

## The influence of culture on older adults' adoption of smart home monitoring

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*R.L. Fritz, C.L. Corbett, R. Vandermause, D. Cook. The influence of culture on older adults' adoption of smart home monitoring. Gerontechnology 2016;14(3):146-156; doi:10.4017/gt.2016.14.3.010.00* **Background** Older adults' acceptability of smart homes that learn their motion patterns and can take an action on their behalf has received little attention. This interdisciplinary study explored the influence of culture on older adults' adoption of smart home monitoring. **Method** In-depth email interviews were used with a purposive sample of US older adults (n=21) age 65 and older. Participants were asked to prospectively consider the question of adoption of a smart home that combines artificial intelligence software with sensor monitoring for the purpose of maintaining safety and health of the community-dwelling older adult. Content analysis, consistent with the qualitative descriptive methodology, was used to organize data into low-inference themes. Themes were iteratively evaluated and consensus among the research team was achieved. **Results and discussion** Themes that emerged from rich text and were supported with participants' own words were privacy, pride and dignity, family, trust, being watched, human touch, features and functionality, cost, and timing. Participants were asked to self-identify their own culture of socially constructed values, which were found to heavily inform perceptions of privacy, independence, and family. Many participants indicated a prospective openness to smart home interventions, including monitoring. Openness depended on (i) the level and specificity of need and whether the smart home would meet that need, (ii) perceived loss of privacy compensated by a feeling of safety and a receipt of health-assistance, (iii) functionality, and (iv) cost. Findings from this study explicate and illuminate older adults' perceptions and descriptions of smart home monitoring, the relation to their own socially constructed values, and the influence on a decision to adopt or not adopt smart home monitoring. Findings may be used to inform the design of future smart homes, marketing, clinical practice and education, health policy, interdisciplinary collaboration, and research.

**Keywords:** older adults, smart home, monitoring, adoption, culture

The growing aging population in the United States is a complex humanitarian issue and society can no longer afford a status quo approach to care. The overwhelming majority of older adults in the United States (88%) indicate a desire to remain in their homes as they age<sup>1</sup>, yet there will not be enough healthcare workers to provide home-based care, and the associated costs are expected to rise significantly<sup>2</sup>. Innovations to promote community-dwelling older adults' abilities to safely 'age in place' are needed. Cost-effective solutions that will improve outcomes and decrease demands on healthcare workers, while providing choices for residential living, safety, and quality of life, are also needed<sup>3,4</sup>.

Smart homes are an innovative solution that may assist older adults with 'aging in place', however, many smart homes do not explicitly address user needs, a requirement of older adult users<sup>5</sup>. Smart

homes are designed by engineers, who are digital natives, for use by older adults, who are not digital natives leaving a potential technology end-user gap. Furthermore, clinical interventions used by older adults often do not consider the complex cultural and contextual issues faced by this population<sup>6</sup>. Exploring the influence of culture in relation to smart home adoption is important because the home is the primary place where freedom exists for full expression of one's culture and where if interrupted, may decrease quality of life and increase vulnerability. The question of culture as it relates to smart home adoption has not previously been addressed.

This qualitative descriptive study explored the solution of smart home monitoring and the influence of culture on older adults' decisions to adopt monitoring. The research was interdisciplinary, combining knowledge from the fields of engineering and

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nursing. Through the lens of socially constructed values and beliefs, the purpose of this research was to explore older adults' perceptions and descriptions of smart home monitoring, discover factors that might influence adoption of smart home monitoring, and empower older adults by encouraging them to share their views. Research questions were: (i) What is commonly known about smart home monitoring by older adults? (ii) What are older adults' perceptions and descriptions of smart home monitoring? (iii) What are the influencing factors in older adults' decisions to adopt smart home monitoring? (iv) How do older adults' perceptions of their own socially constructed values and beliefs influence their decisions to adopt or not adopt smart home monitoring? Specific aims were to explicate and illuminate older adults' perceptions and descriptions of smart home monitoring as these relate to self-identified culturally based expectations, and to understand the influence of socially constructed predictors and barriers to adoption of smart home monitoring.

## SMART HOMES

The term 'smart home technology' is used in a variety of ways and may refer to smart appliances within the home or health-assistive technologies such as medication reminder systems and telemonitoring. The smart home of interest in this study was the Washington State University Center for Advanced Studies in Adaptive Systems (CASAS) smart home. In this study, the term 'smart home monitoring' was defined as an intelligent agent that "perceives its environment through the use of sensors, and can act upon the environment through the use of actuators"<sup>7</sup>. The sensors referred to in this study were unobtrusive, non-video, non-wearable, and did not require action by the older adult. They were identified as non-video motion-activated sensory units that would be placed on the ceiling and walls of the home and provide quantitative information about the state of the environment within the home.

Common environmental sensors in the CASAS smart home include motion, heat, light, and contact. The smart home uses quantitative data mined with software algorithms to identify changes in activity and motion patterns. Detected changes may indicate a change in health status supporting the need for an intervention(s) on behalf of the older adult. Examples of smart home interventions include alerting family, a friend, or a healthcare worker of a change in health status needing further assessment, turning off a burner, or verbal prompting to promote medication adherence.

## AGING AND INDEPENDENCE

Safety and comfort are a concern for the community-dwelling older adult and housing envi-

ronments need to change as people age<sup>8</sup>. Over time, the process of aging can create changes in older adults' abilities related to activities of daily living, self-management of health conditions, and socialization. When an acute change in health status occurs that requires intervention by a healthcare provider, nurses can evaluate the home environment to which the older adult will return making recommendations or instituting changes to improve the health, safety, and quality of life for community-dwelling older adults.

Health-assistive smart home technologies such as unobtrusive monitoring with interpretive software that can take an action on behalf of a resident are designed to improve safety and comfort for those who wish to age in place. Although major decisions such as leaving the home for an assisted living facility or staying at home with health-assistive technology each carry a set of risks and benefits, expanding options from which older adults can choose is important. Health-assistive smart home environments are one evolving option. Nurses coordinating care, evaluating home environments, and educating older adults and their families regarding intervention options will increasingly be able to use health-assistive smart environments as a resource. Health-assistive smart homes may improve quality of life for the large number of older adults who remain at home despite functional limitations and may decrease rising costs associated with injuries and declining health.

## THEORETICAL FRAMEWORK

### Importance of language

Three main theories frame current discussions on acceptance of smart technology: Unified Theory of Acceptance and Use of Technology<sup>9,10</sup>, Technology Acceptance Model<sup>11</sup>, and the Almere Model<sup>12</sup>. Each of these theories falls within a Cartesian framework, which fits well with a multifactorial experimental study design, but is not a good fit for descriptive or interpretive methodologies, and were not used in this study. Rogers' 'Diffusion of innovation'<sup>13,14</sup> theoretically framed this study because it includes language important to the theoretical and methodological coherence of the study. Qualitative descriptive methodologies highlight language to promote the contextual understanding of human perceptions and experiences and the interpretation of meaning<sup>15,16</sup>. Language (words) used by Rogers and considered important to the study design were 'culture', 'population', and 'adoption'.

Historically, there is a direct connection in Rogers' language between culture and adoption. Furthermore, the language of adoption refers to a population instead of an individual, which aligned with the study's aim of exploring adop-

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tion of a technology in the older adult population. The word 'adoption' is preferred over the word 'acceptance', which is used in theories such as the Unified Theory of Acceptance and Use of Technology and Technology Acceptance Model, because 'adoption' infers a literal action without judgment; judgment may be inferred with use of the word 'acceptance'. The word 'acceptance' and its antonym 'refusal' imply an action that may be in reference or deference to a professional recommendation.

This study explores smart home monitoring, which may or may not feel comfortable to older adults, and which may be recommended by a professional at some point in the future. Discomfort with being monitored in one's own home is neither right nor wrong. It may be possible to adopt a technology based on need without fully 'accepting' it. Therefore, use of the word 'adoption' is preferred.

## Diffusion of Innovation theory

Diffusion of Innovation Theory<sup>13</sup> offers three valuable insights: (i) it identifies what qualities make an innovation spread through a social system, (ii) it highlights the importance of communication channels among a social system, and (iii) it helps with understanding the needs of different segments of the potential users of a social system. It is a well-honed and well-used theory developed in the 1950s by Everett M. Rogers with many cross applications to various populations.

Diffusion is defined as a process through which an innovation is spread through a social system<sup>13</sup>. Adopters fall into the different categories based on perceptions that regard managing risk. Categories in which a person might be classified are 'innovator', 'early adopter', 'early majority', 'late majority', or 'laggard'. The majority of people in a social system fall into the early or late majority segments of the population. The earlier one adopts the more risk one incurs. Late and laggard adopters incur a relatively small amount of risk. This study focused on early and early majority adopters because health-assistive technologies, such as smart homes, are new and require some risk management<sup>17</sup>. Because smart home technology has not yet been shown to be beneficial to older adults (i.e., a 'proven technology'), it will be perceived as 'risky' by older adults<sup>18</sup>.

## Person-centered care

The nursing model of 'Person-Centered Care'<sup>19</sup> also informs this work and supports the theoretical and methodological coherence of this study in which culture is defined in neoteric terms. The philosophy of 'Person-Centered Care' encompasses a value-driven focus on the person

to whom care is provided within a healthcare delivery system of managed care<sup>19</sup>. Person-centered care places the focus on the *person*, not just their healthcare needs or available delivery systems. There is solid evidence that person-centered care improves the quality of care and reduces cost<sup>20</sup>. A person-centered model of care frames the discussion on culture as it relates to future delivery of healthcare through health-assistive smart home monitoring. Application of this model allows for conceptualization of a neoteric use of the word 'culture' as 'self-identified' and not the generally accepted categories such as race, ethnicity, gender, or religion. It highlights personhood and allows one to identify his or her culture in his or her words, such as the culture of 'engineering' or 'small town American girl'.

## METHODS

This study received exempt status from the researcher's university Institutional Review Board.

## Situated philosophy

A post-positivist, interdisciplinary, and openly inquisitive qualitative discovery process was used in this study. Rogers' 'Diffusion of Innovation Theory', person-centered care, and a neoteric definition of culture as self-identified, guided the discovery process. The researcher embraced qualitative descriptive traditions handed down from the Husserl line of philosophers<sup>21</sup> who highlighted the value of in-depth interviews and the description of human experiences by discovering the how, who, what, where, and when<sup>15,21</sup>.

## Sampling

The sample was purposive and voluntary and included 21 English speaking older adults living in the United States who were age 65 and over. Participants had internet access and were regular users of a personal email address. Email was used as an inclusion criterion to narrow potential participants to those with a minimum level of exposure to computers and the Internet. Maximum variation of sampling was sought to provide broad insight<sup>22</sup> into understanding the influence of culture on the adoption of smart home monitoring. To obtain maximum variation in the sample the researcher sought to include a wide variety of older adults. Older adult participants were sought from a variety of living environments (remote, rural, urban), as well as those with a variety of life experiences (e.g. immigrant, race, religion, age, gender, comfort level with technology, and so forth). Participants were excluded if there was a suspicion or reported history of cognitive impairment.

Recruitment was done by phone or email via the researcher's circle of influence of known or rec-

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ommended contacts. A snowball effect was accomplished. The sample for this study includes a relatively high number of healthy older adults (Table 1).

## Data collection procedures

Data collection was attained by in-depth asynchronous email interviews<sup>23</sup> and included both discrete and non-discrete unstructured text based data. Discrete data regarding participant demographics were collected in initial email exchanges. Subsequent email exchanges included open-ended questions, which resulted in short-answer, paragraphed, and unstructured responses. Email exchanges ranged from 4-13 separate responses per participant.

After receiving a potential participant's email contact information, the researcher sent an email invitation for study participation that included a description of the study, the approximate time it might take to complete the interview, risks and benefits, and a request for voluntary consent for participation.

Upon receipt of an email response indicating an interest in participating, a series of discrete questions were asked. Discrete questions regarded demographics, whether the participant had been diagnosed with a chronic condition or a form of cognitive decline, and how often the participant sees his or her doctor. Immediately following the demographic questions, and within the same email, three questions were asked to gain knowledge about what is commonly known by older adults regarding smart homes technologies: (i) "Tell me what you know in general about smart home technologies... what they are, what they do?" (ii) "Tell me what you have heard about smart homes designed specifically for helping older adults age with increased safety and with health monitoring?" and (iii) "Is there anything you already know you would want from a smart home if you had one? What might that be?"

Participants were then introduced to the smart home with machine learning capabilities via a two page single-spaced written explanation with pictures of the CASAS smart home testbed interspersed within the text. Descriptions of the smart home's monitoring and action-taking capabilities were provided such as the sensing of motion at night with use of the bathroom and automatically turning off a stove burner that is left on. Questions regarding the CASAS smart home were asked such as "Now, please tell me in your own words about the smart home I just described" and "What thoughts come to mind?", which elicited responses demonstrating each participant's understanding of the technology and the prospective line of questioning and provided answers to the research question "What are older adults' perceptions and descriptions of smart home monitoring?"

All further email exchanges followed qualitative interviewing traditions, which included responsiveness, flexibility, creativity, and sensitivity. Interviewing and analysis was done integrally as accommodations were made for new insights, and questions were flexible based on previous participants' answers. Questions were presented as open-ended yet purposeful, such as "How would you feel about a smart home 'learning your habits' and monitoring you?" which led to rich descriptions in participants' own words. Concluding email exchanges included conversation about culture and the influence of the participant's self-defined culture on adoption of smart home monitoring.

Concepts highlighted during the interview were culture, aging, smart home adoption, and monitoring. Interviewing and analysis were done integrally as accommodations were made for new insights<sup>16</sup>. Theoretical thinking was employed on both macro and micro levels and was iterative and responsive to assure that large cognitive leaps were not made and a solid foundation of data was collected for analysis<sup>24</sup>. When saturation of data

had been reached, the researcher drew conversations to a natural end.

## Analysis

Content analysis was the primary method of organizing data into themes<sup>25</sup>. Themes of low inference were sought and supported by references to original text. The analytic team was comprised of three nursing experts with complementary expertise

Table 1. Description of the sample of US older adults (n=21)

Descriptor	Age, years								Total
	65-70		71-80		81-90		90+		
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	
Caucasian	2	4	5	4	1	0	1	2	19
Asian	1	0	0	0	1	0	0	0	2
Immigrant	1	0	1	0	1	0	1	1	5
Retired (fully)	2	1	3	4	2	0	1	1	14
Retired (part-time)	1	0	0	0	0	0	0	0	1
Not retired	0	3	1	1	0	0	0	1	6
Disability	0	1	0	1	0	0	0	1	3
Have a chronic illness	0	2	1	2	2	0	0	1	8
No chronic illness	3	2	3	3	0	0	1	1	13
Total	10	13	14	15	7	0	4	8	71

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in gerontology, technology, and qualitative descriptive traditions.

Each team member analyzed every individual transcript independently. Analytic team member summaries were compared alongside original text. Transcripts were iteratively and reflexively reviewed, both individually and comparatively. Comparisons were made across transcripts, looking for shared themes. A separate and lengthier summary of developing themes was written after the review of each set of five summaries and after all 21 transcripts were reviewed. All summaries were supported with multiple lines of rich text and referenced by line. Researcher triangulation was used to iteratively validate proposed themes and findings<sup>22</sup>. Triangulation was achieved through comparative review of transcript summaries written by each analysis team member. All team members reviewed all summaries written by other team members. Analytic team consensus was sought and obtained. Consensus was obtained during discussions that ensued via in-person or phone conferences, or email exchanges. Each team members' perspectives were equally shared and valued.

## Summarizing results

Eight low-inference themes that stood out were 'privacy', 'family', 'trust', 'being watched', 'human touch', 'features and functionality', 'cost', and 'timing'. (Table 2) Minor themes common across transcripts were subsumed by more prominent major themes. No themes were dropped.

## Privacy

The concept of privacy surfaced in all but one interview immediately after the introduction of motion sensor monitors and engineered algorithms that allow data mining and machine learning. Concepts of culture, and language associated with 'culture' and 'privacy', naturally emerged in the discussion on privacy. Four views on privacy emerged: 'privacy as modesty', 'private by nature', 'privacy normed', and 'privacy as American'. 'Privacy as modesty' was portrayed as the

idea of being watched while not fully clothed. For example:

"Monitoring would be OK if there was some way to provide for privacy. I would not want monitoring of me bathing or going to the bathroom".

### *Private by nature*

'Private by nature' was seen as a form of privacy that involved a general way of life in which one maintains a significant part of personal life that is considered private. For example:

"Since we are private it is a new concept to think of someone/something monitoring our habits and taking care of us".

And another similar perspective:

"...I have a large private self that is hard to share. I do understand learning general routines, but some portions of routines are extremely private".

### *Privacy normed*

'Privacy normed' referred to the idea that a group view (societal or cultural) exists regarding what individuals do, or not do, in private. The perception that there may be a normal way to behave in the privacy of one's own home appeared several times across multiple transcripts. For example one participant stated:

"Another problem with technology that learns your habits is that I really like novelty and change my habits every few months. For instance, I live in a three bedroom house and change bedrooms with the seasons".

Another example is seen in this excerpt: "I could actually clean my closet (7x12') and put a chair in there to escape". Some participants expressed concern that the smart home would misinterpret their actions or motion patterns, based on an assumption of a normed privacy.

### *Privacy as American*

'Privacy as American' was associated with the language of the historical values of United States' citizens such as rights to life and liberty, which included the right to privacy. From a cultural context, the idea that smart homes could monitor people in their homes elicited language like 'Big Brother', the mention of news about identity theft, and big government monitoring United States' citizens.

### *Independence, pride and dignity*

Older adults in this study considered independence a desirable trait, which directly related to aging in place. A synergy existed between the concepts of independence and aging; the loss of one seemed to indicate a potential loss of the other, and vice versa. Perceived levels of independence were juxtaposed with perceived levels of need. One participant stated:

"As more people in our society are aging and becoming less self-reliant I think ... modern tech-

Table 2. Organization of themes arising from the interviews of 21 older US adults

I	Privacy	a Independence b Pride and dignity c Cameras i No camera ii Silhouettes
II	Family	
III	Trust	a Low trust b Power and powerlessness
IV	Being watched	
V	Human touch	
VI	Features and functionality	a Safety b Quality of life
VII	Cost	
VIII	Timing	

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*nologies certainly have their place in the home particularly of those who are living alone. However, these employed high technologies should be specific to the needs of the individual without over sacrificing their privacy”.*

A perception exists that smart home monitoring would need to be designed to meet the various intersecting levels of independence and need. The increasing invasion of privacy or ‘evolving of the technology’ was expected and accepted by nearly all participants. A ‘line in the sand’ appeared to exist for most participants that regarded privacy. If the participant was asked to sacrifice privacy beyond their personal level of comfort, they would rather sacrifice independence than privacy. Two participants were not comfortable with the invasion of privacy and indicated they would never use such a technology. Pride and dignity were associated with privacy and independence in the context of individualized technology. A one-size-fits-all solution was not seen as dignified or desired.

## Cameras

Perceptions on privacy with the use of a camera varied greatly. Most participants preferred monitoring only via ambient sensors. Participants verbalized opinions such as, “No camera,” while others indicated “I am not afraid of a video camera”. Those indicating they would agree to cameras said silhouetted images were preferable.

Participants who entertained a conversation about the potential use of cameras indicated that cameras might be acceptable in the main areas inside and outside of the home but not in private areas. Main areas inside the home were considered the kitchen, living room, entry, and hallway. Main areas outside the home were considered entries and patios, sidewalks, the garage, and the barn. Private areas were mentioned as the bathroom and bedroom closet. Some participants considered the bedroom as private while others did not.

Differentiating private locations within the home may indicate a perception that levels of privacy exist. Additionally, language associated with monitoring in private versus main areas of the home differed greatly. Stronger language was used in reference to monitoring in private areas and the mildest language was used when discussing monitoring outside the home. (Several participants indicated they would like to have monitoring outside of the home to improve safety.) Examples of language in reference to private rooms were “cameras in my private spaces would result in refusals” and cameras in main areas elicited language such as “If the camera is used in some locations such as living room, kitchen and hallways it is not a concern to me”.

## Family

References to family included language about living alone or not, physical location and distance from the nearest family member, decision-making, and the idea of being a burden.

Overwhelmingly, participants indicated that family opinions were an important influencing factor of adoption. There was a perception that a smart home capable of helping the older adult remain in their home longer while decreasing the naturally increasing burden on their children was a good thing, as seen in one participant’s statement,

*“Baby-boomers are also more resistant to being dependent on our children, so finding a compromise that allowed us to stay at home without being watched by strangers or a burden on our children would be very positive”.*

## Trust

Older adults generally lacked trust regarding smart home monitoring and management of their data. Level of knowledge was associated in the text with levels of trust. Both knowledge and trust were low. Participants indicated they were more likely to trust their children for recommendations regarding adoption of a smart home. Although participants were quick to understand and discuss the benefits a smart home might provide, they were equally as quick to imagine the potential negative impact on their quality of life, should the smart home take an incorrect action based on misinterpreted data. In the text, trust and the newness of smart home monitoring included language about the dangers associated with a technology designed to monitor health and safety, but that may not work correctly. One participant with diabetes expressed,

*“I would not want my home to be so intelligent that it would, for example, refuse to open the refrigerator door until it ‘saw’ me take my meds”.*

Language found in analytic team members’ interpretative documents included terms such as tech gone awry, safety and safety’s antonym danger, and tech failure. An underlying assumption existed that a human would not misinterpret as easily, which may indicate a preference for care by humans, which was seen in the following statement,

*“...as long as we are close to our daughter, I know she would provide any assistance she could even if it meant putting me in an assisted living facility”.*

Power differentials exist between patients and nurses<sup>20</sup> and this differential was noted across transcripts. Powerlessness appeared within the text on two levels: (i) regarding the interview topic itself and discussion of smart home tech-

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nology, and (ii) regarding potential adoption specifically of ‘monitoring’ and the smart home ‘taking an [inappropriate] action’ on behalf of the resident. Participants used language at the beginning of the interview process that may represent a power differential between the researcher and the participant such as “*I will do the best I can*” and “*I will try to keep up*”. Several participants indicated they would need to talk to their children before making a decision to adopt, which may indicate a feeling of powerlessness to make an autonomous decision regarding smart home technology.

## Being watched

Language associated in the text with the word ‘watched’ differed depending on the context. ‘Being watched’ was nuanced with the idea of ‘being seen’. For example, one participant referred to being “watched” as a comfortable action: “*If then there could be a technology that could help me to continue to be independent longer, yet watched over, I would certainly be open to that*” (underlined emphasis by participant).

Another participant used the word ‘watched’ and likely means ‘watched’ as opposed to being seen:

“*A little disturbing at the thought of someone or something watching me at all times but great ideas for keeping people alive*”.

## Human touch

Part of ‘being seen’ and not ‘watched’ involved the idea of human touch. Some participants directly questioned whether the smart home would eventually ‘replace’ humans or whether it would be used ‘in addition’ to human caregivers. Concerns regarded the extent to which the smart home would provide care and whether the smart home was suitable for all stages of aging. No participants indicated an interest in having a robot provide care for the physical body such as helping with dressing or feeding. One participant indicated,

“*As portrayed in the movie ‘Robot and Frank’ which takes place in the future I could have a robot helper to cook, clean, and keep me company. But I shudder at the thought! Hopefully there will be enough human caregivers to provide us with care in a loving, caring way*”.

Accurate interventions and personalization were associated with the concept of human touch and not smart homes and regarded comfort, both physical and emotional.

## Features and functionality

A main reason given for willingness to participate in the study was a desire to know more about smart homes and the opportunities for aging in

place provided by this technology. Great interest was shown regarding the health-assistive smart home. Desired features were stated in practical terms, such as medication reminders and turning the stove off. A literacy gap initially existed for participants regarding the technology they were asked to prospectively discuss, however, all participants were able to quickly comprehend the introduced technology. Features such as motion sensors, software with machine reasoning capabilities that can alert regarding changes in health status, and actuators that can take an action (turn off a burner), were generally regarded positively. The exception regarded the potential use of cameras. Concerns were otherwise directed at functionality and regarded whether the technology could be relied upon to provide safety, security, and to not take a wrong action.

Safety and its antonym danger were a concern for all participants without exception. The desire for safety throughout the aging journey was revealed as a main factor influencing adoption. Comfort was directly related to quality of life and was associated primarily with safety, and secondarily convenience. The functionality of the smart home (whether it performs as it is supposed to) informed thoughts on quality of life and the use of smart home monitoring. Should the smart home function as designed, the perception was that quality of life would improve because the older adult could remain safely at home, as seen in the comments “*for my safety this would be a good thing*” and “*I would not have to repeat my medical history with each appointment*” and it would “*provide a warning when there were objects in my path I did not see*”.

However, if the smart home malfunctioned quality of life could deteriorate to levels lower than pre-adoption. This was demonstrated in a conversation with one participant who compared his computer difficulties to potential smart home functionality difficulties and sent the following message to the researcher, “*Well, I am still struggling out of my bewildering computer crash last week, but I [will] do the best I can!*”.

## Cost and timing

Cost was seen as a potential barrier to adoption. One participant indicated, “*I will go it alone if it is too expensive*”. Payment by Medicare was seen as a necessity to improve access for all older adults, as expressed in the question: “*Will it be cost effective for all income brackets or just the more affluent people?*”. Timing of the introduction of a smart home also surfaced as important to adoption. Older adults indicated they would rather learn how to use smart technology earlier than later, however, this was juxtaposed with a

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commonly expressed idea that ultimately they would only be willing to adopt if they were truly in need. For example: *"if I thought I needed help... I would be receptive...."*.

## Culture and adoption

Culture emerged as an epochal experience, a composition of a lifetime of social encounters that informed participants' self-identified cultures. The journey of aging was informed by multiple individual human experiences, contextualized within social constructs. Examples of self-identified cultures were 'educated', 'generational mature silent', 'Midwest farmer', and 'female socialite'. Five participants declared that culture would definitely influence older adults' decisions on whether or not to adopt, which was portrayed in the statement, *"Culture definitely has a role in a person's decision to use or not use smart home technology"*. One participant, after initially declaring, *"I am not really sure how my 'cultural values' enter into this picture!"* later decided culture would influence some aspects of adoption. One participant declared culture irrelevant.

'Education', 'gender', 'American independent spirit', and 'privacy' were identified as the primary socially constructed factors influencing adoption decision-making. Education emerged as a theme related to being middle class, and this was seen as being related to the ability to afford the cost of smart home monitoring.

## Gender

'Gender' emerged as a theme within the conversation on culture. Two examples of female perspectives from different participants are:

*"Somehow, in this area, I think that women would be more receptive to the technology than men would. But statistically, women would need it more than men"*.

*"I do believe there are differences in men vs women regarding both needs and acceptances"*.

A male voice indicated:

*"I would accept this home system readily because I would like the challenge. I can see a lot of men not liking it because of their background of independence and not wanting help"*.

## Independence

'Independence' emerged as a theme within the conversation about culture and regarded the independent spirit as an American value. This was tied to American ideas regarding human rights; right to choose one's own destiny and the right to privacy. Concerns with privacy emerged around the idea of 'being monitored' and the smart home 'learning your habits of daily motion'. Lan-

guage used by participants included words like 'Big Brother'. One participant stated, *"Yes, I think that big brother already knows enough about me"*. News coverage on Edward Snowden and other stories of government overreach were also mentioned by participants.

## Privacy

'Privacy' was a theme that directly related to culture. Older adults in this study recognized privacy expectations as different across cultures and highlighted a variety of perspectives such as *privacy as 'modesty' and 'private by nature'*. One participant stated,

*"In my view, what things constitute 'PRIVACY', are definitely both cultural and very personal things. Privacy is definitely tied up with intangible personal values, such as decency, properness, shyness, embarrassment, but also with the local culturally acceptable standards which may vary from culture to culture, and even within one culture ..."*

*... intrusion is a very sensitive issue that not only varies from person to person, from generation to generation, but also strongly from culture to culture ... consider Middle East cultures, where the women have to walk around in burqas and veils: how would in-home and in-private observation go over in such cultures?"*

## Normed values

The concept of culture includes the idea of normed values<sup>26</sup>. An underlying assumption emerged within the conversation on culture that a normal private behavior exists. Several older adults indicated that they did not behave in a 'normal manner' in private and shared concerns that the smart home would misinterpret their private behaviors. Participants provided the following examples of why the smart home might misinterpret their private behaviors:

*"As to my personal habits. I could actually clean my closet (7x12') and put a chair in there to escape"*.

*"I sleep on the floor, not on the bed... I really like novelty and change my habits every few months. For instance, I live in a three bedroom house and change bedrooms with the seasons. I also use all of my bathrooms so the showers, sinks and toilets get regular use. I sleep on the floor, not on the bed and carry my bedroll from room to room depending on whether I want to read, watch television, or listen to an audiobook. I'm sure there is some pattern to my behavior but I really like to change it up"*.

Recognition that a perception exists among older adults regarding the existence of a group-normed set of private behaviors has implications for artificial intelligence technologies, such as the CASAS

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smart home, which norms behavior of the monitored person to that person and not to a group of people sharing a set of private behavior norms.

## DISCUSSION

This research adds to the extant smart home literature regarding factors that influence older adults' adoption, or not, of health-assistive smart homes. No other research studies have addressed the influence of culture on smart home monitoring adoption decisions. Culture was perceived by many older adults in this study to be an influencing factor, specifically with regard to monitoring. A connection was observed between the themes of privacy and independence and the idea of culture. A connection was also observed between the 'family' theme and culture. An older adult's culture informs beliefs and practices, including choices that regard monitoring technologies that may extend independence.

Research questions were effectively answered with the employed qualitative descriptive methods. Knowledge levels of smart home technologies that monitor and can extend independence are low among older adults, however, when introduced to a smart home via email description older adults were quickly able to describe smart home features and options and richly discuss their perceptions of a smart home that monitors.

Factors influencing potential adoption were thoughts about privacy, family (not causing worry or being a burden), features and functionality, readiness to adopt based on need, and cost. The primary socially constructed value influencing adoption was independence, which may be representative of the independent American spirit. This discovery emerged from the conversation on culture and overshadowed culture as an influencing factor. Older adults' in this study desired to remain independent and self-reliant as long as possible throughout the journey of aging. Older adults' desire to remain independent will likely inform adoption rates in the United States. Older adults will entertain the option of smart home monitoring as a way to age in place, even if hesitatingly or as a last resort.

## Implications

The implications of this study are preliminary, however, a few examples are worthy of mention. Implications for adoption arise from the level of help needed to remain independent and the acceptable loss of privacy. As the level of need increases, the acceptable loss of privacy increases with it. This appears to be a recognized fact by older adults in this study. One participant pointed out that moving into an assisted living or nursing home would alter levels of privacy as well.

A desire for independence heavily influences older adults' willingness to entertain a solution that involves a perceived loss of privacy in trade for greater independence. Independence, for many older adults, is more important than privacy and recognition of the need for assistance to remain safe and independent at home informed older adults' willingness to adopt smart home monitoring. Smart home monitoring was perceived as a solution that would increase independence and the ability to age in place, but might also require sacrificing privacy in the home.

Recognition by older adults that smart home monitoring is a potentially viable solution has implications for public readiness and diffusion of smart home innovations. Despite a prospective willingness to adopt smart home monitoring, older adults in this study expressed their desire for the smart home to be individualized to decrease exposure, thereby maintaining higher levels of privacy. Machine learning capabilities for future smart homes addresses this concern.

Smart homes that use machine learning, a form of artificial intelligence, may be a practical solution to address the request for an individualized product. The smart home that uses machines (computers with software algorithms) to learn the motion patterns of the older adult living within the home and to take an action on behalf of that individual, is a technology that specifically performs individualized monitoring and interventions. If a continuum existed where a one-size-fits all product was on one end, the smart home that uses machine learning would be on the opposite end. Machine learning is a highly individualized technological invention used in the delivery of healthcare<sup>27</sup>. However, the perception that some kind of normalcy exists that is associated with private behavior across the human population and the knowledge that smart homes monitor these private behaviors, impacts personal perceptions of prospective use. Older adults' were concerned that the smart home would misinterpret their personal and private motion patterns and behaviors, and would then take an inappropriate action on their behalf. Such concerns will need to be addressed in both product functionality and education of the public.

Education regarding health-assistive smart homes as an option for aging in place is needed for older adults, caregivers, and healthcare professionals. Familiarity with smart home technologies is generally low. Education will need to be purposefully designed to address functionality and concepts of privacy, and should involve the adult children of older adults when appropriate. Consideration should be given to establishing technology literacy programs for older

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adults because the current literacy gap is likely to continue. The development and implementation of new technologies outpaces the aging of America, which will result in an eternal gap between available technologies and familiarity with those technologies.

Health policy will need to address the costs related to care of the aging population, removal of barriers to adoption, and patient rights regarding access to and management of their own health data. Removal of barriers to smart home access will be necessary to address safety with all older adults, not just those who are part of middle and upper socioeconomic status. Barriers that need removed are low levels of health-assistive gerontechnology literacy, Medicare reimbursement for smart home monitoring, and internet connectivity. Rural health policy leaders need to address current suboptimal levels of internet connectivity in rural and remote areas. Rural and remote citizens may have a greater need of smart home monitoring than citizens living in more populated areas where neighbors and resources are nearby. Furthermore, health policy makers need to define "health data" and explicitly state who owns the data and who may access the data. Restrictions placed on corporations or government entities' sharing of health data should be guided by legal and indemnified patient rights and wishes, and should never place the older adult in a position of exposure or exploitation.

## Study limitations

This study was limited by the prospective nature of the interview. The prospective line of questioning may not have evoked comprehensive or fully accurate responses because the participant was asked to consider a product they had not used. The limited racial and ethnic diversity among participants and the neoteric definition of 'self-identified' culture created further limitations. The line of inquiry regarding a 'self-identified' culture initially caused confusion for some participants; however, with additional guidance from the researcher, participants provided rich descriptions of their own self-identified cultures and the potential influence on adoption decisions.

Findings from this study are limited by the characteristics of the sample cohort and reflect subjective responses of 21 individuals. It is likely there are additional views of older US adults that were not addressed by these individuals. Further, the technology described to study participants rep-

resented technology familiar to the researchers. It is possible there are emerging models of smart home technology unknown to the researchers at this time. The technique of email interviewing may have limited the full expression of responses possible for these participants. Non-face-to-face interviews limited the researchers ability to employ all communication techniques available with face-to-face interviews<sup>28</sup>, such as facial and body language expression.

## Future research

Continued exploration regarding the role of culture in the adoption of smart home monitoring is needed. Understanding the role of culture in adoption practices may inform design and marketing, and may elicit a focus on ethical principles of autonomy and the right to self-determination within the healthcare delivery system<sup>3</sup>. Health-assistive smart home research should continue to be interdisciplinary. Aging is a complex process that holistically involves mind, body, and spirit. No single discipline can holistically address the journey through aging. Key interdisciplinary team members currently include computer science and engineering, psychology, neuroscience, social work, and nurses. Future interdisciplinary teams should consider the inclusion of physical therapy, speech therapy, physicians, and health information technology experts. Integration of information into the electronic medical record will be important as personal health data becomes integrated at a national level on the new healthcare information cyber highway. Further concepts that require exploration are trust, caregiver perspectives, features and functionality, human factors engineering, emotion, and cost.

## CONCLUSIONS

Older adults in this study were concerned with safety, health, and independence as they journey through the aging process. When introduced to the health-assistive smart home, which uses data mining and machine learning software to monitor and take actions on behalf of the resident living within the home, the majority of older adult participants in this study indicated a prospective openness to the idea of adopting such a technology. Openness was influenced by (i) the level and specificity of need and whether the smart home would meet that need, (ii) perceived loss of privacy and compensation for this perceived loss with a feeling of safety and knowledge of receipt of health-assistance, (iii) functionality, and (iv) cost.

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