the safety and security-related home technologies the older individuals are most interested in adopting—front door security, and products that automatically shut off appliances (AARP, 2019). Brief descriptions of these products are provided in Table 1. The survey first provided participants with an overview of the selected smart home products. Uses, benefits and cost ranges of the smart home technologies that may support aging in place were explained with visuals (photographs and short videos) and brief textual information.

The cross-sectional survey design was based on a modified version of the TAM framework to predict user acceptance of any technology through perceived usefulness, perceived ease of use, and perceived affordability factors (Davis et al., 1989; Orillaza et al., 2014). Based on Davis (1989), in this study, perceived usefulness is defined as the degree to which an individual believes the product will enhance his/her life at home, and perceived ease of use is the degree an individual believes that a product will be free of effort. Modified versions of the model also include the cost or perceived affordability as a factor that influences attitude towards the adoption of the product, which then predicts the behavioral intention to use (Kuo & Yen, 2009; Wu & Wang, 2005).

The survey consisted of four major sections:

(1) Ratings of the select products with a five-point Likert scale for perceived usefulness, perceived ease of use, perceived affordability, attitude, and intention to use measured through previously validated questions from TAM questionnaires.
(2) Self-reported health and ability characteristics, and physical activity levels using adapted questions from national health surveys; and
(3) Socio-demographic and economic characteristics, including age, gender, income, educational attainment, housing type and arrangements, existing home modifications.
(4) Technology knowledge and use, related to home internet and mobile phone use, smart phone ownership, and self-assessed smart phone and computer skills.

The survey was pilot tested on five adults and revised for question clarity, wording of product descriptions, and legibility of the visuals. The data collection from the online survey of the OAR registry and self-administered

questionnaire at the meal sites were completed in February and March 2018. The recruitment email and the online survey included an introduction describing the study and consent was inferred by submission of the survey. In the lunch program setting, the PI or a designated team member presented the study and informed consent forms were collected prior to participation.

Following an initial analysis of the quantitative data, the independent living community residents were recruited in June 2018 with the assistance of the community event coordinator. After consenting, the participants were asked to complete the same survey and to participate in the focus group.

Qualitative data collection. A subset of participants ($n=15$) were provided in-depth overviews through a presentation and hands-on testing opportunities in a community room of their facility. They later participated in a post-presentation/post-survey completion focus group, facilitated by two researchers. The focus group was recorded and transcribed verbatim. The aim of this second phase is (1) to provide insights and clarifications on the factors inquired in the survey; and (2) to capture other factors that may influence attitudes and intentions to use these stair mobility products but are not addressed in the questionnaire. The 48-minute focus group aimed to complement and further explain the findings of the survey. The semi-structured focus group guide inquired about the challenges the participants faced at home, whether they used any assistance, their views on technology at home, and followed up on the survey questions for each of the four smart home design products (smart fire prevention devices, smart lighting, smart door locks, and a comprehensive smart/home automation system), asking about the factors that would support or inhibit their use at home.

A copy of the survey and the focus group questions are provided in Appendices 1 and 2.

Data Analyses

Qualitative and quantitative data were analyzed separately. Regarding the quantitative survey data, the impact of all investigated factors on the participants' opinions toward the smart home products is evaluated using stepwise regression models. A further covariates screening for all the candidate predictors was conducted using a stepwise selection approach to establish the optimal model. The optimal model is defined as the model that minimizes the corrected Akaike Information Criterion (AIC_c) value (Burnham & Anderson, 2002; Cavanaugh, 1997). The qualitative data were analyzed using systematic text condensation (STC) (Jellesmark et al., 2012; Malterud, 2012). The analysis included the following steps: (1) the transcriptions were read to get an overall impression of the content—total impression; (2) all units of meaning were identified and clustered—coding; (3) all units of meaning were condensed to uncover overall themes and subthemes—condensation; and (4) development of descriptions and concepts with credible stories reflecting the validity and wholeness of their original context—synthesizing.

Table 2. Characteristics of Survey Participants ($n=129$).

Measure	Number	%
Age		
50–64	34	26.8
65–74	44	34.6
75–84	41	32.3
85+	8	6.3
Sex		
Female	96	75
Male	32	25
Education		
High school or less	27	21.3
Some college	14	11
College graduate	33	26
Graduate or Prof. degree	53	41.7
Monthly household income		
<$1,000	17	13.8
$1,000–1,999	22	17.9
$2,000–2,999	18	14.6
$3,000–4,999	20	16.3
$5,000+	46	37.4
Home type		
House	98	76
Apartment	14	10.9
Townhouse/duplex	16	12.4
Mobile home	1	.8
Home ownership		
Own	101	79.5
Rent	26	20.5
Living arrangement		
Lives alone	48	37.2
With 1 other person	68	52.7
With 2 or more other people	13	10.1
Use of technology		
Internet at home	98	76
Mobile phone ownership	121	93.8
Smart phone	80	62
Self-assessed smartphone skills		
Poor/fair	44	35.2
Good	22	17.6
Very good/excellent	59	47.2
Self-assessed computer skills		
Poor/fair	27	21.6
Good	24	19.2
Very good/excellent	74	59.2

Quantitative Results

Descriptive Statistics

Characteristics of the participants ($n=129$) are summarized in Tables 2 and 3.

Table 3. Self-Reported Health Measures ($n = 129$).

Measure	Number	%
General health status		
Poor/fair	19	15
Good	37	29.1
Very good/excellent	71	55.9
Health interference w. activities		
A great deal	8	6.3
Not much/somewhat	80	62.6
Not at all	38	29.7
Assistance from others		
ADL/personal care assistance	3	2.3
IADL assistance	16	12.4
	M	*SD*
Physical activity during last 7 days		
Vigorous activity for at least 10 minutes	2.8	2.45
Walk for at least 10 minutes	3.8	2.44
Moderate activity for at least 10 minutes	4.39	2.39
Sedentary behavior (h/day)	5.38	4.47

The correlations between attitudes toward and intentions to use smart home products and the demographic, health and TAM variables are shown in Table 4. Perceived ease of use, perceived usefulness, and perceived affordability are the three factors that consistently had the high and statistically significant positive correlations with attitudes and intentions to use the four products. Younger age was positively correlated with intentions to use smart door locks, smart lighting, and home automation systems.

Ratings of the Smart Home Design Products

Figure 1 shows the distribution of responses regarding intention to use and attitude regarding the three smart home products and the home automation system. Smart fire prevention device was the highest rated product for attitude and intention to use while the fewest number of participants agreed or strongly agreed that smart door locks were a good idea in general. Participants' attitudes scores toward the products were higher compared to their behavioral intentions to use them in their homes.

Ordinal Regression Models

Table 5 shows the variables selected for each of the attitude and intention to use models fit for each of the four smart home technologies. While the survey contained over 20 predictors for each response, the final models based on stepwise regression with AIC have between five and eight predictors, except the model predicting intention to use the comprehensive home automation system, which had 14 predictors. These models have an *R*-squared ranging from .257 to .426.

Smart door locks. The regression models predict 32.2% of the variance in attitude, and 39.5% of the variance in intention to use smart door locks at home. Among the TAM factors, controlling for other predictors, an individual's higher perceived usefulness of smart door locks is associated with increased odds of having a positive attitude toward the product and a higher intention to use it (odds ratios of 8.61 and 7.52, respectively; $p < .01$).

Increased need for ADL assistance is also positively associated with the odds of a higher intention to use smart door locks ($OR = 7.03$, $p < .01$). However, interestingly, having a widened doorframe (an accessible design feature) at home was negatively associated with intention to use the smart locks. A possible explanation to this could be that widened door frames may indicate an existing mobility challenge that may limit the time spent outside, thus, making the smart door locks undesirable/ unnecessary. Since this result may be indirectly influenced by other factors, further research is needed to verify whether living with certain physical disabilities predicts attitudes and intentions to use this specific type of smart technology.

Smart lighting. The models used to predict a person's attitude towards smart lighting, and their behavioral intention to use the product capture 34% and 40% of the variance in data, respectively. Among the TAM factors, perceived usefulness is associated with increased odds of having a favorable view of the product ($OR = 8.67$, $p < .01$). Having internet service at home also increases one's odds of holding a positive attitude toward smart lighting ($OR = .52$, $p < .05$).

While perceived usefulness stays as a significant predictor of behavioral intention ($OR = 4.81$), an overall positive attitude toward the product appears as a factor that increases one's odds of having a higher intention to use it ($OR = 3.97$, $p < .01$). People who own their homes have significantly higher intentions to use smart lighting in future ($OR = 2.70$, $p < .01$). Interestingly, people with higher incomes, and better self-reported health, and higher smart phone skills had lower intentions to adopt smart lighting in their homes.

Smart fire prevention. The ordinal logistic regression model for predicting a person's attitude about the smart stove fire prevention products captures 37.2% of the variance in the data. When all the other predictors are controlled, perceived ease of use and perceived usefulness are statistically significant predictors of a better attitude toward the smart fire prevention products (*OR* values of 2.63 and 7.84, respectively). Unlike smart door locks, having an accessibility product (a raised toilet) already installed at home is positively associated with the attitude toward the product ($OR = 1.99$, $p < .01$). These findings may be explained by the understanding of the usefulness of the active living-supportive product due to having other

Table 4. Correlations with Attitude Toward and Intention to Use Smart Home Design Products ($n = 129$).

	Smart door lock		Smart lighting		Smart fire prevention		Home automation system	
Measure	Intention	Attitude	Intention	Attitude	Intention	Attitude	Intention	Attitude
Data collection	−0.186	−0.069	**−0.231***	−0.048	−0.099	0	−0.079	0.108
Age	**−0.274***	−0.201	**−0.296***	−0.156	−0.202	−0.134	**−0.253****	−0.031
Sex	−0.098	−0.143	−0.001	−0.043	−0.007	0.037	−0.146	−0.127
Education	**0.114***	**0.074***	**0.082***	0.023	0.087	0.118	−0.075	−0.139
# of people at home	0.180	0.070	0.069	0.023	−0.110	−0.112	0.027	0.021
Monthly income	0.120	0.062	0.026	0.081	0.008	0.064	−0.055	−0.056
Home type	−0.007	−0.038	−0.083	**0.026****	**0.046***	0.033	0.03	**0.116****
Home ownership	−0.131	−0.052	−0.19	−0.026	0.012	0.114	−0.057	0.029
HM:Grab bars in bathroom	−0.001	0.009	−0.028	0.13	0.067	0.133	0.011	0.078
HM:Roll-in shower	−0.106	−0.088	−0.154	−0.075	−0.093	0.009	−0.045	0.022
HM:Shower bench/chair	−0.051	0.027	−0.068	−0.113	−0.05	0.12	−0.046	0.092
HM:Raised toilet height	**−0.164***	**0.008***	**−0.226****	−0.025	−0.101	0.156	−0.158	0.036
HM:Ramp into home	−0.012	0.149	−0.086	−0.030	0.071	0.164	−0.041	0.007
HM:Level door handles	0.011	0.082	−0.005	0.060	−0.019	0.033	−0.063	0.001
HM:Widened door frames	−0.091	−0.045	−0.105	0.048	0.033	0.106	−0.048	−0.041
HM:Other	−0.004	0.020	0.003	−0.033	−0.019	−0.077	−0.077	−0.018
HM:None of the above	−0.006	−0.098	0.093	−0.081	0.001	−0.155	0.058	−0.109
Internet	−0.181	0.032	−0.146	0.030	−0.032	0.148	0.028	0.132
Cellphone	−0.177	−0.109	−0.159	−0.050	−0.098	−0.057	−0.065	0.000
Smart phone	−0.234	−0.151	−0.188	−0.147	−0.059	−0.010	−0.201	−0.014
Smart phone skills	−0.229	**−0.204****	**−0.262***	−0.165	−0.143	−0.089	**−0.169****	−0.045
Laptop/tablet skills	**−0.144***	−0.102	−0.172	−0.112	−0.111	−0.094	−0.103	0.064
Self-reported health	−0.060	−0.034	−0.082	0.022	−0.021	−0.020	0.016	0.071
Health interference	−0.192	−0.099	**−0.185****	−0.091	0.043	−0.023	−0.051	**−0.004***
ADL assistance	−0.064	0.001	0.074	−0.002	0.041	0.077	0.012	−0.082
IADL assistance	0.058	0.010	−0.016	−0.124	0.012	−0.167	0.019	−0.054
Vigorous PA	0.100	−0.071	0.143	−0.006	−0.005	−0.051	0.025	−0.082
Walking	0.084	0.026	0.124	0.043	−0.077	−0.063	−0.018	−0.097
Moderate PA	0.061	0.037	0.107	0.086	**−0.022***	0.032	−0.026	−0.067
Sedentary behavior	−0.039	0.075	−0.051	0.022	−0.008	−0.001	**0.000***	0.048
Perceived ease of use	**0.402****	**0.395****	**0.438****	**0.387****	**0.364****	**0.527****	**0.438****	**0.414****
Perceived usefulness	**0.660****	**0.647****	**0.649****	**0.667****	**0.577****	**0.588****	**0.628****	**0.583****
Perceived affordability	**0.309****	**0.154***	**0.301****	**0.253****	**0.256****	**0.211****	**0.266****	**0.115****
Attitude	**0.554****		**0.583****		**0.427****		**0.506****	

Note. Kendal's tau correlation coefficients presented. HM = home modification; ADL = activities of daily living; IADL = instrumental activities of daily living; PA = physical activity.
Chi-square test is used for significance, *$p < .05$, **$p < .01$. Significant correlations in bold.

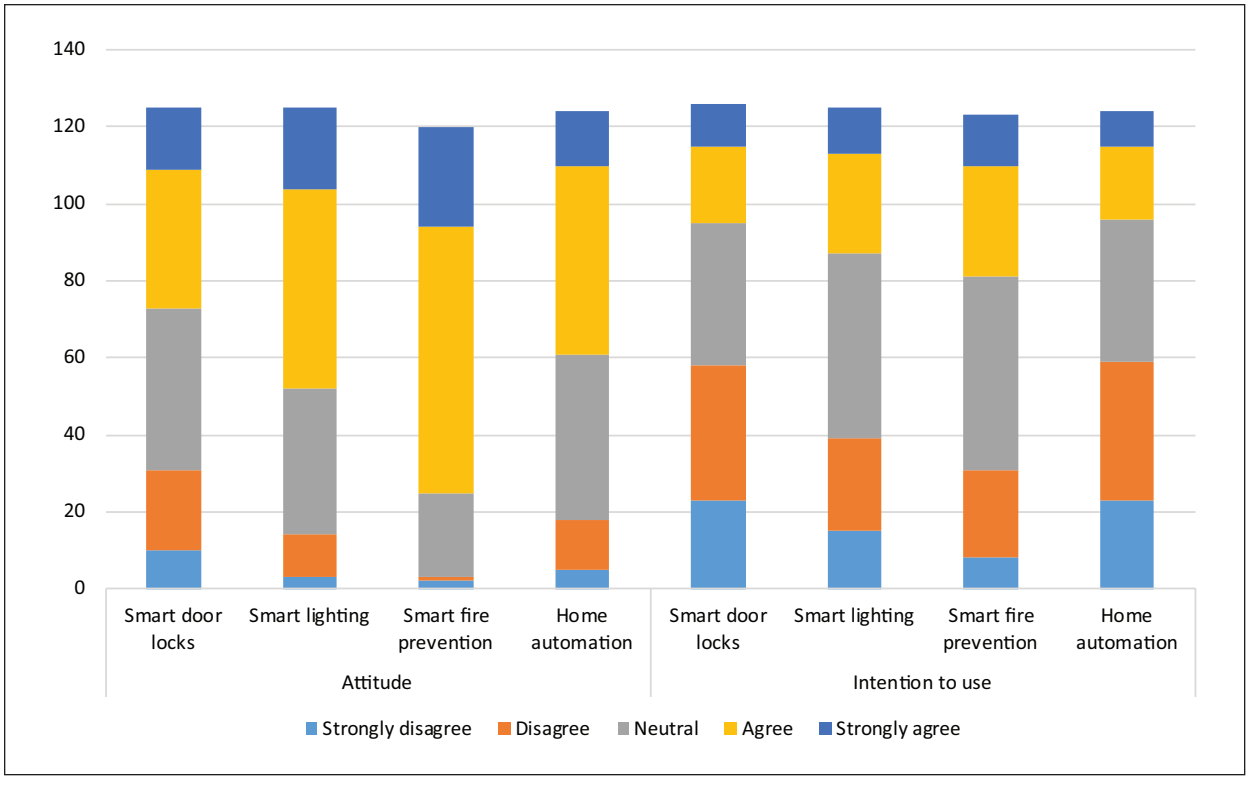

Figure 1. Ratings of smart home products for attitudes and intentions to use.

accessibility assistive products. As for health-related factors, people who reported having health issues interfere with their daily lives had a more negative attitude toward this product ($OR = .58$, $p < .05$).

The model for the intention to use a smart fire prevention product accounts for 25.7% of the variation in the response. Perceived usefulness and perceived affordability are positively associated with intentions to use the product ($OR = 7.56$, $p < .01$; and $OR = 1.51$, $p < .05$, respectively). The only demographic predictor that is negatively associated with the intention to use the fire prevention product is the education level ($OR = .94$, $p < .05$).

Home automation/smart home systems. The model used to predict a person's attitude towards a home automation/smart home system captures 31% of the variance in data. As for the individual smart home products, perceived usefulness is the strongest predictor of a better attitude toward a home automation/smart home system ($OR = 10.20$, $p < .01$).

The regression model predicts 42.6 % of the variance in intention to use home automation systems. Perceived usefulness, perceived ease of use and attitude are significant TAM predictors for higher intentions to use such systems. While younger people, females and smartphone owners are more likely to use the systems in future, higher levels of education and having more people living at home are negatively associated with higher odds of intention to use the products (see Table 5).

Qualitative Insights

The sociodemographic profile of our focus group participants were relatively similar to the survey respondents: All lived in attached or detached single-family housing, with 66% owning their homes. Among the three male and 12 female participants, the age distribution was as follows: three between 65 and 74 years old, 11 of them between the ages of 74 to 84, and one person aged 85 or older. The sample was highly educated, all but one with a college degree or higher, and 11 of them having a $5,000+ monthly income. Two-thirds reported having very good or excellent health, none requiring ADL or IADL assistance.

There was considerable variability in responses to the different products among the focus group participants. In line with the quantitative findings, the product that was viewed as the most favorable was the smart fire prevention product, due to its potential to provide increased safety in participants' daily lives. Smart lighting, for example, was viewed as a luxury product with no immediate perceived benefits. Although some participants held favorable opinions toward smart door locks and home automation systems, the others felt uncomfortable using these products for personal, financial, or technology-specific reasons.

Themes

The five themes emerged from the analysis of the focus group data regarding the factors that most influence

Table 5. Regression Models.

	Smart door lock				Smart lighting				Smart fire prevention				Home automation system			
Predictors	$\hat{\beta}$	*SE*	*OR*	95% CI	$\hat{\beta}$	*SE*	*OR*	95% CI	$\hat{\beta}$	*SE*	*OR*	95% CI	$\hat{\beta}$	*SE*	*OR*	95% CI
Attitude																
Gender													0.269	0.234	0.764	[0.48, 1.21]
Home ownership	−0.328	0.237	1.388	[0.87, 2.21]												
HM: Roll-in shower					0.295	0.198	0.745	[0.5, 1.1]								
HM: Raised toilet									−0.690**	0.241	1.993	[1.24, 3.2]	−0.432*	0.201	1.540	[1.04, 2.28]
HM: Widened door					−0.491*	0.215	1.634	[1.07, 2.49]								
Internet					0.645*	0.276	0.525	[0.31, 0.9]	0.594*	0.287	0.552	[0.31, 0.97]	0.760**	0.261	0.468	[0.28, 0.78]
Smartphone skills	−0.260	0.136	1.297	[0.99, 1.69]												
Self-reported health													0.376	0.257	0.687	[0.41, 1.14]
Health interference									0.550*	0.267	0.577	[0.34, 0.97]	0.540	0.279	0.583	[0.34, 1.01]
ADL assistance	−0.071	0.579	1.073	[0.34, 3.34]												
Vigorous PA	0.140	0.082	0.869	[0.74, 1.02]												
P. ease of use									−0.967**	0.295	2.631	[1.48, 4.69]				
P. usefulness	−2.152**	0.261	8.605	[5.16, 14.36]	−2.160**	0.275	8.672	[5.06, 14.87]	−2.059**	0.350	7.838	[3.95, 15.56]	−2.322**	0.293	10.195	[5.74, 18.11]
P. affordability					−0.443	0.188	1.557	[1.08, 2.25]								
R square (U)	0.322				0.338				0.372				0.310			
Chi Square	191.066				155.559				121.655				166.682			
AICc	246.194				231.014				171.377				240.757			
N	112				120				112				117			
Intention to use																
Age	0.444	0.243	0.642	[0.4, 1.03]					0.523	0.226	0.593	[0.38, 0.92]	1.138**	0.309	0.321	[0.17,0.59]
Gender													−0.621*	0.288	1.861	[1.06,3.27]
Education									0.064*	0.122	0.938	[0.74, 1.19]	0.752**	0.186	0.471	[0.33, 0.68]
# of people at home													0.897*	0.420	0.408	[0.18, 0.93]
Monthly income					0.500**	0.172	0.606	[0.43, 0.85]								
Home ownership	−0.484	0.260	1.623	[0.98,2.7]	−0.995**	0.282	2.704	[1.56, 4.69]	−0.051	0.248	1.052	[0.65, 1.71]	−1.062**	0.334	2.893	[1.5,5.57]
HM: Raised toilet					0.413	0.212	0.662	[0.44, 1]								
HM: Widened door	0.455*	0.211	0.635	[0.42,0.96]												
Internet													0.317	0.366	0.729	[0.36,1.49]
Cell phone									−0.373	0.461	1.453	[0.59, 3.58]	1.381	0.780	0.251	[0.05,1.16]
Smart phone													−0.969**	0.311	2.636	[1.43, 4.85]
Smartphone skills					0.389*	0.168	0.677	[0.49, 0.94]								
Self-reported health					0.574*	0.238	0.563	[0.35, 0.9]								
ADL assistance	−1.950**	0.653	7.028	[1.95,25.28]					0.013	0.610	0.987	[0.3, 3.26]				
IADL assistance					−0.463	0.332	1.588	[0.83, 3.04]					−0.643	0.404	1.902	[0.86, 4.2]
Vigorous PA													0.159	0.103	0.853	[0.7, 1.04]
Moderate PA									0.099	0.080	0.906	[0.77, 1.06]	−0.107	0.112	1.113	[0.89, 1.39]
P. usefulness	−2.018**	0.314	7.520	[4.06, 13.92]	−1.570**	0.308	4.808	[2.63, 8.8]	−2.022**	0.284	7.555	[4.33, 13.19]	−2.080**	0.408	8.005	[3.6, 17.8]
P. affordability	−0.391	0.155	1.479	[1.09, 2.01]					−0.410*	0.160	1.507	[1.1, 2.06]	−0.367*	0.183	1.443	[1.01, 2.07]
Attitude	−0.502	0.259	1.652	[0.99, 2.74]	−1.379**	0.329	3.972	[2.08, 7.58]					−0.711*	0.335	2.035	[1.06, 3.93]
R square (U)	0.395				0.400				0.257				0.426			
Chi square	188.361				192.817				229.822				173.393			
AICc	242.809				225.546				267.291				217.837			
N	118				111				115				100			

*$p < .05$. **$p < .01$.

community-dwelling older adults' attitudes and intention to use smart home features:

Technology skepticism. Older adults worry about the problems technology may cause in their homes, such as not being able to complete the tasks due to technology failure, as exemplified by an older female participant's question regarding the smart door lock: "*What if the battery goes down?*" This can partly be explained by lack of knowledge on how the technology works. For example, a male participant, P02 said, "*I don't believe [the smart fire prevention device] works with gas stoves at all.*" Even after the researchers explained that the device works with both gas and electric stoves, he insisted on his belief.

Some of this technology distrust originated from the feedback from other adopters:

> *P03 (female, late 70s): How many times you talked to someone very knowledgeable about smart homes, etc., they said "oh, something happened to my computer, my smart phone, and I lost everything. I lost all my information. How helpful is that?*
>
> Several participants: Yeah.

Another issue is the rapid changes in technology and the fear that an investment made in smart technologies today that may be obsolete in just a few years: "*If you have a smart house, the technology will change in just a few years. And what was the current thing now is going to be different*" (P01).

Privacy concerns. Smart home systems and individual smart home products are perceived as a threat to personal privacy and security. The participants' concerns relate to informational privacy, that is, the right to control access to personal data (Demiris et al., 2006). Aware of the recent privacy breaches of major companies, some older adults are cynical about smart home devices:

> *P02: [Smart homes are] conceptually fabulous, but I have real concerns about privacy. Somebody getting a hold of, hacking your smart home . . . really really serious. They already had, Amazon already had some privacy issues. It's not something I would run around and do right now.*

Other participants echoed that concern, referring to the Samsung refrigerator hacks, and how smaller companies, such as "*the little lock companies*" may not have even thought about such issues (P01). The discussion led to some participants stating that this was the reason they would not use such technologies. "*Until they get industry standards for security systems, I will run the other way*," one male participant (P02), who was a retired engineer, said.

Financial concerns and return on investment (ROI). Another factor influencing older adults' decisions is financial barriers, which relate to the initial cost of products and whether they would get a return on investment at resale. "*If I could afford it, I would. And cover all the bases. Put everything in place*," said a participant, appreciating the value of such smart home technologies for aging in place. However, the relatively high cost of these products remains as a concern, even for the older adults with higher incomes, such as the members of our focus group:

> *P10: So many seniors are living on a fixed income, and not sure how long we're gonna live, so I think everyone is concerned with money. And a lot of it isn't cheap. So I think a good portion of it is geared toward your upper-income seniors.*

Older adults, including the ones who are not financially stretched, have financial worries for the future, and thus, are hesitant in investing in technologies that would not necessarily "pay off." The question of "*would it be a good resale?*" was stated as a factor influencing the initial adoption decision (P08). As one female participant in her late 60s who recently went through selling a property stated:

> *P06: "When you do things like this, there is a smaller and smaller market. People want you to have nifty things like this, and very high-end finishes, but are not willing to pay for it. So if you're going to do it, you do it for yourself, and not necessarily expect to get a return on investment. Because it doesn't matter, what special things you have in terms of appraisal—they compare to the house next door."*

Usability and perception of need. Whether a product fits older adults' current lifestyles, needs and norms was one of the most cited reasons for intentions to use the product. For smart door locks and smart lighting, multiple participants mentioned they were not products they currently need, and not having them is not a problem. They were referred to "things nice to have," rather than "need to have." When one female participant (P11) highlighted a potential use for smart door locks, "*Look at Amazon, they are allowing you to give codes to people and people who deliver your packages are allowed to get into your house*," numerous participants approved the suitability of the product for their daily lives.

For home automation systems and smart fire prevention devices, participants discerned between technologies that they would use themselves versus technologies that would be helpful to others. In response to the idea of operating homes from far through home automation systems, while two participants indicated that they were retirees who spend most of their time at home, and do not need to or want to operate anything from far, another participant mentioned a potential benefit of the systems for others:

> *P06: I have some friends who have two homes. He watches from his smart phone if his home watch person goes in, have they been there, have they actually done anything, before he pays them.*

As for the fire prevention device, when a younger participant mentioned the usability of the product for "*a parent who is starting to have dementia*" as a remedy to "*one of the big fears for children who're starting to take care of parents*" (P09), several others chimed in on the usefulness of the device for their own lives:

> *P04 (female, early 70s): As important as smoke detectors. Something that should be at least in all of the townhouses.*
>
> *P05 (female, late 70s): I bought a gas detector, because we have gas and my husband cannot smell it. So this would be wonderful.*
>
> *P11 (female, early 80s): With stoves, besides dementia, as we get older, we all get problems with multitasking, we are doing something, then a phone call with someone dying, and this and that, so it's a little hard to try to keep all the ducks in a row [laugher]. If you get engaged in some conversation, and it's not like you're demented and the stove has some problems, but you know, the whole thing,. . . as we get older, the multitasking. . ."*

Ease of use. Lastly, confidence in learning and being able to use the smart technology easily is a factor that influences older adults' willingness to use the products. The participants who shared their unease stated that not understanding the technology and not knowing how to operate it "could be concern" for some people. "*I may have trouble with it*," mentioned a female participant. "*How many passwords do I have to remember?*" asked another (P03). One participant highlighted the difficulties of learning new technologies as people age: "*Five years matter. When computers came about, all my brain was sealed* [chuckles]" (P08).

Discussion and Conclusions

This study is one of the few mixed-methods studies that examined the relationships between a range of demographic, self-reported health and physical activity, and TAM variables and older adults' attitudes toward and intentions to use smart home technology products. While factors associated with attitudes and intentions to use smart home technologies are to some extent dependent on the type of the product, certain factors are significant predictors regardless of the technology. In line with previous research, perceived usefulness, perceived ease of use and perceived affordability exhibited strong and significant correlations with attitudes and intentions to use smart home products.

Our regression analyses confirm the relevance of the key TAM factor, perceived usefulness, in predicting older adults' attitudes among all examined smart home technologies, and their intentions to use them in their homes. The "usability and perception of need" theme from our focus groups support this finding and offer additional insights. The focus group participants were very clear in differentiating whether a product would be something useful in their daily lives, something that may be helpful for others, or a vanity, that is, perception of no need. The perception of usefulness as a key determinant is consistent with previous research on adoption of smart home technologies and aging-in-place technologies (Balta-Ozkan et al., 2013; Marikyan et al., 2019; Peek et al., 2014). Stating the usefulness of the technology for others or a hypothetical other older person was observed in other research as well (Demiris et al., 2008). An important finding of our study is the difference in perceptions of usefulness, and consequently, willingness to use the technologies according product types. Both the survey respondents and focus group participants held views that are more favorable toward safety/security products, represented by the smart fire prevention device, more easily grasping the benefits of that product in their household activities.

Costliness of aging-in-place products was identified as a barrier to technology adoption in several studies (Balta-Ozkan et al., 2013; Carnemolla, 2018; Peek et al., 2014; Yusif et al., 2016). As confirmed by our quantitative results, perceived affordability was a significant predictor in intentions to adopt home automation systems and smart fire prevention products. Our focus group findings supported the initial cost of the smart home products as an important factor, highlighting that even adults who have higher incomes may not prioritize smart home technology investment in their expenditures. A relevant contribution of our study is the "return-on-investment" aspect among the financial concerns. Since many older adults downsize or sell their homes to move into institutional residential settings, whether they can get a return on investment during property resale was found to be a reason for investing in smart home technologies.

Privacy and security of personal information seem to be a core issue for willingness to use smart home products as also highlighted by others (Chung et al., 2016; Marikyan et al., 2019; Peek et al., 2016). The distrust among older adults in technology and manufacturers' intent and ability to protect their private data along with the lack for legal conduct was a common theme in the focus group discussions for each smart home product.

The study findings also acknowledge the ease of use as a factor for attitude and intention to use. While this finding is in line with previous studies (Peek et al., 2014; Yusif et al., 2016), a difference worth mentioning is the variable's lack of predictive power in our ordinal regression analyses for any of the product. However, the frequent mentioning of ease of use and learning may point to the relevance of how the products and information regarding the technologies are presented to older adults. We predict that the discrepancy between the survey and focus group findings relate to older adults' opportunity to see and test the products in real life before the discussions versus getting the information through text and video clips when

taking the survey. An implication of this would be the importance of providing opportunities to older clients to try out the technologies to make decisions that are more informed.

As for demographic factors, our findings indicated that being male and increasing age decreased the intentions to use home automation systems. Homeownership increased the intentions to use smart home systems as well. These findings confirm previous research on smart home technology adoption (Arthanat et al., 2019). When the number of people living at home increased, the willingness to use such technologies lessened. This outcome also aligns with previous research (Peek et al., 2014) and suggests that possibility of assistance by other household members can negatively influence the attitude toward aging-in-place technologies. Regarding the tech-savviness factors, our sample had a higher rate of smartphone ownership (62%) in comparison to the 42% national ownership rates (Pew Research Center, 2017). Smartphone ownership was identified as a factor related to higher intentions to use smart home systems. This is in sync with previous research that confirmed the increased likelihood of smart home technology adoption among older adults with exposure and access to advanced ICT, including smartphones (Arthanat et al., 2019).

The digital divide construct is significant for examining the opportunities for aging in place through smart home technologies as those older adults who adopt such technologies will be advantaged. As underscored by Elliott (2019), the barrier to the digital divide is not only access as once thought and it is more of a usability issue due to reasons including prior knowledge, motivation, social support, and technological skill. Along with the other theoretical frameworks, the TAM constructs we utilized in this study were useful in examining the factors that influence attitudes and behavioral intentions of technology-enabled side of the digital divide. On the other hand, the qualitative part of the study provided some empirical evidence on reasons for non-adoption even among technology-enabled side of the digital divide. As our sample had high rates of technology access and self-reported technology skills, coupled with their higher education and income levels compared to the overall older adult population, our research also confirms the complexities of the digital divide, and other factors that may play a role in attitudes and behavioral intentions to use. In that sense, it demonstrates that the digital divide is not static, but influenced by individual factors as well as the type of smart technology.

While our study provides insights into smart home technology acceptance among older adults, the following limitations should be addressed in future studies. First, we acknowledge the geographical limitation of the study, and self-selection bias. Our sampling for the online portion of the survey through the university's older adult registry led to overrepresentation of older adults with higher educational attainment and income levels, compared to the general US population. Our sampling strategy also led to a rather homogenous focus group participants who lived in the same community, had similar demographic characteristics, and might have previously known or interacted with each other. That could have limited the provision of different perspectives during the discussions. The number of products they evaluated also limited the time reserved specifically for smart home technologies. In future, a more heterogenous group reflecting on a smaller number of products may provide richer information with multiple points of view and help identify variables related to such differences. Secondly, the smart home technologies selected for this study represented a range of products that may support safe and active living at home with varying cost ranges but did not capture all product domains. Particularly, the inquiry into the smart home/home automation system that could be customized in multiple ways at varying cost ranges as presented in the survey would not have provided a comprehensive picture older adults' attitudes and behavioral intentions. Future studies should confirm our findings with different smart home products, and with more detailed system configurations. Lastly, the research project and the data collection instruments involved a range of aging-in-place technologies in addition to the smart home technology products due to the exploratory nature of the study. This limited the number of measures of each factor for feasibility purposes, relying on previously validated questions. Further research will need to confirm these preliminary findings, utilizing multiple items for each measure. The number of smart home technology products are growing and hold vast potential for supporting active lifestyles at home. In light of older adults' increasing interest in, coupled by low adoption rates of such technologies, further research in this area will remain relevant for design and marketing of smart home technologies among older adults.

Appendix 1

Survey

Part 1

1. What type of home best describes where you live?
   - □ House
   - □ Mobile home
   - □ Apartment
   - □ Townhouse /Duplex
2. Do you own your current home or are you making payments toward owning it?
   - □ Yes □ No □ I do not know
3. Which of the following home features are in your current home? (check all that apply)

□ Grab bars in bathroom □ Roll-in shower
□ Shower bench /chair □ Raised toilet height
□ Ramp into home □ Lever door handles
□ Door frames wide enough for a wheelchair □ Other (please list): _____
□ *I do not have any of these features in my home*

4. Do you have internet service in your home?
□ Yes □ No □ I do not know
5. Do you have a cell phone (mobile phone)?
□ Yes □ No
If yes: Is your cell phone a smart phone?
□ Yes □ No □ I do not know
6. How would you rate your skills using a smartphone?
□ Excellent: I need no help
□ Very good: I need occasional help learning to use an app or feature
□ Good: Sometimes I need help, sometimes I don't
□ Fair: I need someone to remind me how to use it every time I try
□ Poor: I do not have smartphone skills, or I have never used one and I do not know
7. How would you rate your skills using a laptop, tablet, or desk computer?
□ Excellent: I need no help
□ Very Good: I need occasional help learning new programs or dealing with a virus
□ Good: Sometimes I need help, sometimes I don't
□ Fair: I need someone to remind me how to use it every time I try
□ Poor: I do not have computer skills, or I have never used one and I do not know
8. My age is:
□ 50–64 years. □ 65–74 years.
□ 75–84 years. □ 85+ years.
9. I am:
□ Male □ Female
10. I consider my health to be:
□ Excellent □ Very Good □ Good
□ Fair □ Poor
11. How much does you current health interfere with what you want to do?
□ Not at all □ Not very much
□ Somewhat □ A great deal
12. Because of any impairments or health problems, do you need help from other persons with your:
    a. Personal care needs (e.g., eating, bathing, dressing, or getting around the home)?
    □ Yes □ No □ I do not know
    b. Routine needs (e.g., everyday household chores, paying bills, shopping, or getting out in the community)?
    □ Yes □ No □ I do not know
13. During the last 7 days, how many days did you. . .
    a. Engage in strenuous activity (e.g., heavy lifting, digging, aerobic exercise, heavy gardening) for at least 10 minutes at a time? (circle number of days) 0 1 2 3 4 5 6 7
    b. Walk for at least 10 minutes at a time? (circle number of days) 0 1 2 3 4 5 6 7
    c. Engage in moderate activity (e.g., carrying light loads, moderate housework or gardening, but NOT WALKING) for at least 10 minutes at a time? (circle number of days) 0 1 2 3 4 5 6 7
14. During the last 7 days, how much time did you spend sitting (e.g., watching TV, reading, sitting at a table or desk, lying down to watch TV) each day?
_____ hours per day
15. What is the highest grade or year in school that you have completed?
□ Up to 8th grade
□ Some high school
□ High school diploma or GED certificate
□ Some technical school
□ Some college
□ College graduate
□ Post graduate or professional degree
□ I do not know
16. How many people do you live with in your home?
□ 0 (I live alone)
□ 1 other person
□ 2 or more other people
17. What is your monthly household income (from all sources AND people living with you)?
□ less than $1,000 / mo.
□ $1,000–1,999 / mo.
□ $2,000–2,999 / mo.
□ $3,000–4,999 / mo.
□ $5,000+/ mo.

In the following section, we will ask about your opinions on some design features and technologies that may support health, safety and wellbeing of people who would like to age in their homes. There will be pictures, videos and/or diagrams to demonstrate each product, and we will ask you to rate them.

Part 2 (A page was included for each product). PRODUCT NAME: Product description. [Product image and/or video link]

I currently have a [product name] in my home:
□ Yes □ No □ I do not know

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think that learning to use a [product name] was / will be easy.	1	2	3	4	5
I think that a [product name] is /could be helpful for me.	1	2	3	4	5
There is a good possibility that I will use a [product name] in my home in the future.	1	2	3	4	5
In general, I think using a [product name] is a good idea.	1	2	3	4	5
The current cost range of buying a [product name] is $ – $. If you need professional installation, $ will be added to that cost. I could afford a [product name] if I decided to use it in my home.	1	2	3	4	5

Appendix 2

Focus Group Questions

1. What are the biggest challenges you face in completing your daily activities in your home, such as cooking, cleaning, gardening, and such?
   a. What types of assistance do you currently use to help you complete your tasks?
   b. Have you used any of the products presented today?
   c. In what ways can technology help with alleviate some of these challenges?
   d. Describe for us a technology or a product re-design that would help make the activities that challenge you easier.
2. Next, we would like to quickly review the products displayed and get your feedback on them
   For each product –
   a. What do you like about it?
   b. What don't you like about it?
   c. How would you feel about using this at home now or in future?
   d. What might be the biggest factor that would prohibit people from using it?
   e. Any other comments you would like to share about this product, which you think we need to know?
3. Do you have anything else you would like to bring up now related to use of technology for aging at home?

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This project was supported by the American Society of Interior Designers (ASID) Foundation, and Virginia Tech Open Access Subvention Fund.

ORCID iD

Elif Tural https://orcid.org/0000-0002-8850-8276

References

AARP. (2018). *2018 home and community preferences survey: A national survey of adults age 18-Plus*. AARP Research.

Arthanat, S., Wilcox, J., & Macuch, M. (2019). Profiles and predictors of smart home technology adoption by older adults. *Otjr: Occupation, Participation and Health*, *39*(4), 247–256. https://doi.org/10.1177/1539449218813906

Balta-Ozkan, N., Davidson, R., Bicket, M., & Whitmarsh, L. (2013). Social barriers to the adoption of smart homes. *Energy Policy*, *63*, 363–374. https://doi.org/10.1016/j.enpol.2013.08.043

Barnard, Y., Bradley, M. D., Hodgson, F., & Lloyd, A. D. (2013). Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Computers in Human Behavior*, *29*(4), 1715–1724. https://doi.org/10.1016/j.chb.2013.02.006

Berkowsky, R. W., Sharit, J., & Czaja, S. J. (2018). Factors predicting decisions about technology adoption among older adults. *Innovation in Aging*, *1*(3): 1–12. https://doi.org/10.1093/geroni/igy002

Brookfield, K., Fitzsimons, C., Scott, I., Mead, G., Starr, J., Thin, N., Tinker, A., & Ward Thompson, C. (2015). The home as enabler of more active lifestyles among older people. *Building Research and Information*, *43*(5), 616–630.

Burnham, K. P., & Anderson, D. R. (2002). *Model selection and multimodel inference: A practical information-theoretic approach* (2nd ed.). Springer-Verlag.

Carnemolla, P. (2018). Ageing in place and the internet of things—how smart home technologies, the built environment and caregiving intersect. *Visualization in Engineering*, *6*(1), 1–16. https://doi.org/10.1186/s40327-018-0066-5

Cavanaugh, J. E. (1997). Unifying the derivations for the Akaike and corrected Akaike information criteria. *Statistics & Probability Letters*, *3*(2), 201–208.

Chen, K., & Chan, A. H. S. (2011). A review of technology acceptance by older adults. *Gerontechnology*, *10*(1), 1–12. https://doi.org/10.4017/gt.2011.10.01.006.00

Chen, K., & Chan, A. H. S. (2014). Gerontechnology acceptance by elderly Hong Kong Chinese: A senior technology acceptance model (STAM). *Ergonomics*, *57*(5), 635–652. https://doi.org/10.1080/00140139.2014.895855

Chung, J., Demiris, G., & Thompson, H. J. (2016). Ethical considerations regarding the use of smart home technologies for older adults: An integrative review. *Annual Review of Nursing Research*, *34*(1), 155–181. https://doi.org/10.1891/0739-6686.34.155

Cisneros, H., Martinez, M., Schwartz, A., & Weber V. (2015). *America's growing senior population: Assessing the dimensions of the demographic challenge*. Bipartisan Policy Center Health and Housing Task Force. https://bipartisanpolicy.org/wp-content/uploads/2019/03/BPC-Housing-Health-Senior-Population.pdf

Creswell, J. W. (2015). *Revisiting mixed methods and advancing scientific practices*. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199933624.013.39

Creswell, J. W., & Clark, V. (2011). *Designing and conducting mixed methods research* (2nd ed.). SAGE.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *Mis Quarterly*, *13*, 319–340. https://doi.org/10.2307/249008

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*, 982–1003. https://doi.org/10.1287/mnsc.35.8.982

Demiris, G., Oliver, D. P., & Courtney, K. L. (2006). Ethical considerations for the utilization of tele-health technologies in home and hospice care by the nursing profession. *Nursing Administration Quarterly*, *30*(1), 56–66.

Demiris, G., Oliver, D. P., Dickey, G., Skubic, M., & Rantz, M. (2008). Findings from a participatory evaluation of a smart home application for older adults. *Technology and Health Care: Official Journal of the European Society for Engineering and Medicine*, *16*(2), 111–118.

DiMaggio, P., Hargittai, E., Celeste, C., & Shafer, S. (2001). *From unequal access to differentiated use: A literature review and agenda for research on digital inequality*. https://www.russellsage.org/research/reports/dimaggio

Elliott, L. J. (2019). The digital divide and usability. In H. C. Lum (Ed.), *Critical issues impacting science, technology, society (STS), and our future* (pp. 197–217). IGI Global.

Humphreys, C. (2018). Can smart home technology support older people? *British Journal of Community Nursing*, *23*(9), 435–438. https://doi.org/10.12968/bjcn.2018.23.9.435

Jellesmark, A., Herling, S. F., & Egerod, I. (2012). Fear of falling and changed functional ability following hip fracture among community-dwelling elderly people: An explanatory sequential mixed method study. *Disability and Rehabilitation*, *34*(25), 2124–2131. https://doi.org/10.3109/09638288.2012.673685

Kakulla, B. (2019). *2020 tech trends of the 50+*. AARP Research.

Kuo, Y. F., & Yen, S. N. (2009). Towards an understanding of the behavioral intention to use 3G mobile value-added services. *Computers in Human Behavior*, *25*(1), 103–110. https://doi.org/10.1016/j.chb.2008.07.007

Liu, L., Stroulia, E., Nikolaidis, I., Miguel-Cruz, A., & Rios Rincon, A. (2016). Smart homes and home health monitoring technologies for older adults: A systematic review. *International Journal of Medical Informatics*, *91*, 44–59. https://doi.org/10.1016/j.ijmedinf.2016.04.007

Loges, W. E., & Jung, J.-Y. (2001). Exploring the digital divide: Internet connectedness and age. *Communication Research*, *28*(4), 536–562.

Macedo, I. M. (2017). Predicting the acceptance and use of information and communication technology by older adults: An empirical examination of the revised utaut2. *Computers in Human Behavior*, *75*, 935–948. https://doi.org/10.1016/j.chb.2017.06.013

Malterud, K. (2012). Systematic text condensation: A strategy for qualitative analysis. *Scandinavian Journal of Public Health*, *40*(8), 795–805. https://doi.org/10.1177/1403494812465030

Marikyan, D., Papagiannidis, S., & Alamanos, E. (2019). A systematic review of the smart home literature: A user perspective. *Technological Forecasting & Social Change*, *138*, 139–154. https://doi.org/10.1016/j.techfore.2018.08.015

Marston, H. R., Genoe, R., Freeman, S., Kulczycki, C., & Musselwhite, C. (2019). Older adults' perceptions of ICT: Main findings from the technology in later life (till) study. *Healthcare*, *7*(3), 86. https://doi.org/10.3390/healthcare7030086

Mitzner, T. L., Boron, J. B., Fausset, C. B., Adams, A. E., Charness, N., Czaja, S. J., Dijkstra, K., Fisk, A. D., Rogers, W. A., & Sharit, J. (2010). Older adults talk technology: Technology usage and attitudes. *Computers in Human Behavior*, *26*(6), 1710–1721. https://doi.org/10.1016/j.chb.2010.06.020

Orillaza, J, Orillaza, L., & Barra, A. (2014). *Consumer acceptance of prepaid metering and consumer preferences* [Conference session]. IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), Kowloon, Hong Kong, pp. 1–5.

Peek, S. T. M., Wouters, E. J. M., van Hoof, J., Luijkx, K. G., Boeije, H. R., & Vrijhoef, H. J. M. (2014). Factors influencing acceptance of technology for aging in place: A systematic review. *International Journal of Medical Informatics*, *83*(4), 235–248.

Peek, S. T., Wouters, E. J., Luijkx, K. G., & Vrijhoef, H. J. (2016). What it takes to successfully implement technology for aging in place: Focus groups with stakeholders. *Journal of Medical Internet Research*, *18*(5), 98. https://doi.org/10.2196/jmir.5253

Pew Research Center. (2017). *Tech adoption climbs among older adults*. https://www.pewresearch.org/internet/2017/05/17/tech-adoption-climbs-among-older-adults/

Sallis, J., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual Review of Public Health*, *27*, 297–322. https://doi.org/10.1146/annurev.publhealth.27.021405.102100

Selwyn, N. (2004). Reconsidering political and popular understandings of the digital divide. *New Media & Society*, *6*(3), 341–362.

Turjamaa, R., Pehkonen, A., & Kangasniemi, M. (2019). How smart homes are used to support older people: An integrative review. *International Journal of Older People Nursing*, *14*(4), 12260. https://doi.org/10.1111/opn.12260

Van Dijk, J. A. G. M. (2006). Digital divide research, achievements and shortcomings. *Poetics*, *34*, 221–235.

van Hoof, J., Kort, H. S. M., Rutten, P. G. S., & Duijnstee, M. S. H. (2011). Ageing-in-place with the use of ambient intelligence technology: Perspectives of older users. *International Journal of Medical Informatics*, *80*(5), 310–331.

Vehovar, V., Sicherl, P., Husing, T., & Dolnicar, V. (2006). Methodological challenges of digital divide measurements. *Information Society*, *22*(5), 279–290.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *Mis Quarterly*, *27*(3), 425–478.

Viherä, M.-L., & Nurmela, J. (2001). Communication capability as an intrinsic determinant for information age. *Futures*, *33*(3), 245–265. https://doi.org/10.1016/S0016-3287(00)00070-7

Wei, K.-K., Teo, H.-H., Chan, H. C., & Tan, B. C. Y. (2011). Conceptualizing and testing a social cognitive model of the digital divide. *Information Systems Research*, *22*(1), 170–187. https://doi.org/10.1287/isre.1090.0273

Wu, J. H., & Wang, S. C. (2005). What drives mobile commerce? An empirical evaluation of the revised technology acceptance model. *Information Management*, *42*, 719–729. http://dx.doi.org/10.1016/j.im.2004.07.001

Yusif, S., Soar, J., & Hafeez-Baig, A. (2016). Older people, assistive technologies, and the barriers to adoption: A systematic review. *International Journal of Medical Informatics*, *94*, 112–116. https://doi.org/10.1016/j.ijmedinf.2016.07.004