

Identifying Barriers to Usability: Smart Speaker Testing by Military Veterans with Mild Brain Injury and PTSD

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Abstract: Emerging technologies need to be tested for usability and usefulness by target users in the context in which they would likely use these technologies. This is especially true for people with disabilities who may have specific use cases and access needs. This paper describes the research protocol and results from usability testing of smart speakers with home hub capability – Amazon Echo and Google Home – by military combat veterans with mild traumatic brain injury (mTBI) and post-traumatic stress disorder (PTSD). Research was conducted with 8 clients in a rehabilitation program for military service members at Shepherd Center in Atlanta, Georgia, USA. Smart speakers and 2 smart plugs were installed in residences owned by Shepherd Center and occupied by clients undergoing rehabilitation. Participants tested each device for 2 weeks, including setup and daily use, and completed electronic diary entries about their experience. Additionally, they completed a summative questionnaire interview about their experience at the end of each phase. The goal of the research is to identify usability opportunities and challenges of each device in order to inform development of in-home therapeutic solutions using emerging smart home technologies for this population.

1 Introduction

Smart home technology (smart speakers, smart plugs, smart thermostats, etc.) has emerged as a new category of consumer electronics that offers potential as assistive technology (AT) for people with disabilities. These Internet of Things (IoT) technologies connect to Wi-Fi networks, or smartphones via Wi-Fi or Bluetooth. IoT technologies offer substantial assistive and accessibility benefits to users, including multiple ways to collect and retrieve data and control the environment using voice, touch, and gesture.

Amazon Echo and Google Home are internet connected smart speakers equipped with far field microphones to support voice recognition and hands-free interaction with voice-enabled smart assistants (e.g., Amazon Alexa and Google Assistant). They provide information or assistance, play music or control smart home devices in response to voice commands. Both can add “skills”, much like adding smartphone applications, and connect to third party smartphone apps to add functionality.

2 Smart Speakers: PTSD and mild TBI

Smart speakers sit at the intersection of in-home intelligent personal assistants (IPAs, including Alexa, Siri, Cortana, and Google Assistant) and home automation. They are particularly useful for their combination of access to information (news, weather, sports scores, trivia, etc.) and entertainment (music, games, etc.), and access to environmental controls (lights, thermostat, door locks, and other devices).

PTSD and mTBI frequently co-occur in combat veterans returning from Iraq and Afghanistan, often impacting independent living and quality of life (Tschiffely, et al. 2015). Common features of PTSD include anxiety, perceived threat, avoidance behaviors and hyper-vigilance (American Psychiatric Association 2013). Combat veterans with persistent mTBI symptoms often experience challenges with memory, attention and executive functioning. Those experiencing both PTSD and mTBI also commonly report depression, sleep problems and emotional disturbances (Tanielian et al. 2008; Chen et al. 2011).

The considerable AT potential and rapid pace of development of smart speakers points to the need for systematic assessment of usability by people with specific functional difficulties, including difficulties confronting combat veterans with PTSD and mTBI. Such assessment will help designers and developers ensure equitable access to these increasingly important technologies and will help inform and guide AT consumers.

Amazon has promoted the assistive and accessibility capabilities of the Echo at disability conferences and has won favorable coverage for its potential as assistive technology (St. John 2017). Both Echo and Home show potential to support independent living of people with disabilities (Capan 2016; Woyke 2017). However, only limited investigation of the usability, user-preferences and potential to meet the unique needs of users with disabilities has been conducted, particularly for users with cognitive and psychological disability. A literature search of research on the usability of Echo and Home yielded limited results, and none addressed usability by military service members with TBI and PTSD.

2.1 Consumer Technology: Accessibility as a Fundamental Need

Usability of mainstream consumer electronics (information and communications technology, or ICT) has been a central concern of rehabilitation researchers and engineers. Each new generation of technology – personal computers (Kessler Foundation/National Organization on Disability 2010), cellphones, smartphones and tablets (Fox 2011; Morris et al. 2014), wearable

technology (Wallace et al. 2017) – has prompted new lines of investigation and rehabilitation engineering.

The literature on access and use of consumer technology by people with disabilities comprises a number of themes, often focused on so-called “divides”, including most centrally the disability divide. This line of inquiry was energized in the United States by the publication of two seminal reports published in the early years of the smartphone era: the Kessler Foundation/National Council on Disabilities survey research report on technology access (2010) and the U.S. Federal Communications Commission working paper on broadband adoption (Horrigan 2010). There has also been research into age, education and income divides for both the general population (Blumberg & Luke 2017); and people with disabilities (Morris et al. 2016). Morris & Mueller (2014), have also documented differences in the use of consumer technologies across disability types, specifically blind and deaf individuals.

At the core of research into these divides – including the “disability divide” – is concern for equitable access to technology. Increasingly, access to information and communication technology is essential to community participation, education, and employment. For people with disabilities these concerns are enshrined in public policy on the national level in the United States (Americans with Disabilities Act of 1991; 21st Century Communications and Video Accessibility Act of 2010, for example), and on the international level (UN Convention on the Rights of Persons with Disabilities). CRPD’s Article 9 on Accessibility stresses that signatory partners should take appropriate measures:

To promote access for persons with disabilities to new information and communications technologies and systems, including the Internet; [...]

To promote the design, development, production and distribution of accessible information and communications technologies and systems *at an early stage* (emphasis added), so that these technologies and systems become accessible at minimum cost.

2.2 Smart Speakers and Usability

Their versatility and the centrality of voice control in their operation endow smart speakers with considerable potential as assistive technology. But usability challenges remain for smart speakers/smart assistants. Controlling multiple smart speakers/smarthome hubs (e.g., Echo’s and Echo Dots) can be confusing on a single mobile app. The use of multiple connected devices in your smart home can make learning their “dialogue path” (e.g., “Alexa, ...”) and device names complicated and confusing for users, family members and guests (Stinson 2017).

Other usability challenges identified for specific devices have been documented. Google Home cannot set reminders (Murnane 2017) – a potentially key assistive function for people with difficulty remembering. One product reviewer noted that a requested list of ingredients for cooking recipes was spoken too fast (even at the optional slower rate) to be useful (McGregor 2017). For the recently released updated version of the primary Echo device, Amazon has

replaced the twist-top volume ring found on the original Echo device with harder-to-find unlighted buttons, just like those on the cheaper and smaller Echo Dot.

More fundamental questions about ease of set-up and use by people who may have uneven or limited speech, dexterity, hearing or vision also need to be answered. Can Alexa and OK Google understand slurred, slow or halting speech? Can users hear and distinguish the various tones and other audio output? What are the physical interactions like with these devices and do they provide sufficient flexibility of use as recommended by principles of Universal Design (Center for Universal Design 1997)? The present focuses on user experiences and preferences from real world use. More in-depth laboratory testing will follow.

3 Methodology

An in-home usability diary study of Amazon Echo and Google Home smart speakers was conducted with 8 military service members with PTSD and mTBI. Information about the accuracy, reliability and usability, user acceptance, user preference and potential for future development of skills for the smart home speakers was gathered.

Participants were recruited from the SHARE Military Initiative program at Shepherd Center, a rehabilitation hospital for people with spinal cord injury, brain injury and other neurological disorders. The SHARE program is a comprehensive outpatient day rehabilitation program for military service members with mTBI and PTSD. Participants live in an apartment complex owned by Shepherd Center while receiving intensive physical, cognitive and behavioral outpatient therapy for up to 12 weeks. The structure of the SHARE program provided a unique opportunity for this in-residence usability testing of smart speakers.

Purposive sampling was undertaken to identify participants with mTBI and PTSD with functional language, speech, hearing and vision. The research team consulted with the SHARE psychologists and speech-language pathologists to identify appropriate candidates for in-residence technology testing. Fourteen potential participants were identified. Two declined to participate in the study; one reported discomfort with having a speaker in his apartment that was “listening to everything” while the other stated he was “not big on technology” because he found learning to use new technology was often frustrating.

In all, 8 individuals, 7 males and 1 female, completed testing of both devices. Participant age ranged from 30 to 57 years with time since initial onset of injury ranging from 1 to 24 years. Most reported experiencing multiple mTBIs resulting from direct fire or explosive blasts, falling and/or motor vehicle accidents. All reported one or more trauma events resulting in PTSD. Difficulties with anger, anxiety, depression, aggression, isolation, memory, attention, back pain and headache were reported by more than half of the participants.

Information on experience with computers and smart technology was collected for each user prior to initiation of technology testing (Table 1). All owned a smartphone, an inclusion criterion for participation in the study, which are needed to setup and use these two smart speakers.

Table 1 Participants experience with and use of technology (n=8)

Do you use any of the following on a regular basis?	
Smartphone	100%
Laptop or desktop computer	50%
Fitness tracker	50%
Tablet	38%
Regular cell phone	13%
Smartwatch	13%
Amazon Echo, Dot or Tap	13%
Google Home	0%
Mp3 player (separate from another device)	0%
Google Glass	0%

Participants tested each smart speaker, either Amazon Echo or Google Home, in their apartment for 2-weeks using a cross-over design for a total of 4 weeks testing of the 2 devices per participant. Half of the participants tested Echo first and half tested Home first to minimize bias related to which smart speaker was experienced first. Each participant was also given 2 TP-Link mini-smart plugs. Participants were asked to set up the technology in their apartments and were provided with assistance if they were unsuccessful. Participants completed one-on-one interviews on their experience setting up each device.

They were also asked to complete electronic diary entries about their experience twice weekly. And they completed a summative questionnaire interview about their experience at the end of each phase. Guiding questions in each interview and electronic diary entry were aimed at identifying usability opportunities and challenges of each device to illustrate usability for this population and to inform future development of in-home therapeutic solutions using emerging smart home technologies.

For usability questions, a 5-point Likert scale was used that ranged from “very hard” to “very easy.” Questions related to preferences for either device or the voice input/output used other formats. Additionally, the questionnaires for study intake, setup, use diary, and exit interview relied on numerous open-ended question formats to encourage unstructured user feedback. These were more suited to the exploratory nature of the research. The small sample size also supported including many qualitative questions. The questionnaires were brief in order to ensure that cognitive load was minimized and to avoid causing emotional frustration.

4 Results

Most users found Amazon Echo easier to set up than Google Home, mainly because of difficulties connecting the latter to the WiFi network maintained by Shepherd Center for apartment complex provided to SHARE program clients. Google Home required considerably more assistance, apparently the result of difficulties using the required 2-step authentication process of the devices with the shared secure network. Also, three of participants required assistance setting up the smart plugs.

Some users reported frustration with the lack of written instructions provided by Amazon, Google and TP-Link for setting up these smart devices. Their makers state setup of the devices is intuitive and guided by the apps installed during the setup. However, this user-testing indicates setup may be less intuitive for users with cognitive and/or psychological dysfunction. Some users may benefit from access to supplementary written instructions. A written description of possible error messages (and associated changes in light color or blinking patterns) for each device may also be helpful.

During and after use of the smart speakers, 75% of participants reported Amazon Echo was easy or very easy to use compared to 71% (1 observation missing) for Google Home (Table 2). One participant reported difficulty manually controlling the volume on Google Home, which requires fine motor use of a finger to swipe clockwise or counter clockwise on the top of the device. Participants reported Home correctly understood their voice commands more often than Echo, rating Home as understanding what the users were saying an average of 93% of the time, versus 81% for Echo.

Table 2 User assessment of the setup process and use of Amazon Echo and Google Home

	Amazon Echo	Google Home
How easy/hard was it to set up each device?	Easy or very easy – 75%	Easy or very easy – 25%
How easy/hard has it been to use each device in last 3-4 days? (Final diary entry)	Easy or very easy – 75%	Easy or very easy – 71% (1 missing observation)
How useful has each device been in your life over the past 3-4 days? (Final diary entry)	Somewhat or very useful – 88%	Somewhat or very useful – 71%

Participants also reported a preference for the sound of the Alexa smart assistant's voice on Echo, compared to Google Assistant's voice on Home, rating the former at average of 8.1 out of 10, versus 7.5 for the latter (Table 3). Several participants reported they preferred the Echo's wake word (Alexa) to Google Home's (OK Google or Hey Google), noting that it felt more personal. Participants also preferred Echo's look and aesthetic design, rating it at an average 7.4/10

versus a 6.8/10 for Home. Overall, at study conclusion, 7 of the 8 participants said they preferred Amazon Echo to Google Home.

Table 3 User assessment of the design of Amazon Echo and Google Home

	Amazon Echo	Google Home
How do you feel about the sound of smart assistant's voice on each device?	8.1/10 average rating	7.5/10 average rating
How do you like the look of each device?	7.4/10 average rating:	6.8/10 average rating

Participants made numerous suggestions about things or activities they wish the devices could do or things they would change about the devices (Table 4). Some referred to improving setup process and minimizing connectivity issues. Many mentioned that they wish they could access other media and devices with the smart speakers, including their iTunes library and other, the television, and voice calling.

Many of the participants used the devices for alarms and reminder, for which they made several suggestions on how they want those reminders to function, with specific requests for more details on what the alarm is for or for reminders of items on their daily calendars. Additionally, several wanted improved voice interaction. Some wished that the smart speakers understood what they were saying better. Others complained of the need to speak slowly or of the need to use specific vocabulary for commands. Additionally, one participant complained of the perceived required lag between saying the “wake-up” word (“Alexa”, or “OK Google”) and being able to voice the desired command.

Table 4 What would you change about each device/What else do you wish each device could do?

Amazon Echo	Google Home
I would like for the Echo to be more active in being used as a reminder for people with memory problems, more uses such as alarms and or appointments, and to be more sensitive to commands. Sometimes the device could not process commands.	When an alarm goes off I want the details. I don't just want an alarm sound. I want it to be like hey - you gotta do ... now. Or hey, it's time for you to do ...
Have a repeating alarm. I had to set one every day for medications.	I wish it could automatically call a contact. If a timer was set and I wish it could tell me my daily schedule.
Connect to and control a firestick. Ask permission of owner/operator before allowing drop ins. Better voice recognition and learning.	Turn on the TV for me, hook it up with more things in my house.

Choices for different voices.	A different voice.
A few times I got the red ring and it had trouble connecting. I wish that didn't happen because I didn't know what was going on.	Make the set up easier.
Improve the lag time between having to say "Hey Alexa" or "Alexa" and the statement of what it is I am needing.	Its appearance, configuration, and smartphone app.

Participants reported similar uses for both devices. Nearly all participants used them to stream music regularly and most commented on how useful that feature was for helping them relax. Others functions commonly performed by most participants included turning lamps off or on (with connected smart plugs), asking for information (e.g., the time, date, weather or sports scores) and using timers, alerts or calendar integration to recall and complete planned tasks. All participants reported the smart speakers were useful in their daily life and all reported they would like to continue to use the smart speakers at study conclusion.

Table 5 What do you think overall about the smart home devices you tested?

The Google Home was good at reminders, music, and a great sleep therapy device. I used it with my grounding technique from therapy to relax and wind down for sleep. I was able to increase my sleep by an hour and a half. I also liked the idea of the reminders for appointments, medication, and wake-ups.
Something I would continue to use in my own home. The Alexa was much easier to connect and use than the Home device. It aided me on scheduling, alarms, timers, music, tasks, reminders, information
I thought it was really cool. It made me feel not so alone.
It was interesting. I think I'm going to get one.

When asked if they thought smart speakers could help them or if they had helped them, participants were unanimously positive. Specific areas identified were support for relaxation, memory and communication or sharing of important information with family and caregivers (Table 6).

Table 6 Do you see this type of technology as something that could help you? Did it help you? How?

Yes, it was very helpful for assisting me with my memory problems about dates and events. It also helped with relaxation from the different music options.
It aided me on scheduling, alarms, timers, music, tasks, reminders, information.
Yes. To distract me with music or games. And to set alarms.
Yes, it can help. With things around the house it could help me control things. Now that I'm more into schedules, when I have time I can apply that to the device and it can keep me on track. I could track when finances are due and have it notify me.

5 Conclusion

This study identified insights into the usability, needs and user preferences for smart speakers by military veterans with PTSD and mTBI. It also indicates further exploration of the usability challenges of smart speakers for this population is needed.

Overall, it showed that most participants found both devices easy to use, which is critical for this population, which can have difficulty handling added stress and frustrations.. Both devices were also reported to have high reliability in recognizing spoken commands by these users. On the other hand, it showed that setup is not as seamless as it needs to be, particularly for Google Home.

From a research design perspective, the study proved challenging. Testing technology over an extended period in the user's place of residence adds considerable logistical requirements. Setup and troubleshooting required considerable time on the part of the research team, an investment that would have been greatly reduced with a sit-by testing design in the lab with it's ideal conditions.

Additionally, in-residence testing required more careful screening of participants to make sure that they would be in the rehabilitation program long enough to complete the study. Enrolling new participants early in the program became a key strategy, but was not fail-safe, as the personal lives of a number of participants interrupted our carefully planned testing schedule. Vacations, holidays, family emergencies, and other unanticipated events required regular readjusting of testing schedules.

Our experience conducting this pilot study has encouraged us to explore developing a more detailed study for this population, and has inspired us to consider testing with other disability populations. The rapid pace of consumer technology innovation – including smart speakers – requires ongoing testing to ensure accessibility and usefulness by consumers with disabilities.

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