Deaf Users' Preferences Among Wake-Up Approaches during Sign-Language Interaction with Personal Assistant Devices

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ABSTRACT

Personal-assistant devices like Amazon Alexa and Google Assistant are increasingly popular among consumers. Users activate these systems through some type of wake-up approach, e.g. using a wake-word "Alexa" or "Ok, Google." Voice-based interaction poses accessibility barriers for Deaf and Hard of Hearing (DHH) users, and technologies for sign-language recognition are improving. We therefore explore wake-up interactions for DHH users for potential personal assistant devices that understand sign language commands. Interviews with DHH users (N=21) motivated the design of six wake-up approaches, and we produced video prototypes demonstrating each using a Wizard-of-Oz approach. These prototypes were evaluated in a follow-up study in which DHH users (N=12) identified factors that influenced their preference among approaches. This study contributes empirical knowledge about DHH ASL signers' preferences and concerns with wake-up interaction, thereby providing guidance for future designers of these systems.

CCS CONCEPTS

• **Human-centered computing → Accessibility design and evaluation methods**; **Personal digital assistants**.

KEYWORDS

Deaf and Hard of Hearing, Accessibility, Sign Language, Personal Assistants

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1 INTRODUCTION

Personal-assistant devices, also known as virtual assistant devices, are becoming popular and ubiquitous. These physical devices, e.g. smart speakers or smart screens, respond to user queries; these devices provide information or/and enable control of other smart devices. To interact with a personal-assistant device, the user needs to get its attention, typically by saying a wake-word, i.e. "Alexa" for Amazon Alexa or "Ok, Google" for Google Assistants. Once the device is ready, the user issues the command.

Interaction with these devices is typically voice-based and poses accessibility barriers for people who are Deaf or Hard of Hearing (DHH), many of whom would prefer sign-language interaction, rather than text input or non-sign gestural input [15]. Given advances in computer vision technologies [8], HCI researchers are beginning to consider future device-interaction using American Sign Language (ASL) commands [7, 12].

In this paper, we focus on how DHH users would wake-up a personal-assistant device. With the help of a formative interview study with 21 DHH ASL signers, we identified 6 approaches for wake-up interactions for potential sign-language-enabled personal assistant devices. We evaluate video prototypes of these 6 approaches with 12 DHH ASL signers, and a qualitative analysis revealed key attributes users' considered when selecting their preference of a wake-up technique. The empirical contribution of this study is in identifying the preferences and concerns among DHH users in regard to this new form of interaction, which in term may provide guidance for future designers of these systems.

2 RELATED WORK

2.1 Accessibility of personal-assistant devices and need for ASL interaction

Prior research has examined the accessibility of personal-assistant devices for various users, e.g. blind users [1] and children [9]. However, there has been limited research on personal-assistant device accessibility among DHH users. Pradhan et al. surveyed device users who have a disability and found few DHH participants had used personal-assistant technology [14], suggesting a need for further research to understand the barriers to use of this technology among DHH users.

Personal-assistant devices use automatic-speech recognition (ASR) for voice-based interactions. However, prior work has found that ASR technology is often unsuccessful at understanding the voices of DHH individuals [11]. To ensure personal-assistant technologies are accessible to DHH users, alternate interaction modalities are essential. While some personal-assistant devices provide alternate text-based input and output methods (e.g. via an on-screen keyboard) [3, 4] these workarounds do not provide DHH users with an equivalent, hands-free experience.

Rodolitz et al. conducted an exploratory study that asked DHH participants to issue commands to a device (in a Wizard-of-Oz manner) using ASL, non-ASL gestures, and computer speech synthesized from text typed by the user. Their participants found it awkward to learn to and remember non-ASL gesture commands, and they preferred issuing commands in ASL. While this initial work has established some interest among the DHH community, the study had relatively few participants [15], and the authors called for more HCI researchers to explore interaction methods for DHH users, before these devices become even more widespread.

To understand what DHH users may want from personal-assistant technology and how to best design the interaction, Glasser et. al have begun to engage the DHH community to investigate users' requirements through interviews and surveys [12]. The authors discuss their future plans to use a Wizard-of-Oz approach to investigate DHH user's reactions and preferences when interacting with a device that appears to understand sign-language commands. However, none of this prior work has examined how users may wish to wake-up or activate the device.

2.2 Wake-up interactions

Personal-assistant devices can be thought of as spoken dialogue systems, which typically enable question-answer interaction with users [10]. This interaction requires the user to first obtain the device's attention, before issuing a command, a process that is referred to as "waking up" the device. Generally, the user calls to the device by speaking a wake-word; calling the device by its name is the most commonly used wake-word technique [13], i.e. "Alexa" or "Echo" for Amazon devices or "Ok, Google" for Google devices. This interaction may be categorized as a "talk-to-talk" method. Alternatively, some devices support "push-to-talk," whereby a user may press a button to invoke the personal-assistant device without speaking a wake word [5].

Relatively little prior work has focused on this wake-up interaction. One study identified usability problems with wake-words, e.g. the need to construct a sentence to place the wake-word first, the robotic nature of the wake-word, or even accidental device wake-up due to similar-sounding words [2]. The authors proposed avoiding the use of wake-words and propose alternate approaches; however, this work did not consider DHH users nor sign-language interaction. Another study investigated the effectiveness of wake-up techniques for conversational agents among children, comparing several approaches: a wake-word, pressing a digital button, pressing a physical button, gazing towards the device, using a mouse pointer on the device screen, and other techniques [9]. That study revealed that among users who are children, a physical button (a push-to-talk technique) was the most appropriate solution.

To the best of our knowledge, no prior research has investigated the device wake-up process among DHH users, especially in the context of sign-language interaction. Within the cultural and linguistic context of American Sign Language (ASL) users, it is useful to consider analogs of various push-to-talk and talk-to-talk methods, as well as the typical ASL dialogue structure. In U.S. Deaf culture, it is acceptable for an individual to tap someone gently on the shoulder to get their attention. If beyond the reach to tap, someone may wave their hand in the air, in the direction of the person, until eye contact is established [16]. As ASL is a visual language, individuals must ensure that there is proper lighting and line-of-sight such that their conversational partner may clearly see their manual signs and linguistic facial expressions, e.g. avoiding standing in front of bright light or window [16]. With this context in mind, we conducted studies to explore how DHH users may prefer to wake up personal assistant devices if they were to interact with those devices in ASL.

3 STUDY 1: FORMATIVE INTERVIEWS

We conducted interviews with 21 DHH ASL signers to collect ideas and recommendations about how users would like to wake up a personal-assistant device, with which they could interact in ASL. Results from these interviews were used to identify potential wake-up interactions that we evaluated in a subsequent study.

3.0.1 Participants. We recruited 21 DHH ASL signers (8 female, 12 male, and 1 non-binary) from our university through poster advertisements. Each interview was scheduled for 30 minutes and was conducted face-to-face in ASL by a DHH researcher from our lab. Our participants were between the age of 18 to 25, and all had some college education. Most participants had very little experience with personal-assistant devices, but all reported having tried a personal-assistant device at least once. There was 1 participant who owned 6 personal-assistant devices and used them regularly.

3.0.2 Procedure. In the interview, we asked questions about participants' familiarity and usage experience with current voice-controlled personal assistant devices, their expectations for interacting with these devices in sign-language, their ideas about possible wake-up approaches, and concerns they envision with such interaction.

During the interview, the interviewer demonstrated to participants the typical steps involved in interacting with a voice-based personal-assistant device, by displaying a captioned video of a user engaging with a voice-based device. The purpose of this video was to provide participants with context about how the wake-up process typically occurs. The researcher paused the video to indicate the initial wake-up phase of the interaction, to clarify the specific portion of the interaction that was the focus of the interview.

Interviews were transcribed into written English for analysis, and an affinity mapping methodology was used to identify users' ideas for waking-up the device. In this process, participant quotes were organized and grouped, and our analysis resulted in identifying major types of wake-up interactions that had been mentioned by participants.

3.1 Findings

Our analysis revealed that users' envisioned six major types of wake-up interactions. Four can be classified as talk-to-talk approaches, i.e. signing the ASL sign-name of the device, waving in the direction of the device, finger-spelling the device name using the English letters, and clapping to get the devices' attention. (Details of each are discussed below.) The other two approaches are push-to-talk techniques, i.e. using a phone app to trigger the device or using a physical remote control. These six types of wake-up approaches were investigated further in Study 2 (section 4).

3.1.1 Talk-to-talk Techniques. A majority of the participants (13 out of 21) suggested using talk-to-talk methods, such as using an ASL sign or waving in the direction of the device to wake it. As mentioned above, waving one's hand in someone's direction is a culturally acceptable method for gaining attention in Deaf culture [16]. Users also suggested waving in a specific pattern to wake-up the device, using the device name in the form of sign-name (a unique ASL sign used to uniquely identify someone), or fingerspelling the English letters of the device name. Users expressed concern that commonly used signs or waving might lead to accidental device wake-ups. For instance, P17 mentioned, *"what if I am waving to get another person's attention then the device will wake up and I don't want that."* Few participants suggested making noise (e.g. clapping or tapping), for instance, P11 suggested *"clapping or snapping or some noise to alert her [the Alexa device] to wake-up."*

3.1.2 Push-to-talk Techniques. Other participants (8 out of 21) suggested push-to-talk techniques, i.e. using a physical button to get the device's attention by pressing a button on another device, e.g. a smartphone app or a physical remote control. For example, P11 said, *"I like [using] the phone app because it is easy to control,"* and P08 suggested using a physical remote control that is paired with the personal-assistant device, commenting *"A remote or something to press."* Participants interested in push-to-talk methods mentioned how these wake-up approaches were more reliable. Specifically, users mentioned how push-to-talk approaches could avoid false-positives (the device waking up when the user had not intended it to do so, perhaps due to the system incorrectly detecting signing or gestures) or false-negatives (the device missing a user's attempt to wake it). For instance, P20 preferred *"touch, [because it] will ensure that the device will wake up. If I wave maybe the camera won't recognize it."*

4 STUDY 2: VIDEO PROTOTYPE EVALUATION

While Study 1 had enabled us to collect some ideas from users who imagined how they might wake-up a personal assistant device that understands sign language, there was a limitation in that study. Specifically, participants had to imagine their interaction. To provide a means for participants to better visualize each type of wake-up interaction without being overwhelmed by the personal-assistant device interaction, we developed video simulations in which a DHH actor demonstrated using each of the six wake-up techniques (see figure 1 for a video storyboard). By displaying these video prototypes in Study 2, we hoped to gain further insight into the factors DHH users had in mind when they considered which wake-up approaches they preferred.

In order to create the 6 video simulations of each wake-up techniques, we filmed a DHH actor interacting with a personal assistant device. This was a Wizard-of-Oz set-up where a hearing person was voicing commands to the device while we recorded a DHH actor pretending to issue commands to an Amazon Echo Show device in ASL. The video recording location, device placement, command given to the device and actor were constant in all the simulations. Only the wake-up technique changed with each video. Figure 1 shows the video storyboard layout and screenshots of the six wake-up techniques.

4.1 Method

4.1.1 Participants. We recruited 12 DHH ASL signers (6 Male and 6 Female) who were in the age range of 21 to 29. All participants indicated they were aware of what personal-assistant devices were, but a majority of the participants (10 out of 12) did not have any experience of using such a device. The remaining two had used a device using their voice.

4.1.2 Procedure. We conducted a within-subject evaluation of the video prototypes, with the one independent variable being the wake-up technique. The sequence in which the wake-up technique videos were shown to the participants was counterbalanced via a Latin Square schedule. Each session lasted 45 minutes, and participants were compensated with $40. The session was conducted in ASL and later transcribed in English for analysis.

We collected demographic data, including participants' familiarity and experience with personal-assistant devices. Next, we presented and discussed each video-simulation. For each, we asked the participants to share their thoughts on the technique, including any benefits or problems they envision. We analyzed the transcriptions of the sessions using an affinity-mapping methodology, by inductively grouping the participant quotes, based on the various trade-offs or factors discussed.

At the end of the study, we asked participants to rank the six wake-up techniques from least- to most-preferred. We encoded these ranks with integers (1 to 6), and then we summed the responses for each technique for analysis.

4.2 Findings

Based on participants' ranking of wake-up techniques, using the ASL sign-name of the device was the most preferred. The remaining techniques in descending order of preference were: waving in the direction of the device, clapping, using a remote control, using a phone app, and fingerspelling the English name of the device.

The affinity-mapping analysis of participants' open-ended responses revealed that participants were concerned about various factors when comparing their preference for each wake-up approach. Factors mentioned by participants included: whether interaction success depends upon the surrounding environment (e.g. lighting), whether the interaction depends on availability of another device, the reliability of the technique, how convenient it would be to use that technique, if it was easy to use, the speed of the technique, or the speed with which the device would wake-up. Users' responses are summarized below, presented in the preference-ranking order determined during the study.

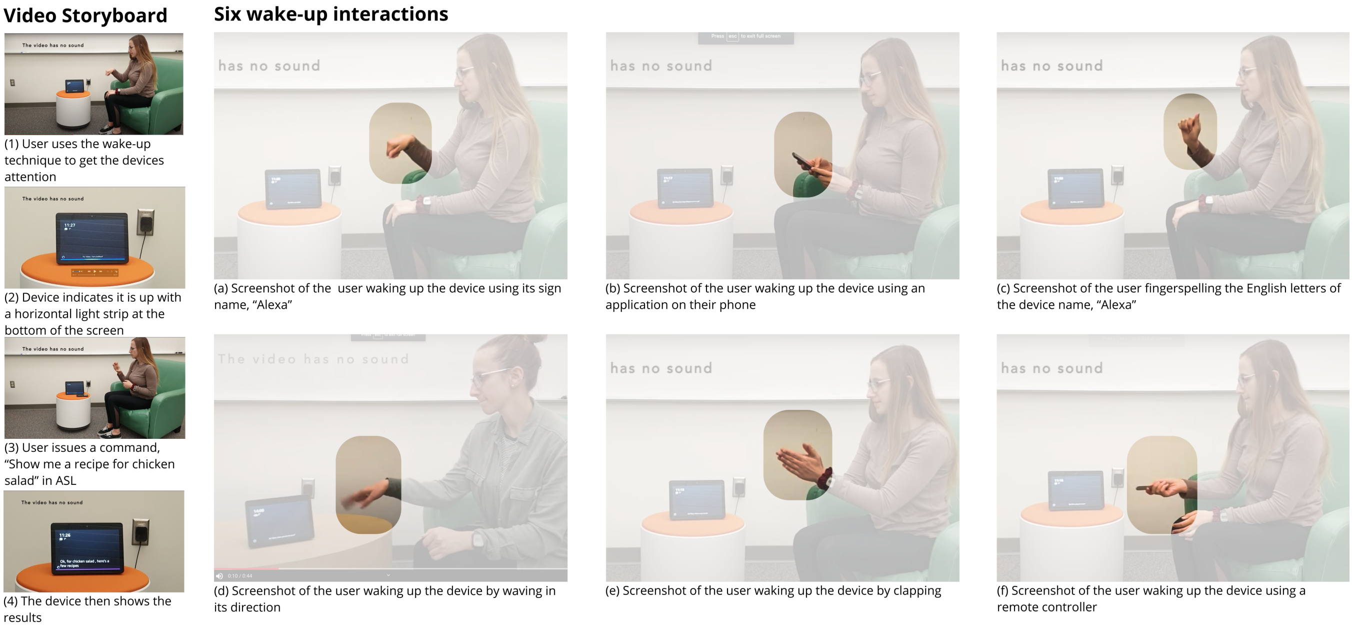

Figure 1: Video storyboard with the device-user interaction steps: (1) user uses the wake-up technique (2), device wakes-up, (3) user gives the command, and (4) device responds. To the right are screenshots of the actor using the wake-up techniques: (a) using the sign-name technique, (b) using the phone application technique, (c) using the fingerspelling technique, (d) using the wave towards the device technique, (e) using the clapping technique, and (f) using the remote technique.

4.2.1 Using the device sign-name. As discussed above, a sign name is an ASL sign that is used to uniquely identify a person. Participants preferred the idea of assigning a sign-name to the device and then waking up the device whenever they produce that sign-name. Participants indicated that using a specific ASL sign solely for waking the device may avoid accidental wake-ups, which users believed would be more likely using other wake-up techniques like waving or clapping. P1 said, *"sign name is more specific than the wave... If another person had the same sign-name it could become an issue but I think that is rare."* Participants liked that this technique would be fast, e.g., P9 indicated that, *"there is not a lot of unnecessary time needed, similar to wave."* Participants also mentioned how this approach would be more convenient than fingerspelling English letters of the device name. Participants also commented how this technique does not require the user to carry an additional device. However, participants did note that this wake-up technique is dependent upon the surrounding environment, i.e. having sufficient light and being in the camera-range of the device. For example, P2 noted, *"Sometimes the device may not be able to see the sign in dark,"* and P9 stated, *"my concern is how good the device would recognize me signing the name across the room."*

4.2.2 Waving in the direction of the device. Section 2.2 discussed how, in Deaf culture, it is common to wave in someone's direction to get their attention. Participants indicated this wake-up technique would feel comfortable and natural, like interacting with a person. P7 pointed out that *"(the wave method) keeps your hands in the same spot during waving and then signing."* Additionally, participants discussed how waving would be more convenient for people who prefer to use sign-language over English. As P1 mentioned, *"I think it could benefit DHH especially those who prefer sign over written English."* Participants also liked how this technique was not dependent upon the user having an additional device. However, a majority of participants noted that this wake-up method is susceptible to accidental wake-ups; P11 said, *"something in the background may get Alexa's attention like if a cat waves at it and Alexa may get its attention"*. Similarly, P7 said, *"I am concerned if I were to wave to someone else if the device would accidentally wake up."* Similar to the sign-name method, participants noted that this method depended upon the lighting and distance to the camera.

4.2.3 Clapping to wake-up the device. Similar to other talk-to-talk methods (using the device sign-name, waving, and fingerspelling), participants mentioned how they liked that the clapping technique did not require the user to carry another device. Participants commented that they found this method to be simple to execute, fast, and comfortable. While participants mentioned that this approach would work regardless of lighting or camera distance, several participants did mention that they would require training to select the appropriate loudness of clapping. P6 mentioned, *"In the beginning I would have to figure out how loud I would need to clap but eventually would figure that out."* Also, similar to the waving technique, participants mentioned how clapping is susceptible to accidental device wake-ups because of background noises. P9 noted, *"Alexa can't detect whether people are clapping for fun or clapping for her attention."* To avoid that, P12 suggested a pattern of claps for waking up of the device, saying *"maybe set up how often you need to clap like 1 or 2 times."* As clapping by different people may sound alike, some participants were concerned that anyone could access and operate the device.

4.2.4 Using a remote to get the devices' attention. Many personal-assistant devices come with an additional remote-control device, which can be used to trigger the system. Using a remote to wake the device would be classified as a push-to-talk technique. Participants liked that this wake-up method would work regardless of surrounding lighting or distance to the camera. They also liked that this approach would be fast, and it would likely avoid false positives or negatives. P12 suggested that this approach may be preferred by older users, saying *"The remote is a good replacement for those who are senior citizens or people who are annoyed with fingerspelling."* Participants also noted that this technique may feel familiar, as remote controls are ubiquitous, e.g. P6 said, *"(Remote technique) is easy as we already use remotes and are okay with this concept."* Despite these advantages, participants did not rank this approach highly. Many noted that this approach would not provide DHH users with a hands-free experience (like talk-to-talk methods). As P8 said, *"I would like the remote options but going through these options, I don't think it is the best option. Plus, one of the biggest appeals about Alexa is that you just have to say her name you don't need a remote or get up."* Participants were also worried about misplacing the remote or the remote battery dying.

4.2.5 Using a smartphone app to wake the device. When discussing this approach, participants raised several factors similar to those when using a remote control, e.g. commenting on how this may be a fast or reliable method of waking the device. Additionally, participants believed this approach would be easy to use, e.g. as P10 said, *"everyone has their phone with them so I think it would be easier to use that"*. Similarly, P12 said, *"I would use it for smart home kits like smart home devices, and [it would have] less errors so I know Alexa would wake up right away."*

P8 also suggested that there are *"situational benefits like if you can't sign to Alexa, you can text (the command using the phone app)."* Similar to the remote-control wake-up approach, participants noted that they might misplace their phone or its battery may die. Participants suggested that using a phone app might be useful as a reliable backup approach for waking a device, e.g. as P11 said, *"I would use the phone app if Alexa didn't catch my signing."*

4.2.6 Fingerspelling the device name. Fingerspelling the device's English name was the ranked as the least-preferred method by participants. Although participants noted that this wake-up method would be hands-free (i.e. nothing to hold in the hand or touch) and would not depend upon the user having an additional device, they also noted that it may be slower and more error-prone, e.g. due to spelling mistakes. P10 wondered, *"I am curious how picky Alexa would be like what if I misspelled her name."* Participants noted that this method may be less convenient for people who prefer sign to English. P1 said, *"It takes a little bit longer to spell name and may not be as efficient for others who may have difficulty with fingerspelling,"* and P8 was concerned, *"Some people have a hard time moving their fingers so fingerspelling would be no good."* Participants were worried about the device's accuracy in detecting fingerspelling, e.g. with P12 saying, *"sometimes it (fingerspelling) can become sloppy."* Additionally, participants noted that this wake-up approach would be dependent upon the lighting and distance to the camera.

5 DISCUSSION

The findings of our two studies have revealed preferences and concerns of DHH users for how to wake up future personal-assistant technologies that could understand sign language. A key contribution of this work has been identifying a set of six wake-up techniques, as recommended by 21 DHH users who participated in a formative interview study. In addition, our subsequent study, with video prototypes, enabled 12 DHH participants to visualize how these approaches may work. In addition to indicating their overall ranking preference among the wake-up techniques, participants discussed the trade-offs between various wake-up approaches, and they identified key factors that affected their preferences of each.

In this study, we identified the specific trade-offs and factors for each of the wake-up techniques. These factors were based on the convenience and reliability of the wake-up techniques and did not rely on specific brand of device shown in the video. In this section, we discuss the participants' concerns about wake-up interaction aligned with two key underlying factors:

5.0.1 Convenience of using the wake-up technique. Overall, we found that participants were more inclined towards techniques that were easy for them to use and easy to access. Talk-to-talk techniques provided them with a hands-free experience, requiring no prior setup to interact with the personal-assistant device. Similarly, these techniques also enabled users to keep their hands free, in order to next issue the command in ASL. Broadly, we found that users preferred methods of waking up the device that enabled them to have as equivalent an experience as possible to hearing individuals who use voice-based interaction, e.g. with wake-words. However, participants discussed how talk-to-talk techniques (except for clapping) depended upon the lighting or camera distance in the environment, which could restrict users' access to the device in some situations. Despite push-to-talk techniques being more robust to these environmental factors, participants still did not find them as convenient to use.

5.0.2 The link between privacy and the reliability of the wake-up technique. Our findings revealed that participants were broadly concerned with the reliability of the wake-up technique. Participants indicated a clear preference for wake-up methods that avoid accidental device wake-ups. In particular, they were concerned that the device not have to access conversations that were not meant for it. In addition to concerns about false wake-ups, participants were also concerned about the privacy implications of a camera-based interaction with the device, which is necessary for ASL interaction.

Although participants noted the reliability benefits of push-to-talk techniques, this did not lead participants to prefer them to talk-to-talk techniques. Although it would be ideal for future designers of sign-language based personal-assistant devices to identify wake-up techniques that are both convenient and secure, our study suggests that DHH users prioritize convenience. This finding is in alignment with prior work on usable security which reveals the importance of any security and privacy approaches to be easy to use [1, 6].

6 LIMITATIONS AND FUTURE WORK

As mentioned by Pradhan et al. in their study [14], a very small number of DHH users are using personal-assistant devices. We noticed a similar trend among our study participants. Most of our participants had tried to use the personal-assistant device at least once but faced problems issuing a command to the device or understanding its output. Therefore, we foresee the need for several of the wake-up techniques investigated in this study to be implemented in a working prototype or interactive Wizard-of-Oz experience for users. Future research on wake-up interactions should include Wizard-of-Oz prototypes that provide the users first-hand experience of using the techniques.

Future research should also consider the accuracy with which an automatic system would correctly detect each type of wake-up interaction, as this may affect users' preferences. Future research should also take into consideration the concerns of DHH users in terms of privacy such as having the device camera on, and participant preferences of using the wake-up techniques in different social settings.

Another limitation of this study was the small sample of the DHH community members, who were within a small age range, and all had some college education. Future studies should consider a more diverse population.

7 CONCLUSION

This paper investigated wake-up approaches for sign-language-enabled personal assistant devices. Through formative interviews with 21 DHH participants, in Study 1, we identified six potential wake-up interactions. We created Wizard-of-Oz video prototypes of a DHH user demonstrating each form of wake-up interaction with a personal-assistant device. In study 2, 12 DHH participants discussed factors that influenced their preferences among these prototypes. Our findings revealed pros and cons of various wake-up techniques, as well as factors that shaped users' views of these interactions. Our findings provide guidance to future researchers and designers of this technology.

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REFERENCES

[1] Ali Abdolrahmani, Ravi Kuber, and Stacy M. Branham. 2018. "Siri Talks at You": An Empirical Investigation of Voice-Activated Personal Assistant (VAPA) Usage by Individuals Who Are Blind. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility* (Galway, Ireland) *(ASSETS '18)*. Association for Computing Machinery, New York, NY, USA, 249–258. https://doi.org/10.1145/3234695.3236344

[2] Shashank Ahire and Michael Rohs. 2020. Tired of Wake Words? Moving Towards Seamless Conversations with Intelligent Personal Assistants. In *Proceedings of the 2nd Conference on Conversational User Interfaces* (Bilbao, Spain) *(CUI '20)*. Association for Computing Machinery, New York, NY, USA, Article 20, 3 pages. https://doi.org/10.1145/3405755.3406141

[3] Amazon. 2020. Accessibility Features for Alexa. https://www.amazon.com/gp/help/customer/display.html?nodeId=202158280

[4] Amazon. 2020. Alexa Accessibility. https://www.amazon.com/b?ie=UTF8&node=21101808011

[5] Amazon. 2020. Invoking Alexa. https://developer.amazon.com/en-US/docs/alexa/alexa-auto/invoking-alexa.html#

[6] D. Balfanz, G. Durfee, D. K. Smetters, and R. E. Grinter. 2004. In search of usable security: five lessons from the field. *IEEE Security Privacy* 2, 5 (2004), 19–24. https://doi.org/10.1109/MSP.2004.71

[7] BBC. 2018. Sign-language hack lets Amazon Alexa respond to gestures. https://www.bbc.com/news/technology-44891054

[8] Danielle Bragg, Oscar Koller, Mary Bellard, Larwan Berke, Patrick Boudreault, Annelies Braffort, Naomi Caselli, Matt Huenerfauth, Hernisa Kacorri, Tessa Verhoef, Christian Vogler, and Meredith Ringel Morris. 2019. Sign Language Recognition, Generation, and Translation: An Interdisciplinary Perspective. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility* (Pittsburgh, PA, USA) *(ASSETS '19)*. Association for Computing Machinery, New York, NY, USA, 16–31. https://doi.org/10.1145/3308561.3353774

[9] Fabio Catania, Micol Spitale, Giulia Cosentino, and Franca Garzotto. 2020. What is the Best Action for Children to "Wake Up" and "Put to Sleep" a Conversational Agent? A Multi-Criteria Decision Analysis Approach. In *Proceedings of the 2nd Conference on Conversational User Interfaces* (Bilbao, Spain) *(CUI '20)*. Association for Computing Machinery, New York, NY, USA, Article 4, 10 pages. https://doi.org/10.1145/3405755.3406129

[10] Benjamin R. Cowan, Nadia Pantidi, David Coyle, Kellie Morrissey, Peter Clarke, Sara Al-Shehri, David Earley, and Natasha Bandeira. 2017. "What Can i Help You with?": Infrequent Users' Experiences of Intelligent Personal Assistants. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services* (Vienna, Austria) *(MobileHCI '17)*. Association for Computing Machinery, New York, NY, USA, Article 43, 12 pages. https://doi.org/10.1145/3098279.3098539

[11] Abraham Glasser. 2019. Automatic Speech Recognition Services: Deaf and Hard-of-Hearing Usability. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3290607.3308461

[12] Abraham Glasser, Vaishnavi Mande, and Matt Huenerfauth. 2020. Accessibility for Deaf and Hard of Hearing Users: Sign Language Conversational User Interfaces. In *Proceedings of the 2nd Conference on Conversational User Interfaces* (Bilbao, Spain) *(CUI '20)*. Association for Computing Machinery, New York, NY, USA, Article 55, 3 pages. https://doi.org/10.1145/3405755.3406158

[13] Martin Porcheron, Joel E. Fischer, Stuart Reeves, and Sarah Sharples. 2018. Voice Interfaces in Everyday Life. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3174214

[14] Alisha Pradhan, Kanika Mehta, and Leah Findlater. 2018. "Accessibility Came by Accident": Use of Voice-Controlled Intelligent Personal Assistants by People with Disabilities. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3173574.3174033

[15] Jason Rodolitz, Evan Gambill, Brittany Willis, Christian Vogler, and Raja Kushalnagar. 2019. Accessibility of Voice-Activated Agents for People who are Deaf or Hard of Hearing. *Journal on Technology and Persons with Disabilities* 7 (2019), 144–156. http://hdl.handle.net/10211.3/210397

[16] SignGenius. 2020. Do's & Don'ts - Getting Attention in the Deaf Community. https://www.signgenius.com/info-do's&don'ts.shtml