Understanding the potential of digital home assistant devices for older adults through their initial perceptions and attitudes

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Abstract

Background: Voice-activated digital home assistant (DHA) devices, such as Alexa-enabled Amazon Echo products, can help support a broad range of daily activities within home environments. DHAs may address many of the needs of the growing aging population required for independent living. However, there is a lack of research that investigates the initial perceptions and use of these devices for older adults with disabilities (e.g., mobility or hearing impairments), who might particularly benefit from the adoption of DHAs.
Objective: The purpose of this study was to investigate factors that influence initial attitudes and perceptions of DHAs, specifically for older adults who had no prior experience with these technologies.
Method: We introduced 18 older adults with and without disabilities to two different Amazon Echo form-factors to evaluate their initial usage of DHA devices, followed by a series of semi-structured interviews.
Results: Older adults with and without disabilities developed positive initial attitudes and perceptions towards both voice-activated DHA form-factors. In addition, we identified factors that may influence the perceived usefulness and ease of use of voice-activated DHAs. Participants discussed how the devices would be useful for promoting independence, productivity, and enjoyable activities such as playing music. Pertaining to ease of use, participants expressed that both devices had a high degree of learnability, but some participants expressed concerns about the lack of system feedback provided by the Echo speaker which did not have a screen interface.
Conclusion: This diverse sample of older adults with no prior experience using DHAs had positive initial attitudes and perceptions towards the devices, and demonstrated the capability of successfully using the technology upon following a brief demonstration. We discuss implications for the design of DHA devices that meet older adults' needs and capabilities along with directions for future research.

Keywords: voice-activated digital home assistants, older adults, technology acceptance

INTRODUCTION

Aging populations and aging in place

Around the world, populations in economically developed countries are aging, leading older adults to become a disproportionate share of these nations' demographic characteristics (WHO, 2015). As people age, they become more likely to encounter barriers that limit their ability to successfully age in place, which is the capability to live in one's chosen place of residence independently while also maintaining a sense of connection to the community (Rogers, Ramadhani, & Harris, 2020). Common challenges that may impede older adults from aging in place include mobility, cognitive, and/or perceptual disabilities – the most prevalent being mobility disabilities (Health and Retirement Survey, 2014). Older adults may age into or age with a disability

that impacts everyday activities (see Mitzner et al., 2018). Such disabilities can present barriers to community engagement and increase older adults' risk for experiencing social isolation and loneliness, as well as increase the need for support with instrumental activities of daily living (IADLs), such as meal preparation, household cleaning, and medication management. A key prerequisite for independent living and successful aging in place is being able to successfully accomplish IADL tasks. One mechanism through which difficulties with IADL tasks and barriers to aging in place can be supported is with the use of in-home technology innovations. Our aim was to explore voice-activated digital home assistant technology acceptance factors for older adults aging with and without disabilities residing in different types of residential settings.

Potential for DHAs to support older adults

A broad range of technology innovations has been aimed at promoting aging in place and functional independence for older adults (Mitzner et al., 2010). A novel, compact, and relatively low-cost technology for older adults are voice-activated DHAs, such as the Amazon Alexa products (e.g., Echo Show device) and the Google Nest Hub. DHAs (hereafter DHAs) hold the potential to promote social and community engagement for older adults as well as to support functional independence with the use of smart and connected environmental controls (e.g., smart lights and appliances). Because DHAs are an emerging technology, research exploring the efficacy of these consumer technologies for promoting aging in place is maturing and much needed.

There is some evidence to suggest that older adults are willing to use DHAs. For example, according to AARP, device ownership among aging adults has nearly doubled in only one year, from 17% in 2019 to nearly 30% in 2020 (Kakulla, 2021). Older adults use their DHAs for both functional aspects of daily living (e.g., setting timers or reminders) as well as enhanced activities of daily living, such as listening to music and playing games (Koon et al., 2020; Trajkova & Martin-Hammond, 2020). Given the potential for DHAs to promote functional, social, and enriching aspects of daily living, it is critical to gain insight into the factors that influence older adults' decisions to adopt DHAs.

Digital Home Assistant device acceptance

Technology acceptance models (TAMs) propose factors, such as attitudes towards a given technology and perceptions of usefulness and ease of use, as critical to technology adoption and use (e.g., Chen and & Chan, 2014; Davis et al., 1992; Venkatesh, Thong, & Xu, 2012). Within the framework, attitudes are defined as *"a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor"* (Eagly & Chaiken, 1993, p. 1). Attitudes toward technology are consistent with one's valenced evaluation of the system as well as attitude strength (Fazio, 2007). On the other hand, perceptions refer to how individuals process, interpret and make sense of their environment to take action (Pickens, 2005). Within the TAM frameworks, perceptions refer to how individuals subjectively rate specific expectations about a given technology (e.g., how useful the technology could be for them).

Perceived usefulness, referred to as performance expectancy in related frameworks (e.g., Venkatesh et al., 2012), is an individual's expectation of whether the performance of a given technology usage behavior would lead to useful or posi-

tive outcomes (Davis et al., 1989; de Veer et al., 2015; Renaud & van Biljon, 2008). Ease of use, or effort expectancy, refers to the expected effort and difficulty involved with the performance of a given technology usage behavior.

The original TAM framework has been iteratively revised to include additional factors such as perceived enjoyment or hedonic motivations in related theoretical models (e.g., Venkatesh & Bala, 2008; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, Thong, & Xu, 2012). Less research focus has been on developing frameworks that are specifically designed to consider the needs and capabilities of the older adult population, though such approaches are sometimes referred to as senior technology acceptance models (STAMs) within the literature (e.g., Bixter, Blocker, Mitzner, Prakash, & Rogers, 2019; Chen & Chan, 2011, 2014; de Veer et al., 2015; Renaud & van Biljon, 2008). The STAM frameworks extend the TAM by identifying age-related factors that may influence technology adoption and use, such as health status and functional abilities (Chen & Chan, 2014).

Research on older adults who use DHAs supports the TAM frameworks, in that factors such as perceived usefulness, perceived ease of use, and perceived enjoyment were positively associated with continued use (e.g., Koon et al., 2020). Research has primarily focused on older adults without functional limitations who are already experienced users of DHAs. Given the potential for DHAs to promote functional, social, and enriching aspects of daily living, it is critical to gain insight into the factors that influence older adults' decisions to adopt DHAs – especially older adults who have no prior experience with these technologies and who have diverse needs and capabilities (e.g., mobility or perceptual disabilities).

Knowledge gap in the existing research

Though existing technology adoption research focuses on older adults who already use DHAs in general, little is known about the initial attitudes and first impressions of older adults with diverse needs and capabilities, which is a user group that could have much to gain from adopting such devices. Our aim was to garner in-depth qualitative information on the attitudes and perceptions of older adults aging with and without disabilities residing in different types of residential settings. By engaging older adults, especially those aging with diverse needs and capabilities, we can better understand how they may desire to use digital assistant devices to enhance their daily life as well as identify potential challenges or barriers to adoption and use. As such, we explored two general research questions:

Table 1. Sociodemographic characteristics of participants (N=18)

Variables	Total	
	n	**%**
Sex		
Female	13	72
Male	5 (28%)	
Age, Mean (Range)	78 years (66-89)	
Disabilities		
Mobility (lower or upper body)	4 (22%)	
Hearing	5 (28%)	
Racial Group		
White/ Caucasian	18 (100%)	
Marital status		
Single	2 (11%)	
Married	8 (44%)	
Divorced	3 (17%)	
Widowed	5 (28%)	
Highest educational level		
High school/Some college	4 (22%)	
Bachelor's degree	4 (22%)	
Post-graduate degree	10 (56%)	
Technology Experience Profile	M=3.4, SD=1.02	

Note: All participants self-identified as Non-Hispanic.

RQ1. What are older adults' attitudes towards voice-activated DHAs immediately following their first exposure and usage?
RQ2. What are older adults' perceptions towards voice-activated DHAs immediately following their first exposure and usage?

Overview of current study
We explored the underlying factors that may drive and shape initial attitudes and perceptions of usefulness, ease of use, and enjoyment and identified potential barriers to adoption for older adults with diverse needs and capabilities (e.g., older adult participants with and without disabilities). Our mixed-method approach involved a technology demonstration activity, post demonstration questionnaires, and structured interviews. During the demonstration, older adults were introduced to DHAs for the first time. We taught participants about the device's capabilities and features and then demonstrated a range of basic uses for each device (e.g., checking the weather, playing music, setting reminders).

This approach allowed us to garner rich qualitative data on older adults' underlying preferences and perceptions towards DHAs, which can be used to inform the design of future digital assistant form factors for enhanced usability and to better meet their needs and capabilities in home envi-

Figure 1. Amazon Echo Speaker (left) and Amazon Echo Show (right)

ronments. We assessed attitudes by using natural language processing sentiment (NLP) analysis, to inductively explore participants' initial impressions toward each device in an in-depth and open-ended manner. In addition, a combination of open-ended structured-interview questions and brief quantitative assessments were used to understand perceptions (e.g., perceived usefulness). Our work informs the TAM theoretical frameworks by providing qualitative insight regarding the initial development of perceptions of usefulness, usability, and ease of use from older adults who were previously non-users of DHAs.

METHOD
Participants
Data were collected via brief questionnaires and structured interviews from 18 older adult participants, all of whom had no prior experience using Amazon Echo devices (e.g., the Echo Speaker and Echo Show) (Table 1). Data collection took place in Central Illinois. Half of the participants resided in senior housing, whereas the other half lived independently in non-senior housing. Among the participants who resided in senior housing, 3 had mobility disabilities, defined as "Do you have serious difficulty walking or climbing stairs?" and 5 reported hearing disabilities, defined as "Do you have serious difficulty hearing?" All participants were pre-screened using the Montreal Cognitive Assessment (MoCA) and scored 26 points or more (out of the possible 30). Participants were compensated with a $25 Amazon eCode gift card.

Materials/Measures
Devices/Equipment
Participants learned how to use and interacted with two DHAs – the Amazon Echo and the Amazon Echo Show (Figure 1). These DHAs were selected because Amazon Echo devices held the largest market share of consumer adoption at the time of data collection (National Public Radio, 2019). In addition, the Amazon Echo system allows for users to evoke the same commands to different device form factors (i.e., smart speaker and smart display), which could afford older adults more opportunities to tailor use to their needs, capabilities, and preferences. Lastly, the Echo Show device had recently been released and research had yet to explore initial perceptions and attitudes toward the device for older adult residents of senior living facilities.

Initial background questionnaire
Participants completed the TechSAge Background Questionnaire (Remillard et al., 2020), which assessed demographic and health characteristics such as age, sex, educational attainment, and self-identified disabilities (Table 1). We also assessed participants' technology experience

Table 2. Perceived usefulness and perceived ease of use measures

Perceived usefulness	Perceived ease of use
I would find the Echo useful in my daily life	I would find the Echo easy to use,
Using the Echo would enhance my effectiveness in my daily life	I would find the Echo to be flexible for me to interact with
Using the Echo my daily life would increase my productivity	It would be easy for me to become skillful at using the Echo
Using the Echo would make my daily life easier	I would find it easy to do what I want to do with the Echo
Using the Echo would improve my daily life	Learning to operate the Echo would be easy for me
Using the Echo in my daily life would enable me to accomplish tasks more quickly	My interaction with the Echo would be clear and understandable

Note: Response options ranged from 1 (strongly unlikely) to 7 (strongly likely).

and proficiency with the 19-item Technology Experience Profile (TEP) (Barg-Walkow, Mitzner, & Rogers, 2014). Our version of the TEP asked participants about their use of technology across five different domains within the past 12-months – communication technology, computer technology, everyday technology, health technology, and transportation technology. Response options ranged from not sure what it is (1), not used (2), used once (3), used occasionally (4), and used frequently (5) (Table 1).

Structured demonstration, interaction, and interview script
Throughout all data collection procedures, study personnel followed a detailed script to navigate the demonstration activities and instructions for both devices. The script included brief structured interview questions that were administered to participants – immediately following their initial interaction with each device. The structured interview questions were designed to explore older adults' initial impressions of each device as well as elicit perceived benefits/concerns, facilitators, and barriers to use.

Post interaction questionnaire measures
The post interaction questionnaires assessed two key concepts from the Technology Acceptance Model – perceived usefulness and perceived ease of use (Davis et al., 1989), as indicated in Table 2.

Study procedures
After providing informed consent, participants were introduced to the Amazon Echo and Ama-

zon Echo Show devices. Trained study personnel taught each participant about the capabilities of each device and demonstrated a series of common Alexa commands. Specifically, participants learned how to use each Amazon Echo device to listen to music; make shopping lists; check the weather and news; and set reminders, timers, and alarms. After the researcher demonstrated each command/task, the participants were provided with notecard instructions/commands and completed the same commands that were demonstrated. Following the interactive demonstration activity, we conducted structured interviews to explore participants' initial attitudes and perceptions toward each device. In addition, participants completed post-interaction questionnaires regarding perceived usefulness and ease of use. Data Availability Statement: Deidentified data, analysis code, and study materials will be made available upon request. The data collection process is shown in Figure 2.

Analytical procedures
We used descriptive statistical procedures and simple data visualization techniques (e.g., histograms) to examine the quantitative post-interaction questionnaire data. In addition, we used inductive qualitative coding procedures (Braun & Clarke, 2006; Blocker et al., 2020) to examine the transcribed audio data from the post-interaction structured interviews. To code the interview transcripts for perceived usefulness (PU) and perceived ease of use (PEOU), inter-coder reliability was established by two research team members (Cohen's Kappa > 0.8). Our goal was
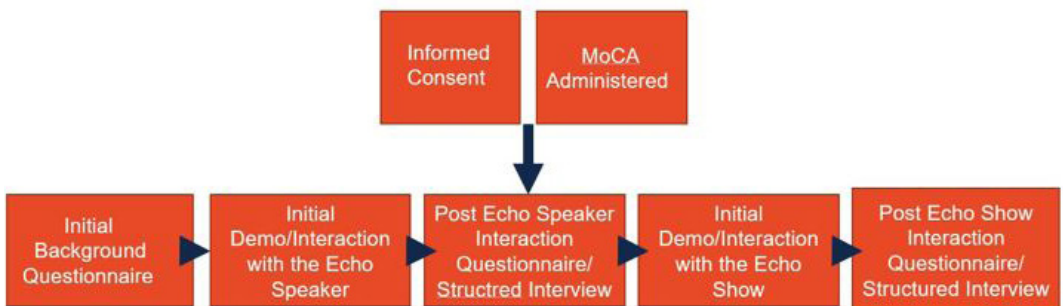

Figure 2. Study flow diagram

Table 3. Sentiment score attitudes based on initial first impressions

Device	Mean	Standard deviation	Median	Minimum	Maximum
Echo	.40	.24	.37	0	.78
Echo Show	.43	.32	.44	-.34	.84

Note: Scores range from -1 to 1, above zero reflects positive attitudes, whereas below zero reflects negative attitudes.

to identify the most salient emergent themes, especially those related to perceptions of usefulness or ease of use. The emergent sub-themes were iteratively synthesized to reduce discrepancies and redundancy. Lastly, sentiment analysis was performed to evaluate participants' overall attitudes towards each device. The sentiment analysis was performed using the Natural Language Training Kit software package and Python programming language. The Natural Language Training Kit software package is a widely used set of validated algorithms that process text-based data. The software package was used to process the transcribed interview text for the question *"what is your initial impression toward the [Echo and Echo Show]?"* The software then automatically computed the sentiment scores, which could range from -1 to 1, with scores above zero representing positive attitudes and scores below zero as negative attitudes. Subsequently, two research team members reviewed the scores for each statement for accuracy to ensure that no software bugs influenced the scores.

RESULTS
RQ1: What are older adults' initial attitudes toward Amazon Echo Devices?
Participants had positive initial attitudes towards both the Echo and the Echo Show (*Table 3*). In fact, none of the participants held a negative attitude towards the Echo device, with only one participant having an initial negative attitude toward the Echo Show. The descriptive statistics for both devices were otherwise almost identical. Thus, on average, participants had a similarly positive attitude and attitude strength towards each device.
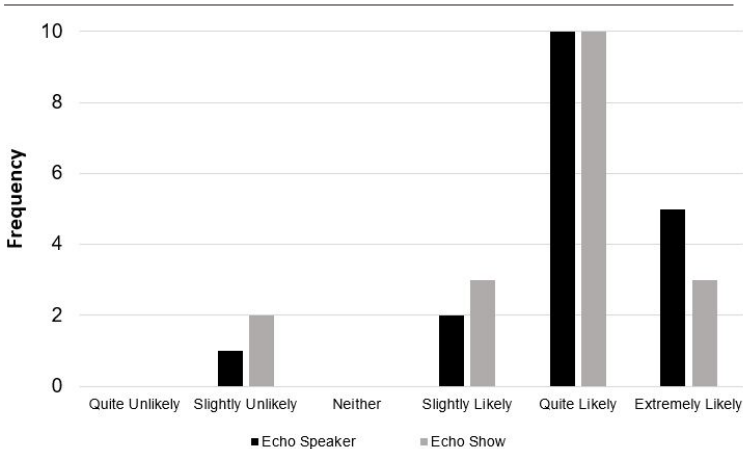

Figure 3. Distribution of response for the questionnaire Item "I found the device useful in my daily life"

RQ2: What are older adults' initial perceptions towards Amazon Echo Devices?
Perceived usefulness results
Overall, participants perceived both devices as highly useful. Only 2 participants perceived that the Echo Show would be slightly unlikely to be useful, whereas only 1 participant rated the Echo as being slightly unlikely to be useful (*Figure 3*).

Enhanced productivity/efficiency
Consistent with the qualitative data, *Figure 4* highlights participants' responses to the post-interaction questionnaire item on perceptions of enhanced productivity. Almost all participants viewed that using either Echo device would increase their productivity.
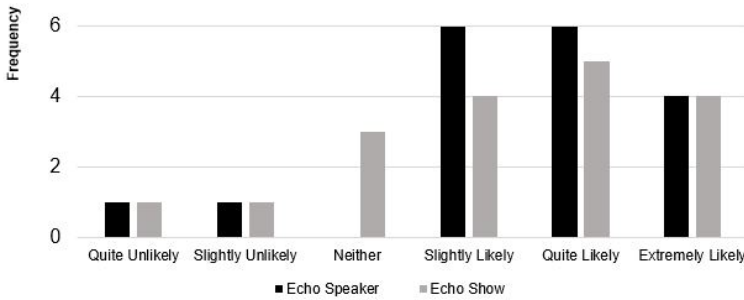
The interview data provided insight into reasons that may be driving these initial positive perceptions towards both devices. Fourteen of the 18 participants discussed how using Echo devices could help them enhance their daily productivity and efficiency with tasks. Participants described a broad range of possible ways that using the Echo devices could help them be more productive and efficient. In reference to the Echo, one participant who resides in senior housing stated: *"Yes in so many ways, I could use it for reminders, for a time, I mean things I use all the time like a timer and it would tell me, you know like I'm timing I have to go back to the laundry room now and get my laundry, I mean in just so many ways and I have to-do lists all the time and um, I don't remember to do things if they're not on my to-do list. It's so great."*

Regarding the Echo Show, one male participant (non-senior housing resident) stated: *"There are things that I do in my day that I simply must do, for example, picking up my grandson from school, and I have been known to forget that and something like this would help me a great deal to do the things that I'm supposed to do without forgetting."*

Improved independence
Another common theme that emerged from the interview data was related to improved independence for oneself and for other people with diverse needs and capabilities. In total, 11 of the 18 participants discussed that they perceived that the Echo devices were useful because they could help enhance in-

Figure 4. Distribution of response for the questionnaire Item "Using the device in my daily life would increase my productivity"

Enjoyment/fun

The post-survey measure further confirmed that participants viewed both devices as highly enjoyable based on their first interactions and impressions (*Figure 5*).

Another potential underpinning reason for why participants perceived the Echo devices to be useful was that they perceived that it would be fun and enjoyable to use the devices in their daily life. Half of the participants discussed aspects of how using the devices would be fun and enjoyable for themselves or for other older adults. For example, one female participant (who did not reside in senior housing) stated: *"I'm thinking about my mother. She could just tell it to play music, or tell it to remind her to do something, or to remind her to take a pill. It could be kind of fun for her, a novelty."* Other participants went on to state: *"I would enjoy the music"* and *"it would be so convenient and I would enjoy it."*

dependence and work as a support tool in the home. Participants enumerated a diverse range of possible ways that using the Echo devices could help improve independence. For instance, one female participant (who did not live in senior housing) stated, in reference to the Echo, *"in the elderly community, where people aren't mobile, it would be an excellent tool for them."*

In addition, one male participant (resident of senior housing), elaborated: *"Visually impaired, certainly be useable. People do have mobility issues, instead of having to get a device where they left on the counter, or on the desk or whatever, People with memory problems it's just another way that somebody else could program in some helpful reminders I don't remember if it could play a prerecorded message. But for example some who gets worried, where's my husband, where's my husband who she can't live with him, she need more support than she can give her, but it would be able to say honey I love you I'm, with you, I'm thinking about you so she can either get one message or varied messages depending how flexible she is to give her the sense of his voice I don't know. That would be an unusual use of it."*

Perceived ease of use

In general, participants perceived that both Echo devices would be easy to use (*Figure 6*). All participants viewed that the Echo was easy to use and only 3 participants perceived that using the Echo Show would be difficult to use. Participants commonly held the sentiment that *"It's convenient, it's easy"* and *"It's simple to use."*

System learnability

The post-interaction questionnaire data corroborates the system usability theme (*Figure 7*). Specifically, most participants perceived that learning to operate the Echo devices would be easy for them. However, two participants viewed the Echo Show and Echo would be challenging to learn.

One key reason why participants viewed the device as easy to use was their perception that learning to use the device was easy. One participant stated: *"I am extremely impressed with how easy it is, and how versatile it is. A lot of times, in any experience with the interaction, you have to be very, very careful how you pronounce words, and so-on to get them to understand what you're saying and it seems to be no problem with Alexa, so I'm*
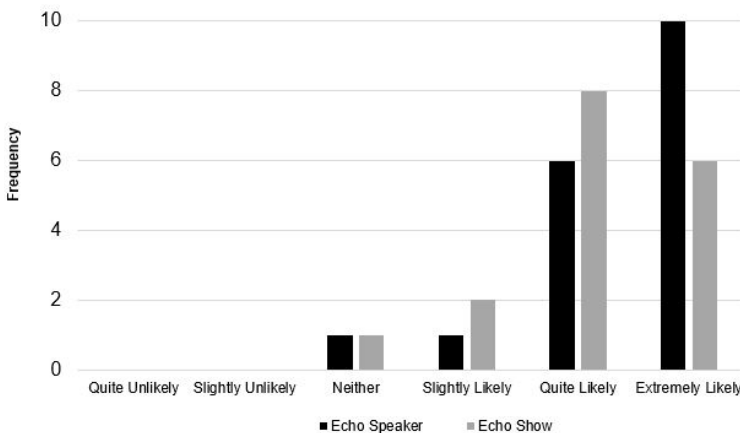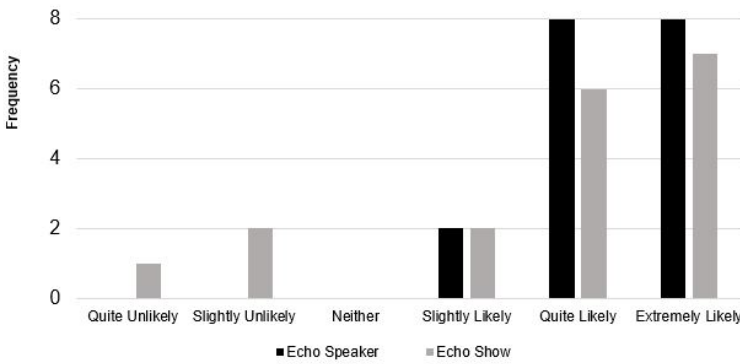

Figure 5. Distribution of response for the questionnaire Item "I find using the Amazon Echo to be enjoyable"

Figure 6. Distribution of response for the questionnaire Item "I would find the device easy to use"

or even Alexa responding, I will, then I would know that my answer was forthcoming."

In addition, another participant said, "I think the only thing I would like to change [about the Echo] is the fact that after you ask a question, or asking for information Alexa doesn't respond to you and there's just that dead silence and you are uncertain as to whether Alexa understood the question."

impressed with that." Other participants stated: "The fact that it was strictly verbal which is always the fastest, easiest way to communicate." However, other participants did express concerns about not knowing what else they could get the Echo devices to do. For example, one participant stated that the devices could be difficult to learn because they would "not always knowing how to word things to get the answer you want."

System feedback theme
Another emergent theme related to perceived ease of use as system feedback. Participants expressed potential barriers and facilitators pertaining to the feedback that the devices provide to help users navigate through commands and complete tasks. Specifically, in reference to the Echo, participants expressed that "The fact that when you request the device to do something there's no indication whether the device acknowledges your voice or that the device understood what I was asking it to do. There was just a silence there. If there was some kind of sound it made

Participants expressed a range of positive perceptions related to the system feedback afforded by the Echo Show device. Specifically, participants stated, "I think it's really neat, cool. I really like it to be able to hear and to see... See things and see my answers and that, I really like that. I like it better than the other one." Another participant stated, "I like the reinforcement of the visual with the audio." Though some participants viewed that they would use both the Echo Show and Echo for similar tasks, they added "I would use it for basically the same activities that I would the Echo itself, and the Show added with it would, I think, help eliminate mistakes and it would help remind you about things that maybe you didn't hear on the Echo itself so that you have both the audio and the visual to bring it home to you what it is that you're supposed to do, or remember, or so on."

DISCUSSION
Initial attitudes
The goal of this study was to learn about the initial attitudes and perceptions towards DHAs by older adults with and without disabilities (e.g., hearing and/or mobility impairments). Despite the qualitative differences between the Echo and Echo Show form-factors (e.g., the Echo Show has a touch screen graphic user interface), participants had similar positive attitudes towards both devices. The touch screen on the Echo Show is a key feature that may promote usability for older adults (e.g., Blocker et al., 2020. We observed that, across our sample of older adult users with diverse physical and perceptual abilities, the positive attitudes were consistent for
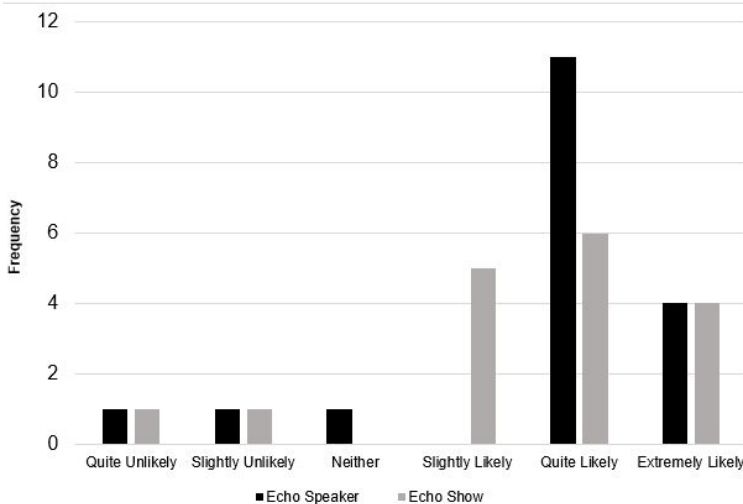

Figure 7. Distribution of response for the questionnaire Item "Learning to operate the device would be easy for me"

both devices. This suggests that although DHAs equipped with a touchscreen user interface may promote ease of use, older adults were still open to accepting voice-activated DHAs without this feature as well.

Initial perceptions

Older adults who are early adopters and long-term users of DHAs tend to hold highly positive perceptions of their devices (e.g., Koon et al., 2020), but a dearth of existing research informs what factors may influence the development of initial attitudes and perceptions of novice users. In taking a mixed-method approach, we identified potential underlying factors that may influence the initial development of older adults' attitudes and perceptions toward DHAs. Specifically, participants perceived both Echo devices as useful, largely because they thought that using the devices would improve their daily efficiency, productivity, and independence.

These findings bode well for the potential for these devices to support successful aging for older adults with diverse health-related needs and capabilities – though future research could benefit from longitudinal observations to better understand the impact of long-term use for supporting aging in place. Moreover, perceptions of usefulness were also associated with enhanced activities of living that go beyond the daily activities required to live independently. For example, the older adults perceived both Echo devices as an accessible and fun options for entertainment purposes, such as for music, interactive games, and videos.

Older adults with disabilities face an increased risk of experiencing social isolation and loneliness (Prieto-Flores et al., 2011). In the present data, we did not identify themes to suggest that DHAs could be a viable tool for promoting social communication and engagement. However, our data were collected prior to the COVID-19 pandemic, which clearly intensified the need for promoting social engagement and communication for older adults, especially those who reside within assisted and independent living facilities that have been subjected to strict social distancing and visitation policies. As such, additional research is needed to revisit older adults' perceptions towards using DHAs for social communication and engagement purposes, as well as if these perceptions differ by device form factors (e.g., Echo Show devices afford video-conferencing capabilities, while the Echo only affords verbal communication).

Identified potential usability challenges

In general, participants held the perception that both devices were generally easy to use and learn; however, we did observe potential usabil-

ity issues related to system feedback and system learnability. Participants expressed that having both the audio and visual system feedback on the Echo Show could help reduce mistakes and provide more system guidance. These findings could help inform the design of future DHAs to support ease of use for older adults with diverse needs and capabilities. Specifically, the Echo was perceived to have a lack of system feedback to let users know Alexa is processing their commands. Moreover, most participants perceived that they would be able to learn how to use both devices over time.

A consistent challenge that we identified was the precision needed to phrase commands correctly. Concerns were expressed about not knowing exactly what to say/how to command the Echo devices for additional desired use-cases that go beyond the basic uses (e.g., checking the weather or setting timers) involved in the demonstration and interaction activity. Despite the fact that several participants had hearing-related disabilities, our quantitative data suggested that, on average, both devices were rated as having a high degree of perceived ease of use. Taken together, we encourage future voice-activated DHA research with older adults aging with perceptual (e.g., auditory) related disabilities to identify additional facilitators and barriers to adoption and use.

CONCLUSIONS

Overall, our findings portray that the inherent potential of voice-activated DHAs to assist older adults in improving/maintaining their quality of life is complemented by mostly positive attitudes and perceptions of the technology by novice older adult users who had relatively low general technology experience (e.g., they only occasionally used the technologies assessed by the TEP). The positive attitudes and perceptions expressed by the older adults in this study not only information technology designers that this population is generally receptive to such a device and its capabilities, but also represent the degree of support that voice-activated DHAs and connected devices may be able to provide to an aging population comprised of a multitude of different needs, challenges, and goals. Compared to other technologies increasingly endorsed by older adults (e.g., personal computers, smartphones, tablets), voice-activated DHAs are still in their infancy and thus much work is needed to not only improve their accessibility and use by all ages but especially for older adults who may have the most to gain from integrating such a device into their daily lives.

The current study provided a glimpse of the initial subjective impressions toward digital home assistants shared by a sample of older adults; however,

to ensure we fully understand the real impact that these devices may have in improving the quality of life for this population, future work should investigate the objective impact that digital home assistant use by aging generations has to assist them in reaching their goals and completing the activities of daily living that are important in successful aging and self-management. Understanding the long-term interaction patterns as well as the real impact that dedicated interventions may have on facilitating aging in place for older adults is important to reveal the utility and usability barriers that may arise upon continued use, especially as these devices, their capabilities, and their form factor continues to iteratively evolve over time. Such interventions may have social, physical, and psychological implications. By improving the usability of voice-activated digital assistants for older adults, usage of the technology could lead to increased social engagement, interpersonal communication, and a stronger sense of community. Physical benefits could range from enhanced environmental controls, medication management, and health information tracking. Lastly, the psychological implications may involve improved support and quality of life across various domains, such as a decline in loneliness.

Continued research is needed to understand how to best inform older adults on the utility of such technologies, how to effectively educate this population to use them to their full potential, as well as lessons that may be learned to improve the usability of digital home assistants specifically for older adults who experience disabilities and chronic health issues. In addition, future research would benefit from a more varied sampling of older adults (i.e., diversity among ethnicities/races, educational attainment, disabilities, among others) interacting with various brands of contemporary digital home assistants (e.g., Google Nest products) to address the limitations of the current study and to effectively improve the generalization of these findings to the broader older adult population. Addressing the many important questions within this space will result in not only a more accessible and usable digital home assistant experience for older adults but can more effectively deliver the potential benefits of using this digital tool to those who are in most in need of support to overcome age-related challenges and live the life they desire to live.

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