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User Personas: Smart Speakers, Home Automation and People with Disabilities

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Abstract

Rapid adoption rates of smart speakers and home automation and control devices, and predicted strong future growth requires ongoing research to understand and anticipate the needs of consumers with disabilities. This paper uses quantitative and qualitative survey research data to develop "personas" for consumers with one of six disability types – limited dexterity, limited mobility, low vision, blindness, hard of hearing, and deafness. Personas are research-based fictional characters developed to represent different user types that might use a service, device or other product in a certain way. They help designers and engineers understand user needs, experiences, behaviors and goals in a more personal way than lists of features and needs. The quantitative data show moderate rates of adoption of smart speakers (38%-54%) by all six disability types except deaf respondents (who have low rates of adoption), and substantially lower rates of adoption for smart-home devices (outlets, light switches, thermostats, etc.). Qualitative data reveal primarily five dimensions of feelings or impressions by owners of smart speakers and smart-home devices: fondness/enjoyment, inspiration/wonder, utility/convenience, usability/accessibility, and safety/security. From these data and our analysis one persona is summarized for each of the six disability types.

Keywords

Information and communication technology, smart speaker, home control, home automation, disability

Introduction

The global market for smart speakers (e.g., Amazon Echo and Google Home) is predicted to grow from US $1.57 billion in 2017 to US $11.79 billion by 2023, at a compound annual growth rate (CAGR) of 34.44% from 2018 to 2023 (Markets and Markets, 2018). Meanwhile the global home automation market is expected to grow from US $39.9 billion in 2016 to US $79.6 billion by the end of 2022 (Fortune Business Insights, 2019).

Smart speakers and their related ecosystems have continued to mature technologically since Amazon essentially created the segment in 2015. The company has partnered with other home device makers (e.g., Philips for smart lightbulbs), and has provided the development environment for third-party "app" developers to build "skills" that can be "enabled" on the Echo smartphone app or via voice interface with Alexa, the Echo's intelligent personal assistant. In January 2019, Amazon CEO Jeff Bezos announced: "In 2018, we improved Alexa's ability to understand requests and answer questions by more than 20% through advances in machine learning, we added billions of facts making Alexa more knowledgeable than ever, developers doubled the number of Alexa skills to over 80,000, and customers spoke to Alexa tens of billions more times in 2018 compared to 2017" (Kinsella, 2019). Google's Home product line has followed a similar approach, offering an extensive list of services and commands (Martin, Priest, & Gebhart, 2019), and compatibility with numerous third-party devices (Halpin, 2019). Google Assistant, the company's voice-enabled intelligent personal assistant also boasts integration across Google's other products, including the Android mobile operating system, which includes Android Auto.

Smart speakers and a broad range of Wi-Fi connected devices for the home – smart plugs, smart doorbells, cameras, security systems, thermostats, door locks, garage doors, blinds, televisions, and more – offer substantial assistive and accessibility benefits, including multiple

ways for users to collect, retrieve, and process information, and to control the home environment using voice, touch, and gesture. Yet, little is known about how people with disabilities use these technologies, and even less is known about their attitudes toward these potentially helpful technologies. Numerous articles in the mainstream media have highlighted the positive benefits of these emerging devices and technologies for people with disabilities. But the evidence is typically anecdotal or emphasizes how these technologies *might* be useful, not how they have been demonstrated to be useful to people with disabilities (Kalish, 2018; Pearl, 2018; Wallace & Morris, 2018). Furthermore, the usability of these devices – even for mainstream consumers – often is not always fully sorted out (Stinson, 2017; Murnane, 2018). While these technologies have matured in recent years, usability and accessibility challenges remain.

This article presents quantitative and qualitative data from our Survey of User Needs for Information and Communication Technology (SUN-ICT), including data on ownership (assets), behaviors (actions), and feelings (attitudes) of people with disabilities regarding consumer technologies. The SUN-ICT was conducted in August-September 2019 by the Rehabilitation Engineering Research Center for Community Living, Health and Function (LiveWell RERC).

Our focus on assets, actions and attitudes is aimed at developing "personas" of prototypical users with specific disabilities (e.g., Morris & Mueller, 2016; Pew Research Center, 2007). Personas are research-based fictional characters developed to represent different user types that might use a service, device or other product in a certain way. "Personas help designers and engineers understand user needs, experiences, behaviors and goals. Creating personas can help you step out of yourself. It can help you to recognize that different people have different needs and expectations, and it can also help you to identify with the user you're designing for. Personas make the design task at hand less complex, they guide your ideation processes, and they can help you to achieve the goal of creating a good user experience for your target user

group" (Dam & Siang, 2019). The development and use of "personas" to inform design and engineering has become a well-established practice in fields as diverse as computer programming (Cooper, 1999), automobile design (Patton, 2009), healthcare (Tanenbaum et al., 2018; Holden, et al., 2017; Warnestal, et al., 2017), and advertising (Jenkinson, 1994; 1995).

Discussion

This survey research is part of an ongoing effort dating back to 2001 by researchers at Shepherd Center to track the use and usability of mainstream ICT by people with disabilities. The questionnaire comprises 7 sections: 1) demographics, 2) disabilities, 3) computers and tablets, 4) mobile phones, 5) smart watches and fitness trackers, 6) smart speakers, and 7) home automation and smart home devices. To develop personas, we focused on Parts 1-2 (demographics and disabilities) and parts 6-7 (smart speakers and home automation/smart home devices). Data analysis was conducted and is presented on two levels: 1) quantitative analysis of responses to questions regarding ownership, duration of ownership, and specific uses of smart speakers and home automation devices; and 2) qualitative analysis of open ended questions regarding respondents' description of how they feel about their smart speakers and home automation devices.

Qualitative data analysis follows a standard grounded theory approach, which emphasizes: 1) description rather than explanation; 2) letting the survey respondents define their reality, rather than the researcher; 3) letting concepts emerge from the data; and 4) representing respondent behavior and attitudes in their full complexity (Hill, et al. 1997). Analysis is based on the "constant comparative method" (Strauss & Corbin, 1990). As Hill, et al. (1997) describe the method: "Researchers continuously cycle through the data, making comparisons between the data and derived categories until the core ideas have been verified" (p. 521).

The survey data reported here were collected from August 20, 2019 through September

30, 2019 using a convenience sampling approach. The total number of respondents who reported having a disability is 322. Table 1 shows that the mean age of respondents with a disability is 50.3 years with a standard deviation of 15.75 years. Females represent 57.2 percent of respondents, while Whites/Caucasian represent 79.5 percent of respondents. Almost two-thirds (63.8%) of the sample have a college degree or higher and almost 41.9% report having annual household income of $50,000 or more. A plurality of respondents reported being employed either full- or part-time (47.2%). Most respondents reported living with someone else (75.5%) and living in a suburban area (51.7%).

Table 1. Demographics: All Respondents with Disability

Demographic	**Response**
Age – mean (years)	50.30
Age - standard deviation (years)	15.75
Race/ethnicity (% white/Anglo)	79.5%
Gender (% female)	57.2%
Education (% completed bachelor's degree or higher)	63.8%
Annual household income (% $50,000 or higher)	41.9%
Employment (% employed either full-time or part-time)	47.2%
Household structure (% live alone)	24.5%
Home location (% living in suburban area)	51.7%

Respondents were asked to identify whether they had difficulties in any of 9 cognitive, sensory, physical and emotional/psychological categories (Table 2). People reporting difficulty seeing and hearing were asked if they were blind or had low vision, and deaf or hard of hearing, respectively. On average 2 functional limitations or difficulties were reported per respondent.

The most frequent disabilities reported were difficulty seeing (51.9%), difficulty hearing (39.1%), and difficulty walking, standing or climbing stairs (23.9%).

Table 2. Functional difficulties of respondents

(percentage of respondents with each type of disability)

Disability type	**Number**	**Percent**
Frequent worrying, nervousness, or anxiety	69	21.4
Difficulty concentrating, remembering or making decisions	38	11.8
Difficulty speaking so people can understand you	25	7.8
Difficulty using your arms	37	11.5
Difficulty using your hands and fingers	55	17.1
Difficulty walking or climbing stairs	77	23.9
Difficulty with fatigue/limited stamina	52	16.1
Low vision (significant difficulty seeing, even using glasses)	55	17.1
Blind (without usable vision or completely blind)	112	34.8
Hard of hearing (significant difficulty hearing, even using hearing aids)	85	26.4
Deaf (unable to hear)	41	12.7

This research article presents prototypical personas for 6 of the disability types listed in Table 3. Mobility, dexterity and vision impairment (blind and low vision) were selected because people with these disabilities seem most likely to benefit from smart speakers and smart-home devices. People with hearing limitations (deaf and hard of hearing) were included because their assets, actions and attitudes might provide additional perspective on emerging in-home consumer technologies.

Personas presented here were developed in part by analyzing quantitative data on ownership and use of smart speakers and home automation devices by disability type. These data have been integrated with qualitative analysis of the open-ended text responses to one question asked separately about smart speakers and home automation and control devices, respectively:

- What word or phrase best describes your feelings about your smart speaker (or smart-home devices)?

These quantitative and qualitative response data provide rich insights into the lived experience of people in each disability group regarding these technologies.

Assets – Ownership of smart speaker and smart-home technology

Table 3 shows ownership rates of smart phones, smart speakers and smart-home devices for each of the 6 disability types for which we will develop personas. Smart phones were included because they often serve as the primary or secondary hub for smart speaker and smart-home technology. All disability groups reported high rates of ownership of smartphone. Blind and deaf respondents reported the highest ownership rates, which confirms perceptions that these respondents are highly invested in information and communication technology (Morris, et al., 2017).

Table 3. Frequency of smartphone, smart speaker and smart-home device ownership by Disability type (%)

Disability Type	**Smart phone**	**Smart speaker**	**Smart-home device/s**
Limited Dexterity	88.9	50.9	43.6
Limited Mobility	90.9	48.1	35.1
Low vision	94.1	38.2	25.5
Blind	97.3	53.6	35.7
Hard of hearing	91.6	28.2	25.9
Deaf	95.0	12.2	41.5
All respondents	*94.5*	*40.7*	*34.2*

Ownership rates for smart speakers (40.7% respondents across all 6 groups) and smart-home devices (34.2%) are considerably lower than smart phones (94.5). The highest rates of ownership of smart speakers were reported by people who are blind (53.6%) or have limited dexterity (50.9%) or mobility (48.1%). This confirms expectations about the utility and accessibility of these devices for people with these specific disabilities. Lower rates of ownership by people with low vision or who are hard of hearing might reflect higher incidence of these conditions among older adults, who in turn tend to be late adopters of emerging technology.

The pattern of ownership rates of smart-home devices is similar to those for smart speakers, with one notable exception: deaf respondents reported the second highest ownership rate (41.5%), slightly lower than people with limited dexterity (43.6%). It seems that deaf consumers seem highly invested in consumer technology, including smart-home technology, but likely face accessibility challenges with smart speakers.

Actions – Uses for smart speakers and smart-home technology

How people use technology (their activities or actions) is a second critical dimension for creating user personas. Table 4 summarizes specific uses for smart speakers identified by respondents with each disability type. Overall, blind users of smart speakers reported the broadest use among the disability groups, followed by people with low vision and limited mobility/dexterity, and people who are hard of hearing. Deaf users of smart speakers are very few (only 5) in our sample, unsurprisingly. These respondents use their devices for tasks which can be visualized, like alerts and making lists (perhaps on smart speakers with video screens like the Amazon Echo Show). Indeed, deaf users report using the alerting features on smart speakers more than any other disability group, perhaps because alerts are often accompanied by visual cues. Blind users, by contrast are intensive users of smart speaker features that can be primarily auditory in nature: checking time and weather, playing music, listening to the news. People with

limited mobility and dexterity similarly use their smart speakers mainly for time, weather, music and news, but less commonly than blind and low vision users. Notably, smart speakers are used for voice calling by the majority of blind and low vision smart speaker users (60.0% and 52.4%, respectively).

Table 4. Smart speaker uses by disability type (percentage of respondents with smart speakers)

Limitation	Check time	Check weather	Play music	Get news	Alerts	Voice calling	Play games	Make lists	Recipes
Limited Dexterity	64.3	75.0	75.0	32.1	32.1	25.0	17.9	32.1	14.3
Limited Mobility	64.9	81.1	83.8	40.5	32.4	35.1	27.0	24.3	18.9
Low vision	81.0	90.5	85.7	57.1	33.3	52.4	47.6	33.3	28.6
Blind	98.3	93.3	90.0	81.7	55.0	60.0	70.0	48.3	58.3
Hard of hearing	54.2	66.7	79.2	50.0	33.3	20.8	25.0	37.5	20.8
Deaf	0.0	0.0	0.0	0.0	40.0	0.0	20.0	40.0	20.0

Smart speakers, like smartphones, are flexible devices that support a variety of activities and actions, often serving as hubs for other devices. In contrast, smart-home devices usually have a single purpose or use, making it challenging to examine the user activities for any single device. (One respondent's sardonic single-word description of these devices was: "on-off".) However, examination of the constellation of smart-home devices owned reveals specific activities for this *category* of devices and the breadth/variety of use by people in each disability group. Table 5 shows generally low rates of ownership of specific smart-home devices by survey respondents. Yet, some patterns emerge. People with limited dexterity or mobility report relatively even ownership rates across many of the six devices displayed, generally in the low-to-mid teens. Low vision and blind respondents tend to favor smart plugs, smart thermostats and smart lightbulbs. Hard of hearing respondents report the lowest levels of ownership of the 6

smart-home devices taken together. Deaf respondents show the highest levels of ownership for 3 devices: smart lightbulbs (19.5%), smart doorbells (24.4%), and smart thermostats (19.5%). Indeed, these are the highest levels of ownership for any device by any disability type.

Table 5. Ownership of specific smart-home automation devices by disability type (%)

Limitation	**Smart outlet or plug**	**Smart light switch**	**Smart lightbulb**	**Smart door locks**	**Smart doorbell**	**Smart thermostat**
Limited Dexterity	14.5	3.6	16.4	9.1	12.7	14.5
Limited Mobility	16.9	10.4	10.4	5.2	11.7	15.6
Low vision	18.2	3.6	9.1	0	1.8	12.7
Blind	13.4	5.4	9.8	2.7	7.1	16.1
Hard of hearing	7.1	4.7	7.1	1.2	7.1	10.6
Deaf	7.3	7.3	19.5	0	24.4	19.5

Attitudes – Single words or phrases to describe feelings toward smart speakers and devices

How people feel (affect or attitude) about their technology constitutes the third critical dimension for creating user personas. Table 6 presents a summary of responses to survey questions asking for a single word or phrase describing respondent feelings toward their smart speaker and their smart-home devices. Using a grounded-theory approach (constant comparative method) the researchers iteratively sorted through the qualitative data to uncover dimensions and structure in respondent attitudes toward their smart speakers and smart-home devices. Five dimensions were uncovered: 1) fondness/joy, 2) inspiration/wonder, 3) utility/convenience; 4) usability/accessibility; 5) safety/security.

Table 6. Five dimensions and specific attitudes toward smart speakers and smart-home devices, all disabilities

Dimension	**Positive**	**Neutral**	**Negative**
Fondness, Affect, Enjoyment	Love, life changing, invaluable, grateful, entertaining, amusing, enjoyment, fun	Good, like it, mixed, love-hate	Dissatisfied, lousy
Inspiration, Wonder	Awesome, amazing, compelling, enthralling, excellent, fantastic, magic, futuristic, cool	Weird, curious, novelty	Overrated optional, novelty, indifference, "meh"
Utility, Convenience, Efficiency	Useful, helpful, handy, utility, necessary, Convenient, efficient, economical, time saver, energy saver	Promising, potential to be more, helpful for simple things, handy as far as it goes	Not useful, not helpful, unnecessary, not all it's advertised to be
Usability, Accessibility	Easy to use, independence, empowering, liberating, use without asking help, helpful b/c hands-free		Confusing, difficult, awkward, unreliable, inaccessible, frustrating, for hearing people only
Safety, security	Safety, peace of mind, comforting to have/use		

To provide an additional view of respondent attitudes and feelings, the researchers also conducted a simple word-count of descriptors by disability type, the most frequent of which are displayed in Tables 7 and 8. People with limited dexterity and mobility, and low vision and blind respondents generally emphasized helpfulness and convenience of both smart speakers and smart-home devices. Hard of hearing and deaf respondents generally did not find smart speakers useful, but some hard of hearing respondents expressed fondness and wonder for these devices. Fondness and inspiration were also prominent in the descriptors of smart-home devices offered by both hard of hearing and deaf respondents, as were safety and security. Smart-home devices also drew more pointed criticism across most disability types ("awkward", "difficult", "lousy"). This may be related to installation, set-up and stability. More investigation is required here.

Table 7. Most frequent words or phrases used to describe feelings about smart speakers

Limitation	**Most frequent**	**2nd most frequent**	**3rd most frequent**	**4th most frequent**	**5th most frequent**
Limited Dexterity	Handy	Helpful	Necessity	Useful	Neat
Limited Mobility	Helpful, handy	Convenient	Entertaining fun	Useful	Necessity, love, cool
Low vision	Helpful	Convenient	Useful	Efficient	Needs to improve
Blind	Fun	Helpful	Convenient	Useful	Invaluable
Hard of hearing	Unnecessary "meh"	Entertaining	Helpful	Impressed, amazing	Really like it, great
Deaf	Amusing	For hearing people	Okay	Love-hate	Mixed

Table 8. Most frequent words or phrases used to describe feelings about smart-home devices

Limitation	**Most frequent**	**2nd most frequent**	**3rd most frequent**	**4th most frequent**	**5th most frequent**
Limited Dexterity	Handy, helpful	Amazing, awesome	Independence Liberating	Grateful, want more	Overrated, awkward
Limited Mobility	Useful	Independence empowering	Handy, helpful	Convenient	Amazing, awesome
Low vision	Helpful	Convenient	Useful	Economical	Awesome
Blind	Helpful	Needs to improve	Amazing, awesome	Frustrating	Convenient
Hard of hearing	Love, awesome	Unnecessary mixed, "meh"	Peace of mind, security empowering	Dissatisfied	Difficult or easy
Deaf	Magic, cool, great	Comforting, security	Inadequate, lousy	Useful	Valuable

User personas

The assets, actions and attitudes uncovered in the survey research data allow identification of a specific user persona for each of the 6 disability types that constitute the focus of this article. It must be emphasized that there are countless combinations of potentially an infinite number of characteristics which could be included in construction of a consumer persona. The populations each persona represents are diverse and complex. Space limitations do

not allow us to explore more than 1 persona for each disability type. The personas identified here are merely non-exhaustive, composite sketches to be used as tools for designers and engineers to help inform their work.

Limited dexterity

Tatiana is a 35-year-old writer-editor for a publishing house specializing in technical and instructional materials. She has cerebral palsy. She is smart and articulate, but her condition limits some of her physical movement, particularly her arms and hands. She uses her 2 smart speakers mainly to listen to music, podcasts and news in her living room and bedroom. Because of her job she likes to stay current on science and technology news. She has smart devices throughout her home, which help her control things that are otherwise difficult to do manually because of her limited dexterity. This includes smart plugs, in-wall switches, light bulbs, thermostat and door locks. These devices make performing these daily tasks much easier.

Limited Mobility

Lionel is a 48-year-old manager at a transportation and shipping company. He has used a wheelchair to get around ever since a motor vehicle accident a decade ago left him paralyzed. He lives in a large suburban house with his wife and two kids. The family has smart speakers throughout the house, and everyone uses them. Lionel loves to cook and likes music, news, and sports. He uses his smart speakers for all these activities, and to control the numerous smart-home devices that have slowly accumulated in the house. He especially likes the front-door camera so he can see if he received a package delivery or identify the person knocking on the door; the smart thermostat, which is otherwise placed too high on the wall to see and set; and a couple of interior cameras in the kids bedrooms upstairs so he can interact with them easily.

Low vision

George is in his late 60s and recently retired from his accounting career. He is a bit of a techno-skeptic. Desktop and laptop computers made a great impact on his profession, but these are practical tools, not toys. He remembers changing the television channel by hand and thought that was fine. But he likes music and is a news-junky, especially stock market and economic news. He has 2 smart speakers, one in his home office where he still does accounting for his household and a few cherished clients, and one in the living room, which he uses to play music and news in the background. He has just one smart-home device, a smart light bulb in the lamp on his desk, which he uses to easily light his way into his dark office.

Blind

Amalia is a 24-year-old university student majoring in Latin American and American literature. She loves reading her audio books and is an avid fan of all auditory forms of popular culture, primarily music, cinema and television. She uses her 2 smart speakers mainly to listen to books and music, and to check time and weather for going to class and meeting up with friends. For smart-home devices, she has only a smart lock on the front door and a smart thermostat, which she manages via voice interaction with her smart speaker, and less frequently via companion apps on her smartphone.

Hard of hearing

Emma is a dentist in her late 50s. Over the years, the whine of the high-speed drills and other equipment in her office had caused progressive hearing loss. She has a smart speaker in her living room and bedroom, and another one with a screen in her kitchen. She uses these in a limited way, mainly to check the time, weather, and news, and to set timers/alerts. She uses the one in the kitchen to follow cooking recipes, mainly by reading the screen. Because of auditory fatigue from the office, she does not listen to her smart speakers at length for music or other

entertainment. As a dentist she necessarily uses a lot of sophisticated equipment, and her home is the same with numerous smart-home devices. She loves programming her smart thermostat and interior/exterior lights to minimize electricity consumption and maximize comfort/convenience in and around her home.

Deaf

Ahmed is a software engineer in his late 30s with congenital deafness. His parents recognized this early and ensured that he receive sign language instruction and other education. He excelled at learning computer languages and coding. Because of his deafness he relies on information and communication technology to a considerable degree. He has a smart speaker with a video screen and several smart-home devices, including smart door locks, exterior smart cameras, and smart lightbulbs, which he monitors and controls via his smartphone and the video screen on his smart speaker. He's confident, but also aware that his lack of hearing prevents him from observing changes in his environment, particularly weather and other conditions outside his home.

Conclusion

Personas are tools for understanding the user needs of real people for consumer products and services. Each persona presented here is simply one of possibly infinite combinations of traits and characteristics of a population group or type. They give life and substance to consumer research in order to engage designers and engineers more intimately with their target users. Rapid adoption rates of smart speakers and home automation and control devices and predicted strong future growth requires continuous exploration of multiple and mixed methods for understanding and modeling the needs of consumers with disabilities.

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