


Attitudes and Perceptions Toward Voice-Operated Smart Speakers Among Low-Income Senior Housing Residents: Comparison of Pre- and Post-Installation Surveys

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Abstract

Smart speakers have the potential to support independent living and wellness among low-income senior housing (LISH) residents. The aim of this study was to examine and compare LISH residents' attitudes and perceptions toward smart speakers at two time points: before and after technology use ($N=47$). A descriptive survey was administered to ask questions about hedonic motivation, perceived ease of use, self-efficacy, perceived usefulness of some potential or existing smart speaker features, cost, and privacy. Participants were initially favorable toward using a smart speaker and its digital agent (e.g., Alexa) as a daily assistant and wellness tool. They especially liked the smart speaker's potential functionality of detecting harmful events and notifying someone to receive immediate help. The comparison of pre- and post-use responses revealed non-significant declines in most items, with the exception of willingness to use Alexa as a reminder system ($p < .01$), asking Alexa for help ($p < .01$), and asking for help in using Alexa ($p < .01$). This finding may reflect confusion or frustration with the device among participants. We conclude with recommendations for the design of smart speakers specifically tailored to the needs of LISH residents.

Keywords

older adults, smart speaker adoption, technology acceptance, virtual assistant, low-income senior housing

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Introduction

Nearly 800,000 older adults live in low-income senior housing (LISH) in the United States (Pew Charitable Trusts, 2015). LISH residents face multiple health issues, such as unmanaged health conditions, coupled with barriers to accessing healthcare, poor physical living environments, a lack of resources for social participation, and a high prevalence of depression (Coe et al., 2018; Park et al., 2018). There is a need for innovative approaches to mitigate these issues and to improve wellness and quality of life among LISH residents.

Advances in artificial intelligence and speech recognition have led to the development of smart speakers (e.g., Amazon Echo, Google Home, or Samsung Galaxy Home), an internet-enabled speaker that has a virtual assistant controlled by voice commands for a wide range of topics, including music, game, entertainment,

news, online shopping, etc. The World Health Organization's Age-Friendly Cities and Communities Initiative recognizes the importance of improving civic and social participation, community support and local health initiatives, and increasing social inclusion and connection to meet the needs of the older adult population (Marston & van Hoof, 2019). Through the design and implementation of intentional smart speaker features and educational materials, smart speakers may contribute to building age-friendly communities in the LISH sector.

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An inter-professional care program, Richmond Health and Wellness Program (RHWP), was developed in 2012 to address the unmet needs of LISH residents with multiple chronic conditions. RHWP operates weekly clinics in five LISH buildings in Richmond, VA and provides wellness services to its enrollees (Parsons et al., 2019). The enrollees are primarily African American (70%); almost one-third of the residents did not complete high school; half of the individuals have multimorbidity, take more than 11 medications, and are at risk for social isolation; and two-third of the residents had low health literacy (Coe et al., 2018; Diallo et al., 2020; Goldman, 2019). The high prevalence of morbidity and social isolation combined with racial and/or poverty disparities in this population led one of the facilities to deploy smart speakers in individual apartment units. A community-academia-industry partnership was created to assess end-user perceptions and to solicit feedback to create a user-friendly technology platform for residents. Our central hypothesis was that existing or potentially available smart speaker features (e.g., a reminder of social activities in the facility, safety risk notifications, or medication reminders) can support independent living in LISH residents as they age.

A growing body of work is investigating how smart speakers can optimize opportunities for healthy aging among older adults (Choi et al., 2020; Kowalski et al., 2019; Marston & Samuels, 2019; Trajkova & Martin-Hammond, 2020). Despite the increased interest, we have found no studies to date regarding *low-income*, senior housing residents' perceptions of smart speakers. The use and deployment of smart speakers in LISH may have a profound effect on the lives of many residents and provide a window of opportunity for interventions that will alleviate problems resulting from limited resources, lack of healthcare access, and social isolation. Furthermore, voice-operated smart speakers may provide a more effective user interface to individuals with physical disability, vision impairment, aging-related dexterity issues, or low literacy. However, smart speaker technology adoption for this population might not be the same as the adoption for older adult groups who reside in other residential settings or are of a higher socioeconomic status. They may have unique characteristics and life situations combined with low literacy, lack of self-efficacy, limited access to information and communication technology, mistrust of the technology, and limited human resources who can assist the technology use (Cashen et al., 2004; Jensen et al., 2010; Marston et al., 2019; McCloud et al., 2016; Schmeida & McNeal, 2007).

The technology acceptance model (TAM) explains the role of perceived usefulness and perceived ease of use in new technology adoption or usage behaviors (Davis, 1989; Venkatesh & Davis, 2000). TAM has been widely used in previous research on older adults' acceptance of smart homes and wearable sensors

(Mercer et al., 2016; Puri et al., 2017; Reeder et al., 2020). Despite its common use in predicting technology acceptance, TAM has been criticized for missing critical determinants of technology adoption and usage that are specific to community-dwelling older adults, such as user characteristics (e.g., cognitive decline, functional limitations, desire to age in place), contextual features (e.g., role of family or peers, available resources), cost, or privacy concerns (Chung, 2017; Gao et al., 2015; Lee & Coughlin, 2015; Peek et al., 2014). In light of the aforementioned, we aimed to examine and compare LISH residents' attitudes and perceptions toward smart speakers at two time points: before and after technology use. This study extends the current literature by examining both TAM constructs and potential determinants outside of TAM that are unique to novel technologies and those living in subsidized senior housing.

Methods

Design and Setting

Our study site was a LISH building in Richmond, VA, which houses 249 older adults or individuals with disabilities. This naturalistic study (Lincoln & Guba, 1985) consisted of two surveys conducted before and after smart speaker installation in individual apartment units. However, the smart speaker deployment process was not part of the study. All study procedures were approved by the Institutional Review Board at Virginia Commonwealth University.

In 2019, the building management company initiated a project to provide the Echo Dot (third Gen) to its residents at no cost. The management company partnered with a technology firm specializing in programming voice technology for senior care, to develop a platform and manage deployment of the devices. In November 2019, Wi-Fi was installed throughout the building in preparation for deployment of the smart speakers. Once implemented, RHWP would provide a full continuum of wellness services through the smart speakers, including virtual care coordination, health education, and self-management support.

Smart Speaker Perceptions Questionnaire

Three team members (JC, MB, and PP) developed the smart speaker perceptions questionnaire based on the TAM and previous research on older adults' acceptability of emerging technologies (Charness et al., 2016; Chung et al., 2017). Before questionnaire development, we convened three meetings of the resident advisory council consisting of six to eight residents who were eager to use a smart speaker, to discuss their needs, expectations, preferences, and privacy concerns. They also made suggestions about a technology perception examination method (survey) and the technology

installation process (e.g., phased implementation approach, training needs, advertisement strategies, and potential value of “super users”). Themes and recommendations mentioned in these meetings informed the development of the questionnaire format and items.

Through an iterative process of reflecting on resident feedback and revising the items, the final version of the questionnaire included 22 questions focusing on the following dimensions: hedonic motivation, interest in technology, self-efficacy, perceived ease of use, perceived usefulness of several potential smart speaker capabilities, privacy, and cost. The questionnaire also included three open-ended questions about prior knowledge of smart speakers, expectations, and any feedback. Considering the potential for low literacy among the participants, we designed the questionnaire to have simple response options (e.g., yes/maybe/no). We also ensured the wording of the survey was at a sixth- to eighth-grade reading level. After the questionnaire was developed, another team member (JW) reviewed the wording of each item.

Recruitment

We used convenience sampling to recruit study participants. In December 2019, the research team, in coordination with the housing staff and industry partner, held a town hall meeting with 40 residents to provide information about how the technology works, to solicit feedback about the secure use of smart speakers, and to explain the study. After the meeting, interested residents signed up separately for the Echo Dot installation and study participation. Building staff facilitated the recruitment by posting flyers and collecting contact information of potential participants. The research team also held separate information sessions at the building to provide study information and encourage study participation. A total of 57 residents signed up for the study.

To be included in the study, participants needed to be residents of the facility, be able to speak and understand English, and without cognitive impairment that prevents effective communication with the research staff. We developed a four-item instrument designed to evaluate participants' ability to understand the nature of the study and decision-making capacity (Moye et al., 2007) and administered the instrument during screening. Out of 57 individuals who signed up for the study, 10 individuals chose not to participate or were found to be ineligible, leaving 47 individuals in the final sample.

In addition to the Echo Dot, residents also received an alert pendant that can be pushed in an emergency situation for immediate support and communication. A representative from the technology firm was onsite twice a week for several months to install the devices and to assist residents with their smart speaker use. The technology deployment started in December 2019. Speakers are operational in the apartments of 85 residents as of July, 2020.

Data Collection

Prior to data collection, we explained the study aims and procedures to study participants, including the voluntary nature of the study, provided them a written consent form, and obtained their signatures. The consent process was conducted in a private room in the facility. The smart speaker pre-installation perceptions questionnaire and a demographic form were verbally administered in 15 to 30 minutes face-to-face sessions with study participants. Before asking questions about smart speakers, we provided a brief description about how the technology works, the currently available features of smart speakers, as well as two photos of the Echo Dot to facilitate their understanding of the technology.

About 2 months after technology deployment, we administered the post-installation surveys to assess residents' attitudes and perceptions after their exposure to and use of the smart speaker. Pre- and post-installation surveys contained the same questions, they differed primarily in item tense. We initially planned for in-person survey administration, but due to COVID-19 restrictions, 14 out of 29 post-use surveys were conducted over the phone. Data collectors used a password-protected online tool (REDCap, Nashville, TN) to enter survey data. After each survey, participants were given a \$5 gift card for their participation.

Data Analysis

The demographic characteristics of the sample are presented as means (with standard deviations) or frequencies with proportions (%). We summarized the number of positive responses for smart speaker- and virtual assistant (hereafter referred to as “Alexa”)-related questions as % for all the responders independently. We also calculated the number of participants who responded yes/maybe/no to the pre-use and post-use questions as an assessment of smart speaker perceptions (Supplemental Material #1). To test for changes in perception of the technology pre-use to post-use, we conducted McNemar's chi-square test of symmetry for paired categorical data (yes vs. maybe/no). Paired responses were available for 27 or 28 participants only, depending on the question, due to non-response. We conducted a multinomial exact test of symmetry for the 3×3 contingency tables of the yes, maybe, and no responses (Supplemental Material #1).

For any questions with a statistically significant change in the pre- and post-positive responses according to McNemar's test, we used logistic regression models to explore the association of demographic characteristics (age and education) and technology use with the change in question response from yes to no. To operationalize technology use, we categorized individuals as (1) using two or more or (2) using one of the following: cellphone, computer, or tablet. We estimated odds ratios and associated *p*-values with the logistic regression

Table 1. Sample Characteristics (N=47).

Variable	N (%)	M ± SD
Demographic characteristics		
Age		66.4 ± 9.8 (range: 31–89)
<55	5 (10.6)	
55–59	1 (2.1)	
60–69	22 (46.8)	
70–79	17 (36.2)	
80–89	2 (4.3)	
Female	23 (48.9)	
Race		
Black/African American	30 (63.8)	
White/Caucasian	12 (25.5)	
Other	5 (10.6)	
Education		
Less than high school	8 (17.0)	
High school diploma/GED	14 (29.8)	
Some college	19 (40.4)	
Bachelor's degree	5 (10.6)	
Graduate or professional degree	1 (2.1)	
Living at the current apartment (years)		5.9 ± 6.4
Richmond health and wellness program (RHWP) use		
I have used services provided by the RHWP (N=45)	39 (86.7)	
Technology use experience		
Smartphone	31 (66.0)	
Laptop or computer	24 (51.1)	
Tablet PC (N=46)	11 (23.9)	
Perceived health		
I am		
Doing well overall and independently managing my health	28 (59.6)	
Doing somewhat well with occasionally getting support in managing my health	15 (31.9)	
Doing not so well and requiring pretty regular support in managing my health	4 (8.5)	

models. All statistical analyses were conducted in the R computing environment.

Results

Sample Characteristics

The study sample included 47 participants (age $M=66.4$, female 48.9%). Five participants with disabilities were younger than 55 years and qualified for inclusion due to residence in the building. About two-thirds of the participants were Black/African American, and 46.8% of the participants had a high school education or less. More than half of the participants were smartphone or laptop/computer users (Table 1).

Attitudes and Perceptions Toward Smart Speakers Before Use

Before technology exposure, 82.6% thought it would be fun to ask Alexa questions. Most participants (80.4%) felt confident in using a smart speaker, 91.3% of participants perceived that they could get used to Alexa as a helper. Most respondents answered that smart speakers

would be easy to use (95.7%), that they would ask Alexa for help (93.5%), and that they would ask for help if they had a question about how to use the device (95.7%).

Participants perceived that smart speakers have the potential to be used as a daily living assistance tool (56.5%), social activities reminder (84.8%), medical appointment reminder (91.3%), medication reminder (77.3%), or a system providing health tips (89.1%), or the news (76.1%). In particular, participants recognized its potential value as a safety tool. With regards to potential barriers to adopting smart speakers, nine respondents answered they would feel uncomfortable to think the technology monitored their activities. Twenty-four participants answered that the cost of the technology is beyond their financial means, and 91.3% of participants expressed their willingness to adopt the technology if they could afford the cost and someone helped them set up the technology. Sixty-three percent of participants wanted to be reminded by Alexa of weekly RHWP wellness services (Table 2).

Participant responses to open-ended questions revealed their excitement over the opportunity to use novel technology and anticipate using it for emergencies, for reminders, or as an information source (Supplemental Material #2).

Table 2. Older Adults' Smart Speaker Perceptions and Comparison of Responses Before and After Use.

Variable	Yes responses (%)		Yes responses (%) and comparison between pre- and post-use ^c		p
	Pre-use ^a	Post-use ^b	Pre-use	Post-use	
It would be fun to ask Alexa questions	82.6	72.4	85.7	75.0	.505
Alexa would be easy to use	95.7	96.6	96.4	96.4	1.000
I feel confident in using a device like Alexa	80.4	85.7	85.2	85.2	1.000
If I had a question, I would ask Alexa for help	93.5	51.7	100.0	50.0	<.01
If I had a question about how to use Alexa, I would ask for help	95.7	31.0	96.4	32.1	<.01
I could get used to Alexa as a helper, such as using her as a reminder system	91.3	55.2	92.9	53.6	<.01
It would be a good thing if Alexa reminded me of my medical appointments	91.3	75.0	92.9	75.0	.131
It would be a good thing if Alexa reminded me to take my medications	77.3	65.5	74.1	66.7	.773
I've thought about using this speaker to help me in my daily living	56.5	71.4	51.9	70.4	.302
If Alexa gave me a health tip for the day, that could help me to think about healthy living	89.1	69.0	82.1	71.4	.450
If Alexa talked to me each morning about activities going on in the building, I would like that	84.8	79.3	89.3	78.6	.450
It would be a good thing if Alexa kept me informed about what is going on in the building, the neighborhood, and in the news	76.1	69.0	78.6	67.9	.505
I would feel safer if Alexa noticed that I didn't respond and it notified someone like the front office or a family member	89.1	79.3	85.7	78.6	.683
I would find it helpful if Alexa could be used to let someone know if I had fallen	97.8	89.7	96.4	89.3	.480
I would feel uncomfortable to think Alexa monitored my activities	19.6	17.2	14.3	17.9	1.000
The cost of a device like Alexa is beyond my financial means	52.2				
If I could afford it and someone helped me set up Alexa, I would use it in my apartment	91.3				
I would like to be reminded by Alexa that RHWYP clinicians are in the building	63.0				

Note. RHWYP = Richmond health and wellness program.

^aThe number of respondents for the pre-use assessment ranges from 44 to 46 for complete responses depending on the question.

^bThe number of respondents for the post-use assessment ranges from 28 to 29 for complete responses depending on the question.

^cPaired responses were available for 27 or 28 participants only depending on the question due to non-response.

Changes in Technology Perceptions Between Pre- and Post-Use

Table 2 also shows the proportions of positive responses for the participants who answered the same question both pre- and post-use, as well as the test for symmetry in positive responses for participants pre and post technology use. The proportions of a yes response were above 80% both pre- and post-use for two items (ease of use and confidence in using a device like Alexa). The proportion for the privacy concern increased slightly, though not statistically significant, indicating that participants were not bothered by the existence of the device at home. There was also an increase, though not statistically significant, in the proportion of yes-responses for the intention to use the technology as a helper in daily living, suggesting the particularly helpful feature of the device. On the other hand, most proportions of a favorable response decreased after residents' smart speaker use, though most changes were non-significant. After technology use, a significantly lower proportion of respondents reported that they would use Alexa as a reminder system ($p < .01$), ask Alexa for help if they had a question ($p < .01$), and ask for help if they had a question about how to use Alexa ($p < .01$) compared to pre-use responses.

The multinomial exact test results that considered the maybe-responses separately from the no-responses were similar to the McNemar's chi-square test according to the p -values (Supplemental Material #1). For the three questions with a significant decrease in favorable responses from pre-use to post-use, logistic regression models revealed that age, education, and technology use were not significant predictors for changing responses from yes to no.

Frequently Used Features and Challenges

The open-ended questions in the post-use questionnaire identified several features that were frequently used by respondents, such as playing music, news, medication or doctor's appointment reminder, conversation buddy, etc. Interestingly, four participants reported they were treating Alexa more like a human: *"I have a conversation with her every morning. My girlfriend is jealous of her."* Several participants reported some technology features as a barrier to smart speaker adoption and use, including the need for additional purchases for desired functionalities, incorrect programming, fear of accidental spending, or a difficulty setting up reminders. Some participants expressed their frustrations with not knowing what Alexa can do or how to train Alexa to recognize their requests properly: *"I'm frustrated that she won't answer the questions that I ask her"* and *"I have a hard time pronouncing the name, it's not usually right."* One participant raised a privacy issue: *"A lot of the old guys are afraid being monitored and having the information sent to the office."*

Discussion

While previous research has studied older adults' perceptions and acceptability of smart speakers (Koon et al., 2020; Trajkova & Martin-Hammond, 2020), there is still lack of focus on vulnerable individuals living in low-income housing. We found overall acceptance of smart speakers to perform various tasks in daily living in LISH residents. However, use was limited to basic tasks, such as listening to music, alarm or time reminders, weather, news, and finding answers, as similarly found in prior work (Koon et al., 2020; Trajkova & Martin-Hammond, 2020). Importantly, our participants favored the ability to use it as a harmful event notification system. Smart speakers could be used to manage emergencies inside and outside the facility when connected with smart systems or smartwatches, for example, by tracking health metrics or detecting functional changes (Reeder & Whitehouse, 2015; Seifert, 2020). Thus, researchers and healthcare professionals should carefully examine which smart speaker features can better serve the domestic, health, and wellness needs of LISH residents and discover factors influencing positive use experience when people interact with digital agents for an extended period of time.

The comparison of pre- and post-use responses revealed that experience with the Echo Dot results in a significant decline in positive attitudes in three survey items and non-significant declines in most items. Higher proportions of "yes" responses in pre-use perceptions could be attributed to general curiosity or excitement to use the smart speaker. Where most post-use positive responses are not as high in comparison to pre-use, we may also correlate this trend with confusion or frustration with device features, or stifled enthusiasm for the device. This observation is supported by open-ended question responses that describe residents' challenges in understanding how to use the technology or how to access information on how to use the Echo Dot. Other studies have found that the initial excitement of using smart speakers alone does not facilitate continued use (Trajkova & Martin-Hammond, 2020) and older adults face difficulties with setting up default features and enabling digital agents' novel capabilities (Koon et al., 2020). The literature suggests a need for developing diffusion strategies or educational materials depending on a target group's age, education level, health literacy, and competency of technology skills (Cashen et al., 2004; Marston et al., 2019; Reeder et al., 2020). Our findings also highlighted the need for tailored information or in-person assistance especially for smart speaker features desired by users and require complicated set-up process and technology knowledge.

While there was a decline in the level of perceived usefulness with regard to some key features (e.g., a reminder system, health tips, or news channel) after using the technology, most participants still felt the technology was an easy tool and had confidence in

their own ability to use the technology. Also, perceptions of obtrusiveness were not observed in the majority of the sample after technology use, but a few people expressed their privacy concerns if Alexa is listening to their conversations. These findings are consistent with the literature that perceived ease of use, self-efficacy, and perception of obtrusiveness are critical factors determining the user's willingness to adopt in-home technologies (Chung et al., 2016; Czaja et al., 2006; Schnall et al., 2015).

We observed the anthropomorphization (or personification) of virtual assistants among a few participants, such as using personal pronouns ("she"). This perception impacts user adoption both positively and negatively. For example, older adults who are socially isolated may see virtual assistants as a social companion and interact with the assistant to feel their desire for social connectedness (Pradhan et al., 2019). On the other hand, human-like attributes of the assistant may cause a constant awareness of the device's prominence or presence, ultimately leading to abandonment (Koon et al., 2020). There is lack of research examining how smart speaker users perceive having social interactions with the assistant or how human-like features of the assistant affect user adoption. Future work should identify aspects of smart speakers related to privacy perceptions and how conversational virtual assistants impact daily mood and loneliness among different user groups.

Limitations and Recommendations

This study had several limitations. First, the sample size was small especially for the post-installation assessment. This was due to resident dropouts due to COVID-19 and the change in plans to deploy tailored smart speaker capabilities to help residents stay connected during the pandemic. Therefore, the findings may not generalize to larger populations of older adults. Second, selection bias is possible because residents interested in novel technology were more likely to participate in the study. This may explain the reason why more than half of our study participants had a college degree. Third, our investigation was based on residents' short-term smart speaker use. Their opinions may change as they use it further. Fourth, we found a decline in positive responses in two safety-related questions although the change was not statistically significant. Because residents were provided with an alert pendant along with the smart speaker, they might not have felt much need for Alexa to address their safety concerns. Last, some participants' responses reflected their expectations toward and experience with the whole safety system consisting of a smart speaker, safety pendant, and emergency notification service rather than referring only to smart speakers.

Current research findings are foundational to better inform designers and developers of smart speakers as they develop applications that can support independent living among LISH residents. Based on our

observations and findings, we recommend the following. First, open-ended responses suggest that the interfacing method needs to be tailored to the user characteristics, such as current disability or impairment, health literacy, prior technology experience, etc. For example, currently when an individual asks Alexa to set a medication reminder, the device will ask several questions to complete the task. It is important to minimize the prompting process and make it easier to browse for those who are not tech-savvy or have low levels of literacy. Control buttons on the device could be bigger, raised, or further depressed for better tactile feedback for those with visual impairment or poor dexterity and provide better contrast for the text and symbols on them (Czaja et al., 2019). Second, feedback from resident meetings indicates the importance of designing voice user interface to be culturally appropriate (e.g., speaking styles, accent, gender of the virtual assistant) because the user interacts with smart speakers through voice commands. Third, user-centered tech-support and instructions are a key factor to successful technology implementation. Differential levels and types of support and strategies are necessary, such as in-person training, easy-to-read pamphlets, or online customer services (Koon et al., 2020). Last but not least, different virtual assistants are available, and each has its own strengths and weaknesses. For instance, Google Assistant is better at answering free-form, web-based queries while Alexa tends to stick to specific syntax; Alexa is better at incorporating new skills mostly with third party apps. It is thus important to assess different agents' functionalities and select the digital agent that could work best for the specific group of older adults and for their specific life contexts (Reis et al., 2018).

Conclusion

To adequately design and implement smart speaker solutions to address the specific needs of older adults, facilitators, and barriers to its adoption and utilization must be examined in the social and living context of the target users. Identified user challenges and barriers present an opportunity to develop educational materials and to redesign voice commands and prompting steps for the next phase of Alexa skills development. Further examination is needed to understand the factors affecting low-income older adults' decisions for continued smart speaker use and motivations for the use of different smart speaker functionalities, such as satisfaction with healthcare services, loneliness, or resilience.

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Supplemental Material

Supplemental material for this article is available online.

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