Towards More Transactional Voice Assistants: Investigating the Potential for a Multimodal Voice-Activated Indoor Navigation Assistant for Blind and Sighted Travelers

Ali Abdolrahmani
University of Maryland Baltimore County
aliab1@umbc.edu

Maya Gupta
University of California Irvine
guptamh@uci.edu

Mei-Lian Vader
University of Maryland Baltimore County
mvader1@umbc.edu

Ravi Kuber
University of Maryland Baltimore County
rkuber@umbc.edu

Stacy M. Branham
University of California Irvine
sbranham@uci.edu

ABSTRACT

Voice assistants (VAs) – like Amazon Alexa or Siri – offer hands-/eyes-free interactions that are beneficial to a range of users, including individuals who are blind, to fulfill tasks that are otherwise difficult or inaccessible. While these interfaces model *conversational* interactions to achieve simple tasks, there have been recent calls for VAs that model more *transactional* interactions for a wider range of complex activities. In this study, we explored the extension of VAs' capabilities in the context of indoor navigation through mixed-ability focus groups with blind and sighted airport travelers. We found high overlap in the difficulties encountered by blind and sighted travelers, as well as shared interest in a voice-activated travel assistant to improve travel experiences. Leveraging user-elicited recommendations, we present interaction design examples that showcase customization of different and multiple modalities, which collectively demonstrate how VAs can more broadly achieve transactional interactions in complex task scenarios.

CCS CONCEPTS

• **Human-Centered Computing**; • **Empirical Studies in Accessibility**; • **Accessibility Technologies**;

KEYWORDS

Accessibility, Voice Assistants, Indoor Navigation, Blind and Sighted Travelers

ACM Reference Format:

Ali Abdolrahmani, Maya Gupta, Mei-Lian Vader, Ravi Kuber, and Stacy M. Branham. 2021. Towards More Transactional Voice Assistants: Investigating the Potential for a Multimodal Voice-Activated Indoor Navigation Assistant for Blind and Sighted Travelers. In *CHI Conference on Human Factors in Computing Systems (CHI '21), May 08–13, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3411764.3445638

CHI '21, May 08–13, 2021, Yokohama, Japan

ACM ISBN 978-1-4503-8096-6/21/05…$15.00
https://doi.org/10.1145/3411764.3445638

1 INTRODUCTION

Voice Assistants (VAs) have become ever more present in the current digital landscape, with technologies like Amazon Alexa [9] serving as at-home personal assistants or Siri [11] providing services during mobile activities. Often these technologies are used for purposes of entertainment or for servicing small requests, like playing music or providing the weather forecast [54]. A unique characteristic of these interfaces is that they offer a hands-/eyes-free mode of interaction, making them suitable for non-visual access in various contexts by different users, including people with visual impairments [2]. This non-visual mode of interaction offers an opportunity for individuals who are blind to have equal access to often otherwise poorly accessible, or completely inaccessible, services or interfaces. This particular characteristic raises expectations for these users to benefit from these mainstream technologies, in the form of a personal assistant, for "transactional" purposes [29] beyond simple human-like conversational dialogs and entertainment [1].

A research domain that we consider to be ripe for the application and introduction of these VAs is indoor navigation. Independent navigation, particularly in indoor spaces, has long been recognized as an important challenge for the blind community [25, 30, 81]. Many research efforts have been made to understand and improve the indoor navigation experiences of people with visual impairments [22, 33, 63, 65, 68]. Airport travel, in particular, is an especially strenuous type of indoor navigation – both for blind and sighted individuals – [40, 44] because of the unique and dynamic trials and obstacles present, including traversing security checks, navigating large open spaces, and erratic congregations of crowds (e.g., at gates or service areas). We view indoor navigation as a design space that would benefit from the possibilities of examining VAs' extended capabilities.

The study described in this paper aims to answer the following question: what are the navigation and information needs of air travelers with varying levels of visual ability, particularly individuals who are blind, that can be addressed through the extension of interactions with mainstream voice assistants? We are approaching these queries through the domain of airport navigation. Research has documented that users face certain challenges when using a device that is designed and marketed as an assistive technology–including higher prices, concerns about social stigma, and adoption rates [46, 71]. Integration of accessible design into a mainstream technology used by millions of people is more likely to be adopted and to mitigate the limitations described above. Accordingly, we gained insight from both blind and sighted participants to attend to this goal of mainstream adoption. In this study, we conducted mixed-ability focus groups with 18 participants, nine of whom had visual impairments and nine whom were sighted, to gain insights from users with and without disabilities about their challenges travelling within airports – including their navigation and information needs, and their reflections on the possibility of extending a mainstream VA to act as a travel assistant. We particularly wanted to examine the ways in which this assistant could or could not offer support and gather feedback on how voice interactions with this system could be designed. Our research aims to use the lens of VAs aiding in blind and sighted airport travel as a means of understanding how to extend the interactions of VAs to be more transactional and functional in nature.

Our findings suggest that both blind and sighted air travelers experience challenges accessing real-time information for effective navigation in airport facilities and across different stages of travel (i.e., departure, connections, baggage claim and leaving the airport). Additionally, both blind and sighted participants identified the promise associated with using a mainstream voice assistant on their mobile devices within an airport setting. Participants posited that this voice assistant could exist as the interface to an integrated ecosystem of multiple services that eliminates/reduces the need to directly interact with their phones. Our research effort shows that users with and without vision impairments believe they would benefit from a mainstream VA with more "transactional" and multimodal interactions to facilitate their use of multiple interfaces. This showcases the VA in the role of an intermediary to integrate services with varying levels of accessibility for easier and more immediate access. We conclude our study by outlining examples of how our participants would like to voice their queries and receive responses from an imagined personal assistant through "transactional" [29] and customizable multimodal interactions. Insights from this research offer implications for the future design of mainstream VAs to provide opportunities to a diverse group of users, particularly individuals who are blind, to have the: immediate access to information needed, ability to obtain services desired, and capability to complete complex tasks otherwise difficult or inaccessible to them.

2 RELATED WORK

It has been argued that incorporating accessible design features into mainstream technology has many benefits for users with disabilities when compared to assistive technology – including reducing cost and social stigma, and increasing adoption [46, 71]. One way to do this is by including blind and sighted participants in studies to develop interfaces that serve the needs of multiple populations [1, 82]. Through this framework, we seek to explore issues with air travel, as a particular type of popular transportation, for both blind and sighted individuals under the belief that users of differing visual ability may have similar or overlapping needs that will inform our understanding of how to make VAs more transactional in nature. Because of this framing of our work, we need to consider previous research that has been conducted in two domains: voice assistants and accessible navigation, particularly within airports. We will discuss prior work relating to VAs, their guidelines, and their use by diverse user groups. We will also review studies relating to airport navigation and wayfinding for blind and sighted travelers.

2.1 Voice Assistants (VAs)

VAs have been developed quite broadly, with various applications and uses being investigated commercially and academically. The most common commercial activities performed using VAs include simple information retrieval tasks, like determining the weather [54], and requesting entertainment, like playing music [17, 51]. In the academic sphere, researchers have explored the use of VAs for supporting speech language pathologists [85], personal fitness tracking [28], learning and education [83], overcoming public anxiety [79], and interactive maps [62]. The popularity of devices such as the Google Home [37] and Amazon Echo [9], and the opportunity for extending the use of VAs as demonstrated in research, have thus raised the need for "updating of HCI curricula to incorporate VUI design" [56] and prompted Human-Computer Interaction (HCI) practitioners to examine the use and usability of VAs, as described in the following sections.

2.2 VA Guidelines and Interactions

A systematic review of the guidelines of several leading VA provider companies (e.g., Google, Amazon, Microsoft, and Apple) concluded that these organizations emphasized a communication model that simulates "human-human" conversation through use of "everyday language" [23, 64]. However, research [29] has demonstrated that current VAs do not actually perform this natural form of conversation. Clark et al. describe this goal as a mix of transactional and social conversation [29]. In their study, participants expressed that the conversational element of interacting with a VA socially was helpful in order to create a more intimate relationship that promoted long-term use, however they ultimately viewed their interaction with the VA as transactional. Clark et al. defined transactional interaction as the pursuit of "a practical goal, often fulfilled during the course of one interaction." [29]. The authors suggested treating human-VA interaction as "a new genre of conversation" [29].

This "new genre of conversation" [29] has recently become a topic of analysis for HCI researchers. Numerous studies [1, 3, 27, 57, 77, 78] indicate the need for customization in these interactions with VAs. Abdolrahmani et al. identified the inability to adjust the speed of a VA's voice hindered its ability to handle complex tasks [3]. The systematic review by Branham and Mukkath Roy [23] reported that VA interaction guidelines often mandate specific durations for pauses, speed and pitch of voice, and degrees of command complexity. Vtyurina et al. [77] noted the similarities between interactions with VAs and the output of screen readers, however they identified that VAs lack the fine-grain control (e.g., the customization of voice, speed, pitch, and verbosity) of screen readers. Users with vision impairments, in particular, have emphasized context as an important factor of how they would prefer to interact with a voice agent

[1, 27]. Choi et al. [27] have suggested that customization of speech output speed is particularly important – with VAs' output being slower in social interaction contexts and faster when responding to service requests.

2.3 VAs for Diverse User Groups

Within the growing body of work relating to VAs, voice assistants have been explored among users for whom alternative interaction modalities are beneficial, including children, older adults, and people with disabilities (including people with visual impairments) [14, 19, 25, 47, 52, 58, 60, 75, 77, 84, 86]. Research has documented that children use voice output systems for exploration, information seeking, and functional tasks [53], and VAs can act as an accessible tool for pre-literate children who may have difficulty finding information through a screen and keyboard [52]. Studies have also shown that older adults appreciate the simplicity of voice-based interaction, but some older users find voice input to be an unnatural process, and have experienced instances of unintentionally interrupting the interaction [60, 84]. Other studies have documented the desire of participants with cognitive impairments to have greater integration of VAs into inaccessible tools [15, 25]. For example, Carroll et al. presented a design for a VA to address this need through simple voice commands and prompts for routine tasks [25].

Research has yet to deeply focus on the use of VAs by users with vision impairments. Tangentially, scholarly work in HCI and Assistive Technology design has explored the benefits gained from and the challenges encountered by users who are blind when interacting with audio input and output technologies. Some examples of the utility of voice input for blind users include the: rise in efficiency for conducting tasks when compared to touch-screen input [14], higher levels of satisfaction relative to their sighted counterparts [14], aid in educational settings [19], and the benefit of hands-free technology use which can be advantageous if the hands are encumbered [77]. But, studies have also documented that voice input often requires users to spend significant time editing text that has been misunderstood [14], voice output does not adequately convey spatial information about web page layout [58], and VAs traverse web pages in a way that results in audio output being frustrating to the user [47].

Our work aims to understand how to make VAs more transactional, and the work conducted on voice interaction in the accessibility sphere helps to give a greater understanding of the benefits and challenges of interacting with a device mostly through audio input-output.

2.4 Accessible Navigation and Wayfinding

Independent navigation for people with vision impairments has been of great interest and importance to the accessibility and assistive design research communities over the past four decades (e.g. [5, 21, 30, 50, 61]). Researchers and commercial designers alike have investigated numerous technological aids to work in tandem with the low-tech support that is more widely available and utilized by users with vision impairments (e.g., white canes, orientation and mobility training) [21]. Examples of commercial outdoor navigation applications developed for people with vision impairments include: BlindSquare [18], ariadneGPS [12], NearbyExplorer [59], etc. Recent research has been dedicated to identifying ways to improve and build upon the functionality offered by these types of tools. Specifically, there have been efforts investigating: the development of interactive maps [8], the inaccuracy of turn-by-turn wayfinding technologies when within the "last-few-meters" [65] of a destination [42, 65], and methods to enhance the communication between user and wayfinding device (or sighted guide) [45, 76].

As a result of the technical limitations of indoor navigation technologies (e.g., lack of GPS signal), prior studies have primarily focused on outdoor navigation solutions. However, more recently, there has been an additional push towards the research in the area of accessible *indoor* navigation [31, 68]. Solutions to the limitations of GPS in indoor spaces include: Bluetooth low energy (BLE) beacons for the precise localization of users [40], smartphone sensors [31, 34], computer vision to identify landmarks [34, 63], and sonar technology [20]. One of the most extensively developed research-driven indoor navigation technologies is the NavCog3 [6, 39, 41, 67, 68], a turn-by-turn navigation app that also identifies points of interest on the route and includes a conversational agent. Further research iterations on NavCog3 have focused on: evaluating the accuracy of the navigation and landmark feedback [67, 68], the addition of further touch gestures and virtual navigation [39, 41], and the errors resulting from difficulty in following rotational instructions [6].

Several navigation technologies, both developed in industry or through research, currently demonstrate multimodal capabilities. Examples include NavCog3 [68], Google Maps [38], Waze [80], etc., which provide users with options to use tactile and voice commands. However, we have not been able to locate work that examines how a voice assistant–that works in tandem with navigation, itinerary, and other applications–can adopt multimodal input and output functionality to enhance interaction.

2.5 Airport Navigation and Wayfinding

One example of indoor navigation that is particularly pertinent to this work is airport travel, in all its various stages (e.g., check-in, in-terminal navigation, layovers, baggage claim). Airport terminals are typically large indoor venues with often complex structures where passengers may access itinerary-related information through multiple sources (e.g., flight displays, overhead announcements, or airline apps/websites). These often crowded and noisy facilities may cause challenges for passengers trying to effectively navigate or locate desired information regardless of their abilities [44]. These challenges may be amplified for people with disabilities, including individuals who are blind [32, 40, 48]. The lack of availability of human assistance, unique and frequent locations of escalators and moving walkways, dynamic and large crowds, and large open areas further complicate the airport navigation of travelers with vision impairments [40]. The study presented in this paper is heavily influenced by the methods of Guerreiro et al. [40] who conducted focus groups to gather information about difficulties faced by blind travelers when within an airport terminal. There has also been work on behaviors and technologies related to general airport navigation conducted by only sighted travelers [44]. However, little work has examined the challenges faced by travelers with vision impairments during the multiple stages of airport travel or explored the differences and similarities between these challenges and those faced by sighted travelers.

U.S. airports, like other public buildings, are required to comply with ADA (Americans with Disabilities Act) regulations [10] to ensure that their facilities are accessible to those with disabilities. As part of this, and as part of a general movement toward acceptance of and independence for people with disabilities, airports have made various moves toward making air travel more accessible. Technologies explored to make airports more accessible include: BLE supported NavCog3 [68] and Access Explorer [36], and remote sighted-guide applications such as Aira [7] and BeMyEyes [16].

Studies have begun to examine blind versus sighted navigation strategies [82], and compared technical attitudes and strategies of blind, partially-, and fully-sighted individuals in various contexts [1, 78]. However, research has yet to deeply examine the common experiences of both blind and sighted airport travelers in various stages of airport travel. We aim to develop a greater understanding of these common experiences and the ways in which the challenges faced may be addressed through extending interactions with mainstream VAs.

3 METHOD

We conducted a series of focus group sessions, bringing together a range of users with and without visual impairments. We asked participants to share their experiences and challenges faced with respect to wayfinding and seeking information when moving through the different stages of travel within an airport. Following that, we asked them to share their thoughts on how a VA serving as a travel assistant, might support them in those frustrating situations. Soliciting opinions of both blind and sighted travelers in a mixed setting offered an opportunity to collect reflections on a broader range of experiences, as well as those common to both groups, and to capture more inclusive design insights for the target users of VAs as a mainstream technology.

3.1 Participants

We recruited a total of eighteen participants – who had airport travel experience at least a few times a year – (seven women, eleven men; aged 21 to 68, mean: 39, median: 36) (Table 1). We advertised the study through our contacts in the blind community, situated in the Mid-Atlantic region of the U.S., and invitation emails to several mailing lists catering to individuals with visual impairments. Nine participants identified as legally blind with little to no residual vision, and nine identified as sighted. All nine blind participants were cane users and utilized screen readers as their primary tool for accessing computing and mobile technologies. Four acquired blindness from birth and five later in life. Three identified they had color perception, and three were able to read large print. However, none relied on their vision for navigation. Three blind participants identified experiencing hearing impairments and relied on hearing aids. Seventeen participants indicated they traveled a few times a year, while one participant indicated he traveled several times per year until he recently became a graduate student, decreasing his frequency of travel to once or twice per year. Nine participants (three blind and six sighted) also indicated that they had international travel experience. All participants had experience using mobile voice assistants, such as Siri or Google Assistant, and were either familiar or owned home VAs, including Amazon Echo and Google Home smart speakers.

3.2 Procedure

The study comprised of three sessions, each with six participants (three blind and three sighted). Each session lasted approximately two hours. We divided each study session into two parts with a 15-minute break in between. The first part (which lasted approximately 60 minutes) provided participants with the opportunity to get to know one another and to ask clarification questions from the researchers regarding the study. We then asked participants to describe their experiences of travel within an airport, including experiences of advancing to the gate and aircraft when departing, arriving at a destination, and making connections. To provide additional structure to the discussion, we asked participants to focus on each of these three stages of travel one at a time, extending the work by Guerreiro et al. [40] where the focus is mainly on the departure stage of airport travel. For our study, we expanded upon their work by including questions related to connections and arrivals to stimulate discussion similar to the approach used in earlier studies [2]. For example, at the beginning of discussions regarding arrival at an airport, the primary researcher described a typical scenario such as, "Now, let's talk about the arrivals. You have landed. You need to claim your baggage and leave the airport to your destination. Or maybe other things you need to do in between." During these discussions, we particularly aimed to understand participants' navigation and information needs, frustrations, and workarounds to address these needs, as well as the situational and environmental factors impacting their experiences at each of these stages.

The second part of the study lasted approximately 45 minutes. At the beginning, we described to participants the possibility of extending a mainstream VA to assist travelers in an airport setting. We then asked participants to reflect on ways this type of travel assistant could or could not offer support for the navigational experiences through an airport which they had highlighted in the first part of the study. We asked participants to suggest ways in which voice interactions for such a system could be designed, taking into account voice commands, the assistant's responses, and configurable parameters.

It should be noted that at the end of the first focus group session, we updated the three stages of travel through an airport to four stages (i.e., departure, connections, baggage claim and leaving the airport) for the subsequent sessions. All of the participants in the first session agreed that the arrival stage in airport travel is a complex one that should be divided into two stages: from the plane to the baggage claim and from baggage claim to the outside of the terminal. All three sessions were audio recorded. A second researcher took notes during the sessions. Participants were paid $40 for their time and an extra $20 for transportation costs incurred (if applicable).

3.3 Data Analysis

The audio recordings were transcribed verbatim with an automated transcription service. Five undergraduate and graduate students

Table 1: – Focus Group Participants. BP = Blind Participant. SP = Sighted Participant. BFB = Legally Blind from Birth. BLL = Legally Blind Later in Life. HI = Hearing Impaired.

ID	Age	Gender	Visual Impairment/Other Disability	Travel Alone or with Companion	International
SP01	38	Man	None	Companion	Yes
BP02	26	Man	BFB	Companion	No
SP03	29	Man	None	Both	No
BP04	28	Woman	BFB	Alone	Yes
BP05	35	Woman	BLL/HI	Alone	No
SP06	51	Woman	None	Alone	Yes
BP07	37	Man	BFB	Alone	Yes
BP08	26	Woman	BFB	Both	Yes
SP09	65	Woman	None	Companion	No
BP10	38	Woman	BLL/HI	Both	No
SP11	68	Man	None	Alone	Yes
SP12	57	Man	None	Both	Yes
BP13	46	Man	BLL/HI	Both	No
SP14	21	Man	None	Alone	No
BP15	29	Woman	BLL	Alone	No
BP16	53	Man	BLL	Alone	No
SP17	33	Man	None	Alone	Yes
SP18	31	Man	None	Both	Yes

performed an initial accuracy check on the auto-transcriptions. Two researchers then performed a second round of rigorous quality checks on the transcriptions. The purpose of this check was to address errors relating to identifying which members of the focus groups were speaking.

Using inductive thematic coding, the primary author in collaboration with two other researchers conducted "segment-by-segment" coding on the transcriptions [26]. We aimed to identify navigation and information needs along with challenges experienced which were common between groups or unique to each group; determine situational and environmental factors impacting these experiences; and benefits offered and challenges addressed by a VA as well as properties of voice interactions recommended by participants in these shared experiences. The primary author and one researcher collaboratively generated initial codes for the first transcription [66]. Later, the primary author and a second researcher performed the coding on each of the remaining transcriptions, using and updating the generated codebook. The two researchers periodically discussed their individual coding efforts for reconciliation through "group consensus" [66]. The primary author then grouped open codes to make axial codes and generate themes from the data.

4 FINDINGS

Through the focus groups conducted, we aimed to understand the ways in which a VA can support the navigational challenges and information needs of both blind and sighted travelers at different stages of travel within an airport. Airport facilities are typically large in size, including areas with wide open spaces and long hallways. The complex structure of airports (e.g., separate areas for checking in, security, gates), and lack of consistency between layout of these areas in different airports can make the process of traversing this type of environment challenging for both blind and sighted groups. Furthermore, the ambient noise from travelers, announcements and alerts can also add to the complexity, particularly if the traveler needs to focus on a specific task. Below, we first describe participants' experiences when moving through the stages of airport travel. We then provide a description of perceptions of using a voice travel assistant to address the challenges encountered during this process.

4.1 Airport Structure and Facilities Impact Navigation

4.1.1 Challenges with Layout and Signage. The layout of the airport environment was identified by both blind and sighted participants as a major factor impacting navigation. The lack of consistency in the layout, such as "different gate layouts and numbering systems" (SP11), between airports was described as challenging and "annoying", particularly in scenarios where time was at a premium (i.e., when taking a connecting flight, when moving to a different level within the terminal (BP04)), or when transportation was needed (e.g., "catching a tram" (BP15) or locating the area for ride-share taxis ("... There is no way you can find your way. Getting out is really difficult." (SP18)). Lack of consistency led to instances of blind travelers "bouncing from one end to the other." (BP02). Confusion could be caused by unannounced structural changes made by the airports during peak usage times, such as changing security lines or pathways towards departure gates:

> "Oh! When did this happen? Where did this go? I was lost." (SP14).

Visual signage was found to be helpful for sighted participants to use. However, inconsistencies or insufficient signage could become confusing in unfamiliar airports especially when they needed to decide which "of these 20 exits" (SP18) to take to reach to their desired transportation zone, or result in "stressful" moments. For example, SP01 shared a "very bad" experience in Istanbul during his transfer:

> "I reached a place I didn't know which side I should go. . . . I was missing my flight. . . .Happened several years ago and still I remember that." (SP01).

While visual signage could not easily be accessed by blind participants traveling independently, different strategies were used to help traverse airport environments. Examples of workarounds included making logical guesses where they were depending on the sounds encountered or distance from prior landmark and asking third parties for assistance. Both blind and sighted participants highlighted the need for more accessible signage, which could reassure travelers that they were moving in the right direction. For example, a blue-colored raised line on the floor, which could be perceived by a white cane to guide travelers towards a specific location independent of sight status.

4.1.2 Lack of Effective Access to Required Information. Both blind and sighted participants stated they would need to have access to different types of information when traveling through an airport. Examples included itinerary-related information presented in real-time (e.g., updates regarding gates and their changes, delays, time to boarding, or the carousel number in the baggage claim area). SP12, for instance, described an experience where he only noticed that the gate had changed at the last minute due to the blinking of information on a monitor. These displays were described by blind participants as being inaccessible (five mentions), and visual cues such as blinking information did not translate well, adding to their concerns regarding missing flights. Interestingly sighted participants (two mentions) also stated that they often times faced difficulties in finding their desired piece of information on these "huge monitors" due to both the volume of information presented and the movement of this information as data was updated: "They keep refreshing it for some reason . . .." (SP18).

4.2 Challenges Vary in Different Stages of Travel, as do Strategies to Overcome Them

Findings highlighted that different challenges were experienced at different stages of travel. These are documented below.

4.2.1 Claiming Baggage. Participants (five blind, three sighted) described disembarking the aircraft and moving towards baggage claim to be a straightforward process, as there is no other choice "but to funnel through a single direction" (SP12) and "you just follow the crowd" (BP04), or in some cases other passengers on the same flight may offer help (BP02). However, experiences varied when claiming baggage. The main challenge related to the lack of resources to identify the appropriate carousel. Relying on auditory announcements was described as challenging, as it was difficult to attend to this information due the presence of other ambient noise. In some cases, baggage claim announcements were not made, causing confusion among travelers.

For blind participants, strategies varied to identify the carousel, such as counting the number of carousels while walking past them anticipating these were numbered sequentially or asking for help from others.

4.2.2 Leaving the Airport. Finding the way out of the terminal was identified as one of the most frustrating processes by both blind and sighted participants, particularly if third party transportation was needed (eight mentions by blind participants, eleven by sighted participants). Examples included locating rideshare taxi pickup zones and locating the vehicle, identifying locations of shuttles and public transportation owing to the many shelters located outside of the airport, and identifying the whereabouts of the rental car garage. Participants highlighted the time spent in the process:

> "It's very difficult to navigate to that and there were no directions to it. . . And I think I walk like 20 miles in the airport before I can find that designated area." (BP05).

Participants highlighted strategies which were imperfect but ultimately helped them to reach their end goal. For example, BP13 stated that to avoid these frustrations including vague directions from others, he would prefer to ask for airport human assistance to navigate with him to the pick-up zone and help locate his ride.

4.2.3 Layovers and Connecting Flights. Participants expressed that challenges encountered in other stages of travel were amplified when navigating between connecting flights. When attempting to make a connection, potential delays during the first leg of the journey could have a knock-on effect to taking their subsequent flight, often causing travelers to rush or miss their next flight. SP12 found connections to be "the most nerving thing" because of the constrained transfer window. Help from third parties would need to be solicited by both blind and sighted participants to confirm that travelers would make it to the correct destination, which could add time to their journey. Participants also ran into issues when gate change announcements were made before they disembarked. BP05 shared one unfortunate experience:

> "When they move your [next] gate while you're in flight, and you have no way of determining. . . and so you're lost and disoriented because you went to the wrong gate that was on your ticket, . . . that's really tedious and aggravating." (BP05).

4.2.4 International Travel. When traveling internationally, differences in language, combined with varied amounts of information available online regarding the airport facility and general differences in the rules and procedures in the airports, could cause confusion for both blind and sighted participants alike (six and five mentions respectively). BP04 explained that for individuals who are blind, international travel can pose specific challenges. She highlighted her frustration with navigation without being able to ask for help when traveling internationally:

> "Your customs can be a little bit crazy and you can't really ask for help. It's beyond frustrating." (BP04).

She then stated "if I could use something that'd just be English only, that would be great."

4.2.5 Undesirable Compromises. To better manage airport travel, participants described making compromises in order to achieve their end goal of reaching their final destination. One blind participant described preferring to stop once the first food outlet reached was identified rather than spending time locating one of choice:

> "I smell food down here, . . . and I'll just stop at any random food thing instead of trying to go to a certain area, because it gets daunting and then you forget what you were doing, trying to go to your flight." (BP05).

Both blind and sighted participants indicated that a lack of navigation cues would lead to extra effort and time in finding their desired points of interest, such as resting areas in large airports. For example, SP01 explained an experience where he faced difficulty in finding a rest area while in the terminal:

> ". . .You see a big screen that shows the flight but nothing about the food or other things. . .. So usually I should walk around to find [those places]." (SP01).

He had to guess and check in order to eventually find a place to rest.

4.2.6 Planning Strategies. Blind and sighted travelers mentioned strategies to prepare as much as possible for the trip ahead of time. These strategies included: identifying the time needed to travel between gates (if there is a transfer), finding how to get to the airport on time using the transportation of choice, looking at the airport layout and overall map (if available) prior to travelling to learn the location of certain points (e.g., concourses, gates), and printing out itinerary information as a low-tech solution for sighted travelers or sighted helpers to view. Blind participants highlighted that maps/floorplans were not always accessible by assistive technologies due to their graphical nature (BP02) and lack of the detailed description which would be necessary (e.g., location of different airlines' checking counters or security relative to the entrance doors). BP05 and BP15 stated that part of their planning strategies was to call the airport ahead of time and ask as many questions as possible, or to show up too early to compensate for the challenges faced during navigation in the terminal.

4.3 Seeking Travel Assistance from Other People

4.3.1 Locating Others to Ask Questions. Blind and sighted participants described relying on asking others (e.g., airport staff as the most knowledgeable people in airports, or other passengers) for directions and assistance, particularly in unfamiliar airports. Blind participants indicated that they would often first try to find the front desk to ask questions immediately after arriving at the airport. As gate changes are fairly common, blind participants stated that they would find themselves constantly repeating the same questions to ensure they were in the correct location due to worries about missing a flight. Three sighted participants also stated they would often ask for directions to gate locations when visual signs were not sufficient or when language barriers made it difficult to read and understand signs.

Participants (twelve blind, four sighted) shared that they often relied upon other passengers to obtain information and directions, as they were easier to access compared to airport staff. Blind participants in particular described themselves as more likely to ask other passengers nearby to obtain information about the following: inaccessible flight displays (BP16), locating their check-in counter (BP08), confirm they had reached the correct gate (BP04 and BP07), and find the baggage claim area and the correct carousel (BP04).

Difficulty in finding airport staff posed particularly frustrating experiences for blind participants in certain situations, such as when there is a delay between disembarking from the first flight in a connection and the staff arriving for assistance. For example, BP10 was once expecting an airport staff member to be available at the gate when she disembarked the aircraft to guide her to the next gate for her connecting flight, but no members of staff arrived. She almost missed her flight due to difficulties in locating a member of staff.

4.3.2 Airport Staff Are Not Helpful Enough. Participants (eleven blind, four sighted) expressed that the airport staff were not helpful enough in supporting them in their journeys. They shared experiences that airport staff gave insufficient instructions, vague and unhelpful answers to questions relating to directions to gates or other desired points of interest; did not have the expected knowledge; or did not do their job right. SP06 found passing through security to be a "confusing" and "chaotic" experience for her because "I get yelled at for different things . . . and they don't give me answers." She stated that if she were not sighted, she "would *really* be more alarmed then."

Another concern related to when the airport staff did not have the expected knowledge or they would respond with unhelpful or overly verbose directions, resulting in feeling of frustration:

> "Really? . . . You work here and you don't know. . . Give me god damn, good direction to the gate." (BP15).

They felt they had to "interrogate" them for the information they needed. Interactions with airport staff had even led to being directed to the wrong gate and missing the flight (BP08). BP13 shared his frustration when being navigated to his gate by an airport staff who stopped mid-journey to "chit chat with somebody else." He had to wait while he was worried about getting to his destination on time.

4.3.3 Directions Provided by Others in the Airport Are Challenging. Participants (six blind, three sighted) expressed frustrations when asking both airport staff or other passengers for directions to points of interest, especially gates (two blind participants), or transportation locations. Vague, incomplete directions or those presented in terms which are visually oriented (e.g., "go over there" where the term "there" has not been defined) would often leave them more confused, stressed, and lost. BP15, who had forgotten directions to her gate and was worried about being there on time, shared a stressful experience going back and forth between two spots in the terminal due to the unhelpful directions given by others:

> "So, for like an hour, I was just walking back and forth into Starbucks and McDonalds. Which is very irritating." (BP15).

Blind and sighted participants expressed annoyance from vague directions given when locating their ride outside the terminal. BP04 had a "horrendous" experience when trying to find an Uber in Las Vegas. She navigated to the spot she thought to be the correct location and was texted by her Uber driver saying "'yeah I'm leaving you, I'm here"'. Because of the confusing directions to the Uber pickup area given by others, BP04 was in one location and the Uber pick up was in a completely different area. Similarly, SP06 shared her lack of confidence in directions from third parties:

> 'Did you trick me?', 'Is there really going to be an Uber place out here?"' (SP06).

Both blind and sighted participants thought relying on these vague and often improper directions given by others would be confusing particularly in unfamiliar airports.

4.3.4 Other People's/Staff's Mistreatments. Blind participants (six mentions) had concerns related to others' misinterpretations regarding their capabilities or whether they needed help when navigating in the airport. Examples included offering unwanted help or "bringing up a wheelchair" (BP13) for navigation without first confirming with them. They stated that these incorrect assumptions would lead to feelings of "annoyance." They had to think about "what tactics" to take "to get them to leave me alone when I don't need them anymore." (BP07); or communicate to them "I can walk" when offering a wheelchair (BP13).

A further concern related to when airport staff would make decisions without the knowledge or consent of blind participants, for example taking BP4 through the fast-track line in security without consulting with her. The change in path caused confusion when realizing she was not where she normally expected to be:

> "It kinda of throws us off for what we consider our normal landmarks and I think that's a big issue for me." (BP04).

This caused participants to feel that their autonomy was being challenged, "it is aggravating to be tossed through without anyone paying attention to what your needs are." (BP05). However, they shared concerns that sometimes this desire for independent navigation expressed by blind individuals might be misinterpreted as being rude.

4.4 Technology Ideas and Voice Assistant Feature Recommendations

4.4.1 General Technology Suggestions for the Airport Facility. Participants were encouraged to envisage how a travel assistant in the form of a voice assistant could help improve their travel experience through airports, with the assumption of no technical limitations. A number of general design suggestions were made to support navigation within an airport environment, including accessible kiosks for independent check-ins (BP07), accessible maps (BP04) and displays (BP10) in the terminals, and an accessible universal app (SP14, BP04) that could be integrated with other apps and airport services. For instance, BP10 suggested:

> "Maybe they could have some of those screens. . . that would speak to everyone, . . . so that you would know that you were headed in the right direction." (BP10).

More specifically, participants made suggestions about having a voice travel assistant on their mobile devices that could improve their overall travel experience, serving them in a more holistic way by integrating with other services such as flight booking, itinerary information in the airport, accessing airline apps etc. while on-the-go. These suggestions related to voice commands that would be more appropriate for usage in travel scenarios, notifications and responses which would be helpful, and settings and preferences they wished to personalize. SP14 provided an example of how Siri can access certain apps using voice commands. He suggested this service could be extended to interact with the airline apps to search flight information. This integration particularly was mentioned to help travelers by tracking their itinerary through, for example, connecting "Google Maps to Expedia" (BP02). BP02 also described a situation where the app tracking his itinerary would notify, "We know you want to go to Southwest . . . 50 yards to your left."

Participants indicated their interest in using such personal voice assistants to book their flights and pre-plan their travel to facilitate their navigation in the airport. BP07 stated:

> ". . . tell it with my voice what time I want to fly and what time of day I would like a flight to match up to come back." (BP07).

BP10 agreed and provided examples of where planning may be needed (e.g., identifying places to obtain rental cars, hotels, eating choices, bathroom locations). When she entered her plan for the entire trip, the assistant would be able to simply direct her as she proceeded. This type of planned navigation could be helpful for BP10 as a blind traveler who desired to be aware of all her options and avoid time constraints.

One blind and two sighted participants suggested that the travel assistant could help them as a real-time translator to alleviate language barriers for flights going to destinations where other languages may be spoken. BP02 expressed his desire for other people to talk into the assistant and have it translated:

> "'Siri translate this' and have them talk into it and then you can hear it [translated into English]." (BP02).

Overall, the participant's suggestions for the use of voice travel assistants were aligned with the previously mentioned information and navigation needs and challenges. The following sections will cover some more of their thoughts and suggestions.

4.4.2 Track the Itinerary and Notify Accordingly. Many participants (four blind, two sighted mentions) indicated that their travel voice assistant could help them to track progress in real-time during their journey by offering responses to their queries and pushing notifications and tracking steps to be taken along the path (Table 2). Participants described wanting to enter their flight information and have the app notify them of any gate changes, flight delays, and baggage claim carousels or "calculate" travel times between landmarks within an airport. Consider BP02's example of the assistant identifying an estimated travel time between locations in Table 2

SP18 stated that based on the time estimates, a travel assistant could tell him if there was enough time for a stop at a restaurant or if he needed to rush:

> "Five minutes [is] left before your connection. The closest Chick-fil-A is two-minute walk, do you want to go there?" (SP18).

BP02 and BP05 stated they would benefit from the assistant notifying them as they walk past gates or when their gate for their flight is changed. Blind and sighted participants alike found receiving these notifications to be helpful because both groups often missed overhead audio announcements and blind participants did not have access to flight displays.

Table 2: – Interaction Examples for Tracking the Itinerary. Q: Voice Command Suggestion. R: Example Response/Notification from Assistant. Number: Interaction Set.

Query/Information	Example Voice Command/Response
Timing and Constraints	R1: "You're 30 minutes away from getting your flight. It takes approximately 45 minutes to get from where you're to your gate." (BP02)
	Q2: "When do I need to leave [home] tomorrow?" (SP12)
Gates and Changes	R3: "It will 'ding' . . . and announce, "Gate 32", as you're walking past gates." (BP05)
	Q4: "'Hey Google, what gate number is.' and you say the flight number." (BP15)
	R4: "Hey P02, your flight's been moved to Gate B." (BP02)
Flight delays	R5: "Hey you get two hours. Your flight had been updated. Instead of eight." (BP16)

In contrast, for some participants the idea of notifications was not appealing, as notifications are continuously presented in airports (e.g., auditory announcements). Instead, they desired to explicitly query the assistant for itinerary-related questions, such as the destination gate and its distance relative to their current location (BP08), resulting in less reliance on asking others. She explained, "it would be nice" to frequently query the travel assistant "Hey, what gate am I at?" instead of trying to find someone, so she could understand the distance (e.g., "two more gates") to her destination.

4.4.3 Help with Navigation. Participants suggested several ways in which they could benefit from interacting with a voice travel assistant within an airport setting. These suggestions included querying for directions (step-by-step or general) and required time to get to different points of interests (e.g., gates, emergency exits); receiving notifications about the path when navigating (e.g., when taking the wrong directions); and planning their in-terminal navigation in advance (Table 3).

There were nine (three blind, six sighted) mentions related to using the travel assistant for step-by-step directions to points of interests such as gates, ATMs, charging stations, and service animal relief areas. SP17 and SP18 compared the step-by-step directions indoors to that of a car GPS which "does the same thing" by indicating turns, exits, and lanes to be on - making it a familiar mental model. SP18 added that his travel assistant could even offer hints about the environment along the path (particularly in wide corridors) for more effective navigation:

> "You need to be on the right side of here because the middle side there's an escalator . . . you don't need to get on." (SP18).

Both blind and sighted participants found this information to be potentially helpful particularly in unfamiliar airports and when "signs are not everywhere" (SP18). However, as indicated by two sighted participants, it would require the facility to provide an accurate indoor map which could be a potential limitation for the use of this technology.

Participants (three blind, one sighted) indicated they would benefit from the travel assistant notifying them of obstacles along the path by, for instance, giving them a heads-up about "part of this section is taped off" (BP16). One suggestion for how to manage this type of obstacle notification was to crowd-source the app similar to "Waze where everybody interacts with it." (BP15). The combined contributions from all travelers within an airport setting would increase the success of identifying and notifying others of obstacles or areas that are temporarily blocked or moved.

Participants stated that their travel assistant could provide the reassurance needed in airport settings by helping to confirm if users are on the right path to their intended destination. They discussed multiple methods of communication with the travel assistant based on their preferences. For instance, they suggested queries such as "Am I going in the right direction?" (SP12). Additionally, they recommended the assistant could notify them if they were headed off track either verbally, "You are now headed in the wrong direction" (SP03) or through vibrations, "if you're going in the wrong direction it's constantly vibrating." (SP03).

Another suggestion related to planning for navigating between multiple points of interest in the terminal. This idea stemmed from the already existing ability to program voice assistants to execute multiple commands in sequence (e.g., Siri shortcuts, Amazon Alexa routines). Consider SP18 suggesting use of this feature:

> "If you could program the travel assistant 'Hey, when I arrived, I need to go to the restroom. Then I got to Chick-fil-A and. . . then drink a coffee.' And then when you are out [of the plane for your connection], it tells you 'okay, do you want me to direct you to your restroom first and then direct you to Chick-fil-A and. . .?"' (SP18).

This type of planning, as previously mentioned by BP05, could help travelers navigate more effectively across the terminal. The travel assistant could offer directions taking into account the time needed to navigate or even changes to the gate that may occur.

4.4.4 Provide Information About the Environment and Staff. Both blind and sighted participants indicated that greater awareness about the "general lay of the land" (SP11) and different landmarks in the airport could help them navigate and make decisions more efficiently (Table 4). For example, SP11 preferred to know about the presence of major landmarks in the terminal along the route to his gate:

> "Do I want to go all the way to the waiting area and put my stuff down with a friend/neighbor and then come back to get something to eat, or should I wait until the next one, which is going to be close to my gate? . . . it could announce, 'You are now crossing over from this place to that place' or 'You're at such and such location."' (SP11).

Table 3: - Interaction Examples for Helping with Navigation. Q: Voice Command Suggestion. R: Example Response/notification from Assistant. Number: Interaction Set.

Query/Information	Example Voice Command/Response
Getting (step-by-step) Directions	Q1: "Okay, I need to go to Gate D." (SP03) Q2: "Siri, cancel direction towards..." (SP03) R3: "Here's the walking steps how to get to Gate B. . . you're Gate C now . . . go right as soon as you come out the gate, the seating area hang a right and go one gate down and [Gate B] is on your left." (BP02)
Planning for Navigating to Multiple POIs	Q4: "Hey, when I arrive, I need to go to the restroom. Then . . . to Chick-fil-A and then . . . drink a coffee." (SP18) R4: "Okay, do you want me to direct you to your restroom first and then . . . Chick-fil-A and . . .?"
Navigation Hints Along the Path	R5: "Okay, you need to be on the right side of here because the middle side there's an escalator going up/down. . ." (SP18) R6: "You are now heading in the wrong direction" (SP03)
Navigation Confirmation	Q7: "Am I going in the right direction?" (SP12) R7: "Yeah, just keep going the way you're going." (SP12)
Emergency Exits	Q8: "Where is the nearest [emergency] exit?" (BP10)
Obstacle Detection	Q9: "Is there something upfront . . . that I need to watch out for." (BP16) R10: "There's a can of soda knocked over. You might wanna watch out." (BP15)

Table 4: - Interaction Examples for Information About the Environment/Staff. Q: Voice Command Suggestion. R: Example Response/Notification from Assistant. Number: Interaction Set.

Query/Information	Example Voice Command/Response
Landmarks	R1: "You are now crossing over from this place to that place." or "You're at such and such location." (SP11) RQ2: "You've now entered the food court area", "I'm hungry Siri, what's here?" (BP02)
General Layout	R3: Concourse A is to your left; B is straight ahead and C to your right." (SP11) Q4: "Hey what is the layout of gates?" (BP04)
General Directions	Q5: "I need to get to 'here', so which direction do I need to go?" (BP05)
Finding Points of Interest	Q6: "Hey Siri, where's the nearest bathroom?" (BP15)
Request Human Assistance	Q7: "Hey google, find me an assistant, or where is the nearest assistant?" (SP01)

As mentioned by BP02, being aware of landmarks could assist blind travelers in making decisions (e.g., eating along the way or not) which would not be otherwise available to him. BP08, interested in independent navigation, expressed that having the assistant announce the landmarks along the route (e.g., "You're approaching a waterfall") would be a way for her to determine her next steps.

Participants indicated that they may need to query the assistant to locate different points of interest as they navigate the airport. Examples included finding bathrooms, shops and food areas, or locations of security and information desks, which would facilitate their access to the services they needed. Finally, based on their challenging experiences with regard to finding staff, participants (one blind and three sighted) stated that they would like to be able to query or be notified when they needed to find staff in the terminal. SP01, recalling that "BP04 had this experience and needed someone in Vegas airport and nobody was there," stated:

> "Okay. find someone to help me here, its urgent, it's an emergency. 'Hey google, find me an assistant, or where is the nearest assistant?"' (SP01).

4.4.5 Help Leaving the Airport and Arranging Transportation. Participants suggested ways in which the travel assistant could access transportation services to support one of the greater challenges of exiting the airport (described in an earlier section, 4.2.2). Recommendations included using the travel assistant to select from transportation options available, get directed to the desired zone and locate the car/driver (Table 5). Participants (three blind, three sighted) were interested to query their travel assistant or be notified of transportation options they could choose from:

> "When you get off the plane, it tells you 'you have the option of Uber, Lyft, Super Shuttle, public transportation, which option would you like to choose from.' . . . and 'I'll direct you how to get there."' (BP02).

They also stated that they would like to query the assistant about which service would cost less or arrive "quicker". Upon selecting their ride, they recommended that the assistant could update them with notifications such as "This such and such car is coming" (BP16) or "Okay, it's gonna be here in four minutes" (BP02). Having non-visual access to this complex process through interaction with the travel assistant was found to be pleasing by BP16, bypassing the need to look at his phone display:

> "If I pick one [option], it automatically has my information. It should be able to tell me back, where I ain't got to look at the phone with my little sight. It tells me

Table 5: - Interaction Examples for Leaving the Airport/Arranging Transportation. Q: Voice Command Suggestion. R: Example Response/Notification from Assistant. Number: Interaction Set.

Query/Information	Example Voice Command/Response
Getting Transportation Options	R1: "You have the option of Uber, Lyft, Super Shuttle, public transportation, which option would you like to choose from?" (BP02) Q1: "I want to take an Uber." (BP02)
Choosing from the Options	Q2: "Which rate is much cheaper here [between Lyft and Uber]?" (BP16) Q3: "Which ride is getting there quicker than the other service?" (BP16) Q4: "Order my Uber." (BP02)
Ride Service Information	R5: "This such and such car is coming, the person name, and a description of them." (BP16)
Transportation Service Status	Q6: "Do I have a delay?" (BP16) R7: "Okay, it's gonna be here in four minutes." (BP02)
Getting to Transportation Zone	R8: "Which one you want and I'll direct you how to get there." or "Go to this point." (BP02)
Locating the Car	R9: "Ding ding ding . . . that's your car!" (BP04)

'this such and such car is coming', the person name, and gives a description of them." (BP16).

Three blind participants indicated that the next role for the travel assistant would be guiding them towards the desired transportation zone. The travel assistant could offer them general directions or, when leaving an unfamiliar airport, it could provide step-by-step directions to the desired area:

"'You need to listen to me. So, I can get you to the right spot!', And it just directs you where you need to go and I catch my Uber." (BP02).

4.4.6 Be Customizable and Adaptable to Personal Preferences. In their discussions regarding features for a travel assistant, participants indicated ways in which they would like to configure different settings on the assistant to meet their personal preferences and goals (Table 6). These included customizing to different modes of operation, filtering the environmental information provided, and customizing based upon personal preferences.

Participants (eight blind, four sighted) were interested in setting the travel assistant to operate in different modes, providing targeted information to the user based upon the desired task. These modes included using the assistant for planning (e.g., booking the travel), navigation (e.g., getting detailed step-by-step directions), or exploration (e.g., querying/receiving information about the surroundings and desired POIs for environmental awareness). When discussing the exploration mode, participants indicated that they would like to query the assistant regarding their surroundings to know about the available POIs. For example, BP02 explained "if it says 'You're now entering the food court area"', he could then query, "'Hey Siri, tell me the restaurants."'. Participants suggested that as another option, the assistant could offer notifications in a continuous manner as they were navigating "down the hallway" such as "Chick-fil-A's on your left, the bathrooms on your right" (BP04). Participants emphasized that the assistant should allow them to filter for which points of interest they would like to receive information (e.g., gates, restaurants, bathrooms, shops), so the assistant is "not telling you things you don't want to know." (SP03).

Another set of features suggested included adjusting the settings related to the interaction with the assistant itself. Participants indicated the assistant should allow them to customize its name and speech output settings such as voice, speed, and verbosity of the responses and notifications. They mentioned that they would like to customize how the assistant would notify them or respond to their queries in different modes of operation. Their suggestions included choosing from multiple modalities, such as: speech output, short non-speech auditory bursts of information (termed "earcons"), or vibration feedback when notifying about the environment (e.g., arriving at/passing a POI) or when prompting for the next direction to be taken during navigation in the terminal. Participants recommended that users should be able to customize other parameters for these notifications - including their timing (i.e., how long in advance they are triggered), their intensity or loudness. Participants (five blind, two sighted) emphasized the utility of a vibration modality for notifications, allowing them "to have the information in an efficient way that's least distracting," (BP07). Listening to the surroundings was critical for blind participants while navigating. Therefore, they preferred not to have their hearing channel occupied. BP08 indicated, "I don't want something talking in my ear the whole time."

Other suggestions made included using their voice to temporarily (de)activate the assistant itself or its notifications (e.g., environmental or navigation prompts) and setting the assistant to use O&M clock directions in its speech output (e.g., head towards three o'clock). Another recommendation related to the flexibility in the format of the voice commands. Instead of always "having to have a full-blown conversation" (BP05) with the assistant, participants would like to have the option to use short commands "like the buzzwords" or to interact using multiple commands for the sake of time and planning such as "Okay. Claim baggage, bathroom, Chinese food." (SP01). Although it may take time to learn which keywords could be utilized, it would save time when performing tasks compared to entering queries in natural language format (i.e., longer sentences). Finally, participants recommended that the travel assistant should allow users to determine their navigation preferences and adapt to these needs (e.g., solely offering elevator

Table 6: – Assistant's Settings, Customization Preferences, Interaction Examples. Q: Voice Command Suggestion. R: Example Response/Notification from Assistant. Number: Interaction Set.

Query/Information/Setting	Example Voice Command/Response/User Choices
Modes of Operation	Travel planning, detailed navigation, environmental awareness and exploration planning. Travel Planning, QR1: "Hey Siri find me a flight starting from 9:00 a.m. to 12:00 p.m. from this place to this place.", "Hey here's the cheapest, here's the most expensive" (SP14) Navigation, Q2: "Hey Siri. Got to go to Carousel 13 where is that?" (BP04) Exploration, R3: "Chick-fil-A's on your left, the bathrooms on your right" (BP04) Exploration, Q4: "Hey Siri what's in this food court Concourse A at BWI?" (BP04)
Filtering the Information	Gates/counters/information desks, food areas, bathrooms, shops
Interaction with the Assistant	Assistant's name, and speech output settings (voice, speed, verbosity of the responses/notifications)
Notifications	Multiple modalities (speech output, earcons, vibration feedback) Timing, intensity/loudness
General	(De)activating the assistant/notifications, using O&M clock orientation Ability to use short/multiple commands Q: "Okay. Claim baggage, bathroom, Chinese food." (SP01)
Personal Preferences	Navigation needs with regard to user abilities, disclosing visual assistance need to ridesharing services

directions as "some people may have a hard time climbing up the stairs." (SP18)).

5 DISCUSSION

In this research effort, we aimed to explore the possibility of extending the use of mainstream voice interfaces to serve beyond their current scenarios of use, which prior research found to often be often for simple information retrieval tasks, such as checking the weather, or for purposes of leisure and entertainment, such as playing news or music [17, 51, 54]. We focused on airport travel as the context of this exploration. Navigating through airport facilities as large indoor venues (with often complex structures and immediate need to different information) is documented to be challenging for people in general [44] and blind travelers in particular [32, 40, 48]. To this end, we first investigated the navigation challenges and information needs of blind and sighted air travelers in different stages of airport travel, and then we explored potential ways that a voice travel assistant may address these challenges for both groups. To the best of our knowledge, this is the first research effort seeking to outline opportunities for extending the transactional use of mainstream voice assistants to augment indoor navigation for both blind and sighted air travelers and offer specific voice interactions, complemented by multiple modalities, that travelers viewed as preferable in this context. Further, this is the first research paper to propose that the challenges of navigation in airport settings can be ameliorated by the strengths of VA interfaces.

Our exploration of a larger and expanded participant (e.g. sighted and blind) pool confirms some preliminary findings from Guerreiro et. al.'s inquiry about the challenges of blind airport travelers. Further, novel findings include shared challenges regarding layout and signage, lack of effective access to required information, and how needs vary across stages of travel (e.g., layovers, baggage claim, leaving the airport). Our findings suggest that blind and sighted air travelers experience overlapping challenges accessing real-time information for effective navigation in airports and across different stages of travel (i.e., departure, connections, baggage claim and leaving the airport). These challenges related to structural complexities, lack of immediate access to information needed, and concerns raised when seeking help from airport staff or other passengers. Structural complexities related to differences in airport facility structures, such as location of concourses, layout of gates or carousels, and ways to get access to different transportation options outside of the terminal. Lack of effective access to physical or online maps negatively impacted the experience of both groups of travelers. Insufficient visual signage in the facility - particularly in unfamiliar airports - was of great concern for sighted travelers, resulting in "stressful" moments, as when SP01 was missing his flight.

Lack of immediate access to information was another major barrier to effective navigation that commonly impacted both blind and sighted participants. This included information about: (1) getting directions to navigate to certain itinerary-related points at certain times (e.g., check-in counters, security, gates, carousels, transportation zones) or other points of interests (e.g., bathrooms, restaurants, charging stations, and resting areas); (2) the flight itinerary (e.g., updates regarding gates and their changes, delays, time to boarding, or the carousel number in the baggage claim area); and (3) general information about the facility (e.g., layout of concourses, gates, carousels, and exit doors of the terminal). This lack of immediate access to information was a result of factors such as: inaccessibility of visual signage and flight displays for blind travelers, difficulties posed by insufficient visual signage for sighted travelers (especially in unfamiliar airports), and missing/lack of overhead announcements in the terminal. These information gaps experienced by blind and sighted travelers could be eased by the extension of a mainstream VA in the form of a travel assistant (as discussed below and in sections 5.1 and 5.2).

Seeking information and assistance from others is a common strategy of blind navigators [81]. Guerreiro et al. [40] reported concerns of blind travelers regarding personal assistance services offered in the airport. While confirming their findings, our findings also revealed that, similar to blind participants, sighted participants felt the need to seek assistance from the airport staff or other passengers. This raised concerns for both groups because of the difficulty to immediately access airport staff; the unhelpfulness of communication resulting from the vague directions or verbose unrelated responses given to questions; and others' misunderstandings, such as airport staff's "bringing up a wheelchair" (BP13) for blind travelers. As reported by past research [43, 82], these misunderstandings related to others' lack of knowledge with regard to mobility capability and navigation needs of individuals who are blind. Our findings revealed that VAs could present a unique opportunity to provide travelers with an alternative to seeking assistance from others, and as a result support people who prefer "technological versus human assistance" - including those with disabilities - when navigating [43].

Among the four stages of airport travel, we found that layovers during connections were "the most nerving thing" (SP12) for both groups. Many of the challenges faced could be amplified because of the short window of the transfer time including missing gate change announcements for the second flight (often due to the delay in the first flight), which particularly makes blind travelers feel "lost and disoriented" (BP05). Next, we found that leaving the airport and locating the desired type of transportation was often a frustrating - even "horrendous" (BP04) - part of travel, especially when carrying luggage or when in "unknown territories" (SP18) for both blind and sighted participants.

Blind and sighted participants in our study commonly reacted positively when solicited about the potential ways of using a voice-based travel assistant in the airport. If future technology affords, they believed that having a voice-based travel assistant with access to proper information resources could offer immediate responses to their voice queries as they move along. Regarding this, they shared their reflections on how interaction with a voice-based travel assistant could address many of the challenges they shared. Participants' suggestions for these interactions comprised of a range of queries and responses/notifications. These related to (1) tracking the itinerary; (2) step-by-step navigation or general environmental awareness; (3) arranging rides outside the terminal; and (4) customizing the assistant based on their needs in different situations.

A series of research studies have been conducted about the development and use of NavCog as an indoor navigation solution for individuals who are blind [4, 67, 68]. Our findings, in the context of airport travel, confirms their general findings with regard to indoor navigation and information needs of blind individuals, such as step-by-step directions (e.g., notifications about steps to be taken or announcement of landmarks along the route) and general information about the environment or different points of interest. Additionally, our work complements their work in two ways. First, our findings revealed that navigating large indoor locations such as airports (where successful navigation is associated with taking steps at certain times) poses challenges not only for blind but also sighted travelers and requires both groups to have immediate access to certain types of information or services (e.g., flight itinerary, transportation services) in addition to the information needed for navigation purposes. This suggests that future design of mainstream technologies may consider these commonalities to offer more inclusive solutions for a broader range of users with varying needs. Second, NavCog, like other existing indoor navigation solutions for blind individuals (e.g., NearbyExplorer [59], BlindSquare [18]) requires hands-on interactions with the mobile device. Although NavCog also offers an in-app conversational interface enabling its users to interact with the app with their voice to search for available points of interest, it still requires users to reach to their mobile device to interact with a special-purpose interface through "one-handed interaction" [68]. Our study, in contrast, suggests that both blind and sighted participants perceived it promising to be able to use a mainstream voice assistant on their mobile devices in airports in the form of an integrated ecosystem of multiple services that eliminates/reduces the need to directly interact with their phones (e.g., "Siri, what gate am I at" (BP05), "Siri, cancel direction towards..." (SP03)). Additionally, they suggested a range of interactions to control the assistant's settings (e.g., mode of operation, verbosity of commands/responses) or customize its functionality and associated modality (e.g., vibrations for notifications) along the way.

Our research effort shows that future design of mainstream (mobile) voice assistants should take into account their use in different contexts where people with varying abilities may leverage them to fulfill tasks otherwise impossible or difficult for them. Among the first studies on using voice assistants in the context of indoor navigation, our findings present user-elicited recommendations to support the argument by Branham and Mukkath Roy [23] that the future design of these mainstream voice assistants may go beyond human-human model of conversational agents. We also argue that their future design should, depending on the context of use, consider (1) offering a more "transactional" model [29]; (2) allowing usage of different modalities over the course of the interaction; and (3) giving more control to the users for customization based on their personal preference and needs.

5.1 Allow Voice Interaction to Be More Transactional

Current approaches in the available design guidelines of commercial voice assistants emphasize a communication model simulating "human-human" conversation [23, 64]. In contrast to this approach, research on examining human-human versus human-agent conversations suggests that the properties of human-agent conversations were perceived almost in purely transactional and functional terms [29]. For example, the common ground development in human-agent conversations was found to be viewed as a one-way process related to the ability to personalize the agent to respond according to the context of use and the users' needs. Aligned with this view towards a more "functional" and "utilitarian" view in the future design of voice assistants [29], our findings revealed that both blind and sighted participants recommended interaction features for a voice-based travel assistant that would fulfill their "transactional" purposes in the context of indoor navigation. One example is querying the travel assistant to plan for a sequence of goals, if timing allows, with regard to their itinerary ("Okay. Claim baggage, bathroom, Chinese food." SP01). This in particular supports how these conversational agents may offer different roles as a personal assistant to help blind users fulfill their desired goals more confidently without worries of uncertainties associated with getting lost or missing their flight, particularly when connecting through an unfamiliar airport.

Therefore, we argue that, aligned with suggestions by past research [23, 29], human-agent conversation should be considered a new genre of interaction, with its own rules, expectations and norms that are more "functional" and "utilitarian" in nature and that supports personalization in line with users' needs and situational context [29]. To support this argument, our findings revealed that both blind and sighted participants expected to configure different settings of their travel assistant depending on the context of use. Examples include choosing different modes of operation and filtering the information provided (Table 6), or using short commands "like the buzzwords" instead of "having to have a full-blown conversation" (BP05). Aligned with past research [3, 29] and our findings, we suggest that voice assistants should offer more flexibility to their users in changing their settings such as the name of the assistant or its speech output settings like voice, speed, and verbosity of the responses/notifications. As frequent users of screen readers, individuals who are blind prefer [3] and are capable of handling higher speech rates of voice assistants for more efficiency [13, 73]. In the context of our research, changing the speech rate of the travel assistant allows blind air travelers to spend less time listening to the assistant's responses/notifications and attend more to their surroundings while navigating. As found by Choi et al [27], similar to sighted users, blind users of voice assistants may prefer the default human-like speech rate when interacting with the voice agent for conversational purposes. However, the user experience of voice assistants would enhance for blind users if these interfaces actively adopt the appropriate speech rates according to the context of use and tasks being performed or allow the users to take on the direct control of the speech rate to align to their personal preferences similar to the speech control of screen readers. We extend these findings by arguing that customization and adaptation to personal and contextual needs of the voice assistant users should go beyond speech-related parameters and should allow the users control other parameters such as types of queries, modality of feedback depending on different contexts, and verbosity of communication.

5.2 Integrate Other Modalities to Support Voice Interaction

Research has shown that conversational agents should be multimodal, specifically including non-verbal communications [49, 69]. Multi-modality is a critical aspect to be considered in the design of voice user interfaces. Design and development of conversational agents has been frequently focused on one communication modality, such as text or speech. However, use of other modalities (e.g., use of visual text or graphical based elements, touch-screen/physical buttons [49]) in their design may offer enhanced ways to better respond to the needs of their users in different contexts.

We suggest that seamless integration of multiple modalities in an accessible way can result in more effective interactions with voice assistants, particularly in mobile contexts. As suggested by our findings, the hands/eyes-free interaction with voice travel assistants offered participants immediate access to required information in different stages of travel. However, there are limitations that may impact the effectiveness of these interactions, including the cognitive load resulting from the continuous spoken output of the assistant while moving (particularly challenging for blind travelers who should keep their environmental awareness through sense of hearing); and hearing difficulties and speech recognition problems in noisy environments. To address these limitations, users should be able to choose from different modalities such as spoken output, earcons, or vibrations to receive responses/notifications offered by the assistant (e.g., when heading in the wrong direction, passing a desired point of interest, reaching a ride-sharing taxi). Integrating voice interactions with other modalities and services in a meaningful way to support different needs of users in different contexts will enhance the usability of voice assistance while still being beneficial to their users by offering a natural mode of interaction.

6 LIMITATIONS

Our study sample of participants included only 18 blind and sighted locally recruited participants, whose travel experiences and insights regarding technology may not represent those of the general population and the blind community at large. A challenge faced by accessibility researchers relates to recruitment of disabled users, due to the smaller number of individuals in their population. Consequently, it is not uncommon to recruit smaller samples and from venues local to the researchers, where the researchers have links with community-based organizations [70]. Additionally, this study focused on participants' individual travel experiences rather than understanding the experiences of those who may have been traveling in a group (e.g., blind parents with sighted children, groups of blind or sighted travelers). The findings of this study could be extended by eliciting experiences of travelers who travel in a group, have a wider range of travel frequency (e.g., those who travel rarely or on a frequent basis), frequently make multiple connections on the same journey, or identify as having other disabilities (e.g., mobility impairments).

7 CONCLUSION

In the study described in this paper, we selected the context of indoor navigation to explore the possibility of extending the use of mainstream voice assistants towards more transactional interactions. We specifically focused on investigating the ways in which voice interaction can offer promise to navigation. Through running mixed-ability focus groups with blind and sighted airport travelers, we reported the high overlap of navigation challenges and information needs between groups in different stages of airport travel. We also described interaction recommendations on the potential offered by using a voice travel assistant to improve user experience. This paper presents user-elicited recommendations that support the need for the future design of voice assistants to less follow a human-human conversation model, and move more towards a "transactional" model, taking into account using different modalities over the course of the interaction and giving more control to the users for customization based on the context of use, personal preference, and users' needs. As the next logical step in the research, we aim to extend our work by further focusing on universal usability. We aim to run a series of iterative online design sessions with a broader range of individuals with varying abilities, including individuals who identify as sighted, blind, mobility impaired, and older adults. We seek to more deeply understand the form factor, interaction and modality preferences of different groups of users with regard to designing a more transactional mainstream voice assistant that will support indoor navigation matching the needs and abilities of a wider set of users.

ACKNOWLEDGMENTS

The authors would like to thank the participants for their valuable feedback; Antony Rishin Mukkath Roy (UMBC) and Priyanka Hitesh Soni (UMBC) for their support facilitating focus group sessions; and Areba Shahab Hazari (UCI), Tiffany Tseng (UCI), Hipolito Ruiz (UCI), Sruti Vijaykumar (UMBC) and Kelly Dickenson (UMBC) for their assistance with transcription and coding. This project is supported by Toyota Manufacturing North America (000890-00001).

REFERENCES

[1] Abdolrahmani, Ali, Kevin M. Storer, Antony Rishin Mukkath Roy, Ravi Kuber, and Stacy M. Branham. "Blind Leading the Sighted: Drawing Design Insights from Blind Users towards More Productivity-oriented Voice Interfaces." *ACM Transactions on Accessible Computing (TACCESS)* 12, no. 4 (2020): 1-35.

[2] Abdolrahmani, Ali, Ravi Kuber, and Amy Hurst. "An empirical investigation of the situationally-induced impairments experienced by blind mobile device users." In *Proceedings of the 13th Web for All Conference,* pp. 1-8. 2016.

[3] Abdolrahmani, Ali, Ravi Kuber, and Stacy M. Branham. "" 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,* pp. 249-258. 2018.

[4] Ahmetovic, Dragan, Cole Gleason, Chengxiong Ruan, Kris Kitani, Hironobu Takagi, and Chieko Asakawa. "NavCog: a navigational cognitive assistant for the blind." In *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services,* pp. 90-99. 2016.

[5] Ahmetovic, Dragan, João Guerreiro, Eshed Ohn-Bar, Kris M. Kitani, and Chieko Asakawa. "Impact of expertise on interaction preferences for navigation assistance of visually impaired individuals." In *Proceedings of the 16th Web For All 2019 Personalization-Personalizing the Web,* pp. 1-9. 2019.

[6] Ahmetovic, Dragan, Uran Oh, Sergio Mascetti, and Chieko Asakawa. "Turn right: Analysis of rotation errors in turn-by-turn navigation for individuals with visual impairments." In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 333-339. 2018.

[7] Aira. Accessed September 8, 2020. https://aira.io/.

[8] Albouys-Perrois, Jérémy, Jérémy Laviole, Carine Briant, and Anke M. Brock. "Towards a multisensory augmented reality map for blind and low vision people: A participatory design approach." In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems,* pp. 1-14. 2018.

[9] Amazon Alexa. 2020. Accessed September 8, 2020 from https://www.amazon.com/b?node=17934671011.

[10] Americans with Disabilities Act of 1990, Pub. L. No. 101-336, §2, 104 Stat. 328 1991.

[11] Apple Siri. 2020. Accessed September 8, 2020 from https://www.apple.com/siri/.

[12] Ariadne GPS. Accessed September 8 2020. http://www.ariadnegps.eu/.

[13] Asakawa, Chieko, Hironobu Takagi, Shuichi Ino, and Tohru Ifukube. "Maximum listening speeds for the blind." Georgia Institute of Technology, 2003.

[14] Azenkot, Shiri, and Nicole B. Lee. "Exploring the use of speech input by blind people on mobile devices." In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 1-8. 2013.

[15] Baldauf, Matthias, Raffael Bösch, Christian Frei, Fabian Hautle, and Marc Jenny. "Exploring requirements and opportunities of conversational user interfaces for the cognitively impaired." In *Proceedings of the 20th International Conference on human-computer interaction with mobile devices and services adjunct,* pp. 119-126. 2018.

[16] Be My Eyes - See the world together. Accessed September 8, 2020. https://www.bemyeyes.com/.

[17] Bentley, Frank, Chris Luvogt, Max Silverman, Rushani Wirasinghe, Brooke White, and Danielle Lottridge. "Understanding the long-term use of smart speaker assistants." *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies 2,* no. 3 (2018): 1-24.

[18] BlindSquare. Accessed September 8, 2020. https://www.blindsquare.com/.

[19] Bouck, Emily C., Sara Flanagan, Gauri S. Joshi, Waseem Sheikh, and Dave Schleppenbach. "Speaking math—A voice input, speech output calculator for students with visual impairments." *Journal of Special Education Technology 26,* no. 4 (2011): 1-14.

[20] Bousbia-Salah, Mounir, Abdelghani Redjati, Mohamed Fezari, and Maamar Bettayeb. "An ultrasonic navigation system for blind people." In *2007 IEEE International Conference on Signal Processing and Communications,* pp. 1003-1006. IEEE, 2007.

[21] Brabyn, John A. "New developments in mobility and orientation aids for the blind." *IEEE Transactions on Biomedical Engineering* 4 (1982): 285-289.

[22] Branham, Stacy M., Ali Abdolrahmani, William Easley, Morgan Scheuerman, Erick Ronquillo, and Amy Hurst. "" Is Someone There? Do They Have a Gun" How Visual Information about Others Can Improve Personal Safety Management for Blind Individuals." In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 260-269. 2017.

[23] Branham, Stacy M., and Antony Rishin Mukkath Roy. "Reading between the guidelines: How commercial voice assistant guidelines hinder accessibility for blind users." In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 446-458. 2019.

[24] Brewer, Robin N., and Anne Marie Piper. "xPress: Rethinking design for aging and accessibility through an IVR blogging system." *Proceedings of the ACM on Human-Computer Interaction* 1, no. CSCW (2017): 1-17.

[25] Carroll, Clare, Catherine Chiodo, Adena Xin Lin, Meg Nidever, and Jayanth Prathipati. "Robin: enabling independence for individuals with cognitive disabilities using voice assistive technology." In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems,* pp. 46-53. 2017.

[26] Charmaz, Kathy. Constructing grounded theory: *A practical guide through qualitative analysis.* sage, 2006.

[27] Choi, Dasom, Daehyun Kwak, Minji Cho, and Sangsu Lee. "" Nobody Speaks that Fast!" An Empirical Study of Speech Rate in Conversational Agents for People with Vision Impairments." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-13. 2020.

[28] Chung, Arlene E., Ashley C. Griffin, Dasha Selezneva, and David Gotz. "Health and fitness apps for hands-free voice-activated assistants: content analysis." *JMIR mHealth and uHealth* 6, no. 9 (2018): e174.

[29] Clark, Leigh, Nadia Pantidi, Orla Cooney, Philip Doyle, Diego Garaialde, Justin Edwards, Brendan Spillane *et al.* "What makes a good conversation? challenges in designing truly conversational agents." In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems,* pp. 1-12. 2019.

[30] Darling, Nancy C., Gregory L. Goodrich, and J. Kenneth Wiley. "A preliminary followup study of electronic travel aid users." *Bulletin of prosthetics research* 10, no. 27 (1977): 82.

[31] Fallah, Navid, Ilias Apostolopoulos, Kostas Bekris, and Eelke Folmer. "Indoor human navigation systems: A survey." *Interacting with Computers* 25, no. 1 (2013): 21-33.

[32] Fewings, Rodney. "Wayfinding and airport terminal design." *The journal of navigation* 54, no. 2 (2001): 177-184.

[33] Fiannaca, Alexander, Ilias Apostolopoulous, and Eelke Folmer. "Headlock: a wearable navigation aid that helps blind cane users traverse large open spaces." In *Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility,* pp. 19-26. 2014.

[34] Flores, German, and Roberto Manduchi. "Easy return: an app for indoor backtracking assistance." In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems,* pp. 1-12. 2018.

[35] Giudice, Nicholas A., and Gordon E. Legge. "Blind navigation and the role of technology." *The engineering handbook of smart technology for aging, disability, and independence* 8 (2008): 479-500.

[36] GoodMaps. 2020. Accessed September 8, 2020 from https://www.goodmaps.com/.

[37] Google Home. 2020. Accessed September 8, 2020 from https://store.google.com/us/product/google_home_speaker.

[38] Google Maps. 2020. Accessed December 22, 2020 from https://www.google.com/maps.

[39] Guerreiro, João, Daisuke Sato, Dragan Ahmetovic, Eshed Ohn-Bar, Kris M. Kitani, and Chieko Asakawa. "Virtual navigation for blind people: Transferring route knowledge to the real-World." *International Journal of Human-Computer Studies* 135 (2020): 102369.

[40] Guerreiro, João, Dragan Ahmetovic, Daisuke Sato, Kris Kitani, and Chieko Asakawa. "Airport accessibility and navigation assistance for people with visual impairments." In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems,* pp. 1-14. 2019.

[41] Guerreiro, João, Dragan Ahmetovic, Kris M. Kitani, and Chieko Asakawa. "Virtual navigation for blind people: Building sequential representations of the real-world." In *Proceedings of the 19th International ACM SIGACCESS Conference on computers and accessibility,* pp. 280-289. 2017.

[42] Guerreiro, João, Eshed Ohn-Bar, Dragan Ahmetovic, Kris Kitani, and Chieko Asakawa. "How context and user behavior affect indoor navigation assistance for blind people." In *Proceedings of the Internet of Accessible Things,* pp. 1-4. 2018.

[43] Gupta, Maya, Ali Abdolrahmani, Emory Edwards, Mayra Cortez, Andrew Tumang, Yasmin Majali, Marc Lazaga *et al.* "Towards More Universal Wayfinding Technologies: Navigation Preferences Across Disabilities." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-13. 2020.

[44] Harding, Jim. "A research-based approach for improving the airport wayfinding experience." *Journal of Airport Management* 13, no. 2 (2019): 133-143.

[45] Kamikubo, Rie, Naoya Kato, Keita Higuchi, Ryo Yonetani, and Yoichi Sato. "Support Strategies for Remote Guides in Assisting People with Visual Impairments for Effective Indoor Navigation." *In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-12. 2020.
[46] Kane, Shaun K., Chandrika Jayant, Jacob O. Wobbrock, and Richard E. Ladner. "Freedom to roam: a study of mobile device adoption and accessibility for people with visual and motor disabilities." In *Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility*, pp. 115-122. 2009.
[47] Lazar, Jonathan, Aaron Allen, Jason Kleinman, and Chris Malarkey. "What frustrates screen reader users on the web: A study of 100 blind users." *International Journal of human-computer interaction* 22, no. 3 (2007): 247-269.
[48] Legge, Gordon E., Chris Downey, Nicholas A. Giudice, and Bosco S. Tjan. *Indoor airport wayfinding for blind and visually impaired travelers.* No. DOT/FAA/TC-TN16/54. 2016.
[49] Lister, Kate, Tim Coughlan, Francisco Iniesto, Nick Freear, and Peter Devine. "Accessible conversational user interfaces: considerations for design." In *Proceedings of the 17th International Web for All Conference,* pp. 1-11. 2020.
[50] Loomis, Jack M., Reginald G. Golledge, Roberta L. Klatzky, Jon M. Speigle, and Jerome Tietz. "Personal guidance system for the visually impaired." In *Proceedings of the first annual ACM conference on Assistive technologies,* pp. 85-91. 1994.
[51] Lopatovska, Irene, Katrina Rink, Ian Knight, Kieran Raines, Kevin Cosenza, Harriet Williams, Perachya Sorsche, David Hirsch, Qi Li, and Adrianna Martinez. "Talk to me: Exploring user interactions with the Amazon Alexa." *Journal of Librarianship and Information Science* 51, no. 4 (2019): 984-997.
[52] Lovato, Silvia B., Anne Marie Piper, and Ellen A. Wartella. "Hey Google, Do Unicorns Exist? Conversational Agents as a Path to Answers to Children's Questions." In *Proceedings of the 18th ACM International Conference on Interaction Design and Children,* pp. 301-313. 2019.
[53] Lovato, Silvia, and Anne Marie Piper. "" Siri, is this you?" Understanding young children's interactions with voice input systems." In *Proceedings of the 14th International Conference on Interaction Design and Children,* pp. 335-338. 2015.
[54] Luger, Ewa, and Abigail Sellen. "" Like Having a Really Bad PA" The Gulf between User Expectation and Experience of Conversational Agents." In *Proceedings of the 2016 CHI conference on human factors in computing systems,* pp. 5286-5297. 2016.
[55] Maskery, Helen. "Crossing the digital divide—possibilities for influencing the private-sector business case." *The Information Society* 23, no. 3 (2007): 187-191.
[56] Murad, Christine, and Cosmin Munteanu. "Designing Voice Interfaces: Back to the (Curriculum) Basics." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-12. 2020.
[57] Murad, Christine, Cosmin Munteanu, Leigh Clark, and Benjamin R. Cowan. "Design guidelines for hands-free speech interaction." In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct,* pp. 269-276. 2018.
[58] Murphy, Emma, Ravi Kuber, Graham McAllister, Philip Strain, and Wai Yu. "An empirical investigation into the difficulties experienced by visually impaired Internet users." *Universal Access in the Information Society* 7, no. 1-2 (2008): 79-91.
[59] Nearby Explorer Online. 2019. Accessed September 8, 2020 from https://apps.apple.com/us/app/nearby-explorer-online/id1095699328.
[60] Portet, François, Michel Vacher, Caroline Golanski, Camille Roux, and Brigitte Meillon. "Design and evaluation of a smart home voice interface for the elderly: acceptability and objection aspects." *Personal and Ubiquitous Computing* 17, no. 1 (2013): 127-144.
[61] Ran, Lisa, Sumi Helal, and Steve Moore. "Drishti: an integrated indoor/outdoor blind navigation system and service." In *Second IEEE Annual Conference on Pervasive Computing and Communications, 2004. Proceedings of the,* pp. 23-30. IEEE, 2004.
[62] Reinders, Samuel, Matthew Butler, and Kim Marriott. "" Hey Model!"–Natural User Interactions and Agency in Accessible Interactive 3D Models." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-13. 2020.
[63] Rituerto, Alejandro, Giovanni Fusco, and James M. Coughlan. "Towards a sign-based indoor navigation system for people with visual impairments." In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 287-288. 2016.
[64] Roy, Antony Rishin Mukkath, Ali Abdolrahmani, Ravi Kuber, and Stacy M. Branham. "Beyond being human: The (in) accessibility consequences of modeling VAPAs after human-human conversation." *Interactions 7* (2019): 5.
[65] Saha, Manaswi, Alexander J. Fiannaca, Melanie Kneisel, Edward Cutrell, and Meredith Ringel Morris. "Closing the Gap: Designing for the Last-Few-Meters Wayfinding Problem for People with Visual Impairments." In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 222-235. 2019.
[66] Saldaña, Johnny. The coding manual for qualitative researchers. Sage, 2015.
[67] Sato, Daisuke, Uran Oh, João Guerreiro, Dragan Ahmetovic, Kakuya Naito, Hironobu Takagi, Kris M. Kitani, and Chieko Asakawa. "NavCog3 in the wild: Large-scale blind indoor navigation assistant with semantic features." *ACM Transactions on Accessible Computing (TACCESS)* 12, no. 3 (2019): 1-30.
[68] Sato, Daisuke, Uran Oh, Kakuya Naito, Hironobu Takagi, Kris Kitani, and Chieko Asakawa. "Navcog3: An evaluation of a smartphone-based blind indoor navigation assistant with semantic features in a large-scale environment." In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 270-279. 2017.
[69] Schaffer, Stefan, and Norbert Reithinger. "Conversation is multimodal: thus conversational user interfaces should be as well." In *Proceedings of the 1st International Conference on Conversational User Interfaces,* pp. 1-3. 2019.
[70] Sears, Andrew, and Vicki Hanson. "Representing users in accessibility research." In *Proceedings of the SIGCHI conference on Human factors in computing systems,* pp. 2235-2238. 2011.
[71] Shinohara, Kristen, and Jacob O. Wobbrock. "In the shadow of misperception: assistive technology use and social interactions." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 705-714. 2011.
[72] Shinohara, Kristen. "Design for social accessibility: incorporating social factors in the design of accessible technologies." PhD diss., 2017.
[73] Stent, Amanda, Ann Syrdal, and Taniya Mishra. "On the intelligibility of fast synthesized speech for individuals with early-onset blindness." In *The proceedings of the 13th international ACM SIGACCESS conference on Computers and accessibility,* pp. 211-218. 2011.
[74] The A11Y Project. Accessed September 8, 2020. https://www.a11yproject.com/.
[75] Trajkova, Milka, and Aqueasha Martin-Hammond. "" Alexa is a Toy": Exploring Older Adults' Reasons for Using, Limiting, and Abandoning Echo." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-13. 2020.
[76] van der Bie, Joey, Christina Jaschinski, and Somaya Ben Allouch. "Sidewalk, a wayfinding message syntax for people with a visual impairment." In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 609-611. 2019.
[77] Vtyurina, Alexandra, Adam Fourney, Meredith Ringel Morris, Leah Findlater, and Ryen W. White. "Bridging screen readers and voice assistants for enhanced eyes-free web search." In *The World Wide Web Conference,* pp. 3590-3594. 2019.
[78] Vtyurina, Alexandra, Adam Fourney, Meredith Ringel Morris, Leah Findlater, and Ryen W. White. "VERSE: Bridging screen readers and voice assistants for enhanced eyes-free web search." In The 21st International ACM SIGACCESS Conference on Computers and Accessibility, pp. 414-426. 2019.
[79] Wang, Jinping, Hyun Yang, Ruosi Shao, Saeed Abdullah, and S. Shyam Sundar. "Alexa as Coach: Leveraging Smart Speakers to Build Social Agents that Reduce Public Speaking Anxiety." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-13. 2020.
[80] Waze. 2020. Accessed December 22, 2020 from https://www.waze.com/.
[81] Williams, Michele A., Amy Hurst, and Shaun K. Kane. "" Pray before you step out" describing personal and situational blind navigation behaviors." In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility,* pp. 1-8. 2013.
[82] Williams, Michele A., Caroline Galbraith, Shaun K. Kane, and Amy Hurst. "" just let the cane hit it" how the blind and sighted see navigation differently." In *Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility,* pp. 217-224. 2014.
[83] Winkler, Rainer, Sebastian Hobert, Antti Salovaara, Matthias Söllner, and Jan Marco Leimeister. "Sara, the lecturer: Improving learning in online education with a scaffolding-based conversational agent." In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* pp. 1-14. 2020.
[84] Wulf, Linda, Markus Garschall, Julia Himmelsbach, and Manfred Tscheligi. "Hands free-care free: elderly people taking advantage of speech-only interaction." In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational,* pp. 203-206. 2014.
[85] Yu, Christina, Howard Shane, Ralf W. Schlosser, Amanda O'Brien, Anna Allen, Jennifer Abramson, and Suzanne Flynn. "An exploratory study of speech-language pathologists using the Echo Show™ to deliver visual supports." *Advances in Neurodevelopmental Disorders* 2, no. 3 (2018): 286-292.
[86] Zhong, Yu, T. V. Raman, Casey Burkhardt, Fadi Biadsy, and Jeffrey P. Bigham. "JustSpeak: enabling universal voice control on Android." In *Proceedings of the 11th Web for All Conference*, pp. 1-4. 2014.