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Co-Designing Auditory Navigation Solutions for Traveling as a Blind Individual During the COVID-19 Pandemic

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Abstract

A group co-design was held in March 2021 with six blind and low-vision individuals (BLIs) from the United States. Participants were asked to discuss problems related to travel during the COVID-19 pandemic and make recommendations for possible solutions. Two probes (prototypes) of a non-visual neighborhood travel map and a non-visual COVID-19 choropleth map (a map using colors or sounds over each state to represent different values) of COVID-19 state data were shown to participants for inspiration. The participants expressed that COVID-19 had significantly increased their apprehension and discomfort associated with activities such as venturing outside, traveling, engaging with strangers, communicating, adapting to changes in familiar environments, and wearing masks. Participants gravitated towards the need for information the probes provided, and made a number of observations and recommendations for improvement. They wanted more detailed geo-referenced COVID-19 data (including by county), information related to voting, a mobile app, and more detailed building information, such as doors on the travel map.

Keywords

COVID-19, navigation, travel, map, choropleth

Disclaimer

This article was originally written in 2022, and references events that happened during 2022 as current. Although this paper is being published in 2024, the findings and discussion are still relevant. COVID-19 highlighted existing inequities in public and digital systems that require attention now, so that history does not repeat itself as other types of global and local disasters occur.

Introduction

COVID-19 has made traveling as a blind or low-vision individual (BLI) much riskier and more difficult than before. The need for social distancing and reduced touching of one's surroundings has a significant negative impact on the orientation and mobility skills of BLI travelers. As a result, people with visual impairments have limited their essential travel, reducing their overall quality of life. The pandemic has exacerbated the public and digital inequities faced by BLIs and it is critical that work be done to insure these inequities do not persist into the next global disaster. This is necessary in order to make resources more accessible to BLIs and to maintain their quality of life, health, and wellbeing.

Based on multiple mixed-methods research papers published on the impact of COVID-19 on BLIs, BLIs have reported significant limitations in excursion opportunities, restricting engagement in leisure activity, shopping for essentials, and health appointments. In May 2020, Sikirić and Fabac (2022) tested differences before and during the pandemic lockdown on 45 BLIs, and found a significant ($p = 0.01$) decline in independent everyday mobility before and during the COVID-19 lockdown. In an online survey, Gombas and Csakvari (2022) assessed the impact of the COVID-19 lockdown on 132 BLI participants. They measured access to shopping, daily support needs, access to remote studies of higher education or work, and leisure habits. Respondents accounted for negative impacts of the lockdown on their participation and independence in all research topics; issues of accessibility were common in both shopping for essential goods and access to remote study and work, negatively impacting their mental health. Difficulties buying essential products was reported by 57.9% of participants, and 22.7% of all respondents confirmed that they needed more help during the lockdown than in other times. Thomas et al. (2020) reported a 72% drop in age-related macular degeneration referrals in April 2020 compared to April 2019. This suggests that BLIs are staying home rather than attending essential doctor appointments as often as they did before the pandemic. Accessible COVID tests for BLIs came out in June 2022, two years after the pandemic began, which has limited travel for BLIs, and is a clear example of how the U.S. and U.K. governments still fund discriminatory design (Morris, 2022; United States Department of Health and Human Services, Administration for Community Living, 2022). The co-design presented in this paper asked a diverse set of six BLIs from the United States to discuss problems related to travel during the pandemic and make recommendations for possible solutions.

According to two large-scale surveys performed by the American Foundation for the Blind on behaviors and attitudes around the COVID-19 pandemic, BLIs are apprehensive when in public or using public amenities, and inaccessible data and social distancing restrictions increased social isolation and seclusion for BLIs (American Foundation for the Blind, 2022; Flatten Inaccessibility, 2020). In May 2020, a survey was conducted on 1,921 BLIs on perceptions and worries around COVID (Flatten Inaccessibility, 2020). The results showed that BLIs are concerned about taking vehicles with other people, getting to doctor's appointments, buying groceries and other key essentials, getting access to accurate and current information about COVID cases in an area, and asking someone for assistance or to be a guide. In 2021, a follow-up survey was conducted on 488 BLIs on their experiences one year into the pandemic (American Foundation for the Blind, 2022). Participants reported greater isolation, difficulty obtaining transportation, uncertainty around medical care and meals, limited access to COVID data, and difficulty around COVID testing. The U.S. Centers for Disease Control and Prevention (CDC) outlined a set of guidelines people should follow to stay safe and lower the spread of COVID-19 back in 2021, most of which relied on vision:

1. Maintain 6 feet of separation from other people.
2. Avoid people who do not live with you.
3. Look for physical barriers.
4. Look for visual reminders to stay 6 feet apart.
5. Don't share items or tools with other people.
6. Review the number of reported COVID-19 cases in your community.
7. Get vaccinated. (Centers for Disease Control and Prevention, 2020b).

Currently, in 2022, numbers 1 and 6 are still applicable and rely on vision. Social distancing is difficult for someone who is visually impaired, and is at odds with skills taught for orientation and mobility (O&M), such as asking strangers for directions and assistance (Wiener et al., 2014). Nicholas A. Giudice, a prominent blind accessibility researcher, wrote an article (Giudice, 2020) reacting to the CDC guidelines and explaining how the necessity of social distancing and limiting the standard practice of exploring his immediate environment by touch negatively impacted his life. Giudice (2020), Sikirić and Fabac (2022), Gombas and Csakvari (2022), and Flatten Inaccessibility (2020) present the overwhelming difficulty and discomfort faced by BLIs during the COVID-19 crisis.

BLIs are also not privy to the wide array of COVID data displayed on many online platforms, maps, and statistics tables, keeping them out of the loop on the most recent changes and trends. The current COVID information trackers for non-visual users such as Littlefield (2020) and Fusco (2020) only present numeric information in a textual table (Fusco [2020] also has a button to play a basic sonification of the incidence numbers over time), and only show COVID cases down to the state level. Visual maps have been very prevalent during the COVID-19 crisis, showing a choropleth of COVID cases (Centers for Disease Control and Prevention, 2020a; New York State Department of Health, 2020), and showing nearest testing sites (New York State Department of Health, 2020). These visual maps mostly lack non-visual information, but the few maps with some kind of text alternative fail to show the spatial relationships or geographic information of that COVID data (Centers for Disease Control and Prevention, 2020a). The CDC also explicitly asks people to view the spread of COVID cases in the community before going out, and a state-level table presentation of COVID cases is too coarse a granularity for traveling in the community, especially for large states such as Texas and California (Centers for Disease Control and Prevention, 2020b). County search boxes also only show one county at a time, which relies on BLIs already knowing the geography of their community, which is probably not the case due to the extremely limited map access and lack of geographic information BLIs have (Biggs, Pitcher-Cooper, et al., 2022; Biggs, Toth, Stockman, Coughlan, & Walker, 2022; Marston & Golledge, 2003). In the United States, section 508 and many state laws require that all digital information be equally accessible to people with disabilities (Discrimination, 1977; Level Access, n.d.-a, n.d.-b, n.d.-c, n.d.-d). The researchers wondered how BLIs perceived their access to accurate COVID-19 data or other COVID-related information, and how it affected attitudes and behaviors around travel both inside and outside one's local community.

One possible reason why the CDC and other government agencies have not yet added accessibility to the spatial elements of their website could be that research is minimal on non-visual maps. Zhao et al. (2008) presented the evaluation with seven BLIs of a prototype non-visual choropleth map, called iSonic, which showed population and disability statistics on U.S. states and counties. Their interface combined a tabular view that had the state as a row and the statistic as the columns. The geographic view was navigated using the arrow keys, where each press of an arrow key moved the cursor to a new state or county in that direction. Participants were very positive about the interface, and were able to answer basic spatial questions. Participants had 95% accuracy when answering spatial questions with iSonic, vs 20% accuracy with tables similar to what is shown on the CDC website. The main problem with this interface was that shapes were not accounted for. For example, California has two states to the east, so pressing the right arrow would have missed one of those states. The SAS graphics accelerator (SAS Institute Inc., 2020), follows a few of these conventions, but again does not show any kind of shape or complex spatial relationship between the features in the map. Neither of these projects can be reused to display COVID-19 data on the CDC website. Little to no research has been done since iSonic in 2008, and the BLI community is still unable to access critical spatial COVID and other geo-referenced data.

Self-Disclosure

This project was led by a BLI, and the team consisted of two other BLIs and three sighted individuals, two of whom have worked with BLIs for over 20 years. This project took many concepts from feminist human computer interaction (HCI), including co-creation, empathetic connection with participants, researcher disclosure, simultaneous commitment to scientific and moral objectivities, and reflexivity (Bardzell & Bardzell, 2011). The personal goal of the lead researcher in conducting this co-design was to highlight problems he faced during the COVID-19 pandemic, and to learn what connection other BLIs thought that maps, his main research focus, had to problems experienced during COVID. The findings in this co-design were not a surprise to the research team, and the discussion of shared isolation and constriction around travel that happened during this session felt cathartic. Both the BLIs on the project team and in the co-design were upset and wanted their voices to be heard by those in power, as human rights and disability justice did not seem important, especially during the early days of the pandemic response.

This project was also funded under a COVID supplement grant to investigate and develop map-related solutions to problems experienced by BLIs during COVID. This was the first main research project under the supplement. The findings were very relatable to the three BLIs on the research team, and many of the items highlighted in the discussion section were selected partly because they were viscerally relatable to the team.

Method

A group, remote, participatory design was conducted with six BLI participants and two BLI team members over a video conferencing platform. The research questions were:

1. What effect has COVID-19 had on the travel attitude and behavior of BLIs?
2. What co-designed solutions could increase travel and COVID-19 knowledge of BLIs?

Further discussion of the methods in this co-design were presented in Biggs, Siu, et al. (2022). Participatory design is a design method that allows users and other stakeholders to design a tool that will work for them, rather than an external team designing a tool that should work for the participants. The researcher asks questions to guide the design process, and at the end of the process, there is a basic specification for the proposed tool. If this process is repeated across several individuals or in a group, then commonalities between the specifications become apparent and inform the final design (Sanders & Stappers, 2008, 2014). Participatory design has successfully been used in similar projects with people with sensory impairments (Biggs, 2019; Biggs, Siu, et al., 2022; Hendriks et al., 2015). This co-design session was designed by and for BLIs to fully participate and contribute in the ideation and prototyping activities based on techniques from Metatla et al. (2015).

Six BLIs from around the United States remotely participated, presented in Table 1. Although the sample size of this study was small, it deeply explores areas highlighted in larger research projects, e.g., American Foundation for the Blind (2022), Flatten Inaccessibility (2020), and Gombas and Csakvari (2022). Six participants is also a standard size of a group co-design, as many more participants would have been difficult to manage (Biggs, Siu, et al., 2022). Future work of this nature should hold multiple co-designs of this size to increase the rigor of the results (Lavender et al., 2020). Additionally, all participants had experience traveling in both urban and rural environments, although there was a greater focus on urban environments. Some of these findings may not translate to very rural settings where delivery and ridesharing applications are limited.

Participants were selected using a convenience sampling technique, with careful attention given to balancing age and gender. Location was not controlled for in recruitment. There were three females and three males. There were two participants between the ages of 19-30, two participants between 31-65, and two participants over the age of 65. Three participants identified as white, two identified as Asian, and one had no response. Four participants were totally blind or with light perception, one could see shapes, and one had low vision. Two participants had read maps visually. There were two dog-guide users and four cane users. Three participants rated their independent traveling skill a 3, where 1 was terrible and 5 was fantastic, one participant rated a 4, and two rated a 5.

The co-design session lasted 3 hours and participants were compensated $30 an hour for their time. The project had institutional review board approval from the Smith-Kettlewell Eye Research Institute. The session took place over video conference and was recorded.

The entire session was independently coded by two of the authors using thematic analysis (Braun & Clarke, 2006). First, important quotes that summarize main points were written down from the session transcript to be "phrasal codes," e.g., "There is a difference from traveling to be somewhere and doing the travel to get there." Because this was meant to be a group co-design, codes were not associated with individual participants. During the session, the facilitator consciously attempted to call individually on participants who did not contribute to the discussion, but there may be a weighted bias for the more talkative participants. The codes were split into two groups: "Shared Experiences" and "Prototype Review," further presented in the results section. For the "Prototype Review" stage of the session, there was both verbal feedback during the session, and written feedback that was sent to the researcher over email after the session by half the participants. Initial intercoder reliability was 73.87% across the entire co-design. The coders reviewed and discussed codes and achieved a final intercoder reliability of 100% with 212 codes. The Shared Experiences section contained 102 codes, and the Prototype Review section contained 110 codes (57 for spoken and 53 for written).

Probes

Two probes, early prototypes of interactive non-visual auditory and text maps, were used to facilitate discussion of researcherdefined problems around navigation and information gathering by BLIs during the COVID-19 pandemic (Sanders & Stappers, 2014). The first probe simulated a neighborhood with roads and buildings. The idea was to play a sonification representing the level of foot traffic in a particular area so users could avoid that area. The probe did not incorporate busyness sounds, instead three example sound files were played before the session to garner participant feedback to see if they should be incorporated. The second probe map showed a choropleth of total COVID-19 cases overlaid onto the U.S. states. The idea was users could view hotspots around their current location before deciding to go out of their house or on trips. Participants were given a link where they could experience the interactive probes online using their own computer, screen reader, and browser. Both non-visual digital maps were based on the technology presented in Biggs, Coughlan, and Coppin (2019) and Biggs, Toth, Stockman, Coughlan, and Walker (2022) where users moved a character by pressing the up, down, left, and right arrow keys on the keyboard to move in the corresponding direction by a user-specified distance (similar to a video game). As they moved over features on the map, they heard speech through their screen reader announcing the name of the features they were on and a short sound representative of the feature, e.g., a pitch corresponding to COVID cases, or a footstep on a wood surface to represent a building. On the choropleth map, users pressed arrow keys to move 50 km each press. Each move to a new square played a pitch representing the number of COVID cases, along with the name of the state and number of cases announced in speech through the user's screen reader. The other map was a basic map of a neighborhood around the research facility. The buildings were taken from OpenStreetMap (OSM) and the roads were added by hand, because the OSM roads were lines and the system needed polygons (OpenStreetMap, 2020). The geometries were created in geojson.io (Mapbox, 2020). Participants navigated one meter at a time through the environment. Each feature was assigned a short sound and a name that would be played and spoken when the user moved over the object. Sounds representing features, such as clinking dishes for restaurants and cars driving on a road for roads, were looped and positioned around the map so users could hear them in spatial audio.

The probes were developed in JavaScript, using the web audio API and were either self-voicing or interfaced with the user's screen reader for all messages (Adenot et al., 2018). None of the probes were connected to live data, and were just meant to give users an idea of what may be possible, as BLIs often have limited access to data representations (Biggs, Pitcher-Cooper, & Coughlan, 2022; Butler et al., 2017; Marston & Golledge, 2003).

A link to view the choropleth probe is: https://www.youtube.com/watch?v=7u8KEoCgXKo

Co-Design Stages

The co-design consisted of four stages: (a) warmup, (b) reflect on Shared Experiences traveling during COVID, (c) concept review and prototype, and (d) prototype generation/review. All participants received a facilitation guide detailing tasks, estimated time, and relevant links to collaborative documents and the prototypes before the session. The warmup took 35 minutes and participants were placed into groups of two in breakout rooms where they got to know one another before being brought back to the main group to introduce their partner to the group. During the reflect on Shared Experiences traveling during COVID stage that took 45 minutes, the group was asked to reflect on how COVID had affected their traveling in activities such as shopping, traveling to a new location, walking along the sidewalk, and using public transportation—all activities of high concern to BLIs (Flatten Inaccessibility, 2020). During this stage, notes were taken by the facilitator in a shared document. For the concept review and prototype stage that took 65 minutes, participants were first asked to visit a link to review the COVID-19 choropleth map; then, after everyone had a chance to get familiar with the concept, they moved on to the travel map example. The facilitator performed both technical troubleshooting and instructed users how to navigate the maps. Finally, the prototype generation stage took 25 minutes and consisted of participants offering ideas for prototypes that could potentially help with concepts in the shared experiences. All of the activities took longer than expected, leading to the final stage being shorter than desired.

Results

The entire codebook can be found at: https://www.openicpsr.org/openicpsr/project/193186/version/V1/view

See Table 2: Code Counts

The six participants started by discussing their experiences on how their travel practices have changed since the COVID-19 pandemic. The themes were split into two sections: (a) shared experiences and (b) prototype feedback. The main themes within the shared experiences section were: social barriers, outdoor travel experiences, and fears. The most prevalent themes within the prototype feedback were: busy sound feedback, feature request, mobile app, and liked.

Shared Experiences

Social Barriers

Sixty-one out of 102 codes in the shared experiences section of the study indicated that the most pressing theme involved surmounting social barriers, which catalyzed as a result of societal miseducation and inadequate tools to assist BLIs when in public. Despite the dire need for social distance, 21 of these 61 codes highlighted how BLIs experienced trouble distancing during the pandemic when they needed to gauge the 6-feet social-distancing requirement. This caused heightened levels of self-consciousness and self-criticism, especially in high-trafficked areas, such as shopping lines: "The way shopping lines are set up make shopping extremely difficult for BLIs." This sentiment by one of the participants, and echoed by many others, framed the feelings of anxiety around travel, particularly around not wanting to contract the COVID-19 virus. With the mask and social distancing mandates, participants stated echolocation was dampened and canes were too short to be beneficial in social distancing. While it is possible for

BLIs to understand the dynamics of the social setting they are in, it requires a higher level of cognizance, which may become draining, especially for mundane tasks such as grocery shopping.

Physical Barriers and Outdoor Travel Experiences

None of the participants had independently traveled to a new location since the pandemic began, despite being frequent travelers before, as shared in the shared experiences part of the study. Ten out of 102 codes were grouped into a theme titled "the inconvenience of travel," which detailed how BLIs stuck to areas they were familiar with and how they felt unable to explore new locations. Participants described the desire to be in an area that was socially distanced and safe, but when in need of assistance, communication was increasingly difficult. A participant stated, "I have a terrible time communicating with people behind plexiglass." This experience around plexiglass barriers was unanimous, and one participant concluded, "I hope these barriers are not something that will stick around forever." In three codes, participants described avoiding subways and public transportation, and how that has had a significant negative impact on quality of life, simply because public transit is how BLIs get around (Wiener et al., 2014). But even within one's community, participants kept to their known locations. The result of these frequent and negative interactions has encouraged the participants to use delivery apps for food, groceries, or other goods, decreasing the number of trips the participants took out of the house.

Fears

Seven of 102 codes discuss how communication barriers; the lack of employee training (particularly in retail); and discomfort in interpersonal interaction, which is critical for some BLIs; have forced many BLIs to harbor feelings of fear when it comes to the need for them to reach out for help. For many BLIs, shopping in person is not only inconvenient, but fearful, as asking for and receiving help is much more taxing. One participant described the experience of having to overcome judgements of others before going up to people to ask for help: "We have seen people go from being willing to help during lockdown, to walking past when you asked for help;" "Maybe you have a briefing from the sighted people and you have to just wing it and use assistance and just be bold." As a result of these adverse experiences, many BLIs have had to go without asking for help, which has kept them from traveling to new places independently.

Busy Sound

After sharing pandemic experiences, a set of three sounds to indicate busyness-level of streets on the travel map were played to solicit participant feedback before implementation. Five codes critiqued the current system's sound and suggested changing the sounds to better emulate the natural environment when traveling in public. The sounds were described as being too busy, inaccurate, and/or loud.

Probe Review

After giving their feedback on the busy sounds, participants were shown the two probes and were then asked to think about how they would solve some of the problems outlined in the Shared Experiences using the probes. The first probe was a choropleth map and the second was the travel map. Participants focused mostly on how they would want to incorporate the probes into their life and provided an unprompted review of what they liked, disliked, and wanted to see in the probes. Their responses are broken up in two sections below with a total of 110 codes.

Choropleth Map: Sound Feedback

While the choropleth map provided useful COVID data, participants thought the way in which the sound communicated data left much to be desired. In the choropleth map, two participants suggested that sounds should allow the user to change or remove them: "I didn't care for the cello sounds. I thought they were too invasive…I was wondering if there was a way to choose a different sound." Thirteen of 110 codes indicate that some users were unable to tell the difference between notes representing different values.

Choropleth Map: Feature Request and Wants

Of the 32 codes discussing feature requests and wants on the choropleth map, 12 "Feature Request" codes mentioned participants wanting to see more up-to-date COVID data that was particular to smaller geographical areas (such as counties or cities), and focusing on one variant: "Especially now with the variant, if you can show folks the number cases by variant [that would be helpful]" in order to see sudden spikes in cases and better plan for the future. With a more detailed choropleth map, three codes detail the desire for participants to be able to look at a county and see the COVID statistics or public transportation routes. Political data and congressional districts were another point of interest for several participants. Five codes expressed users' desire for showing the political party or representation of a particular district. The map could show the demographic makeup of that location while also showing the way counties are gerrymandered. Others requested an overlay feature where the choropleth and travel maps could be combined so users could see clustering of cases on the travel map. "You could start with one map and overlay the other map on top… I want to see, while I'm in a neighborhood, what the COVID data is for that neighborhood." One code suggested an overlay feature where the choropleth maps could be combined so users could see clustering of cases on the travel map.

Choropleth Map: Liked

Twenty-eight of 110 codes reported general appreciation for the choropleth map. One participant described, "this is an audio graphical presentation as opposed to words. You can take in a lot of information quickly." Another participant commented, "during the first lockdown, I would have loved something like the heat map." When talking about sounds versus text that were both available in the prototype, one statement succinctly summarized the general sentiment: "The pitches show information very similar to how a graphic would show it, they give a general sense of what the data is saying, but if you want detailed information, you need to go to the numbers." The prototype presented a pitch representing the value, and pressing a key command gave the exact value in speech, allowing both a general overview and exact number to be ascertained.

Travel Map: Feature Request and Wants

Twelve of 44 "feature request" and "wants" codes stated that users wanted changes to be made that would improve overall accessibility for its users. The data for the travel map, sourced from OpenStreetMap, offered limited details. Consequently, there was a general agreement that the information should more accurately reflect real-world conditions and options that users encounter when they are out on the streets. This way, they could have more realistic expectations of the nature of the locations they will be traveling to, e.g., sidewalk and doorway information: "The ability to see the broad picture [of what is communicated by a travel map] internally and learn with sounds needs to be integrated or else it [the map] is useless." As emphasized in one code, the ability to zoom in and out of areas on a macro or micro scale would better allow users to get the overview of the location they plan to travel to, reducing room for error or unanticipated surprises.

Travel Map: Mobile App

The piece that garnered a significant amount of discussion with 18 codes was viewing the COVID data and travel information on a mobile app, rather than on the computer. Participants emphasized the importance of the development of a mobile app to make travel easier on the go. Two codes suggested the temporal tracking would be helpful in determining the travel time to specific locations based on the street congestion: "I think that you could also show a third dimension to this, and have it be time. Then you could move through the map through space and time." In three codes, BLIs expressed concerns about the accessibility of the travel map with deafblind people. When in loud areas, it would be difficult to hear the notifications over the screen reader, so the use of vibrations should be implemented into the travel map to communicate different information that could be interpreted by both blind and deafblind individuals. Five codes described a touchscreen experience where the user could move their finger and change the scale of a location, and also jump to different geographical locations, which would make spontaneous travel more feasible. Seven codes shed light on an important point communicated, which was that the travel map needs to be available both in public while users are on the go and at home, in order to give users the option to be as engaged with the system as they desire.

Travel Map: Liked

Despite the criticisms of the choropleth map, there was an overwhelming gratitude for the travel map, as it was able to give BLIs access to information that they were not previously privy to, as discussed in 39 "liked" codes. Four codes highlighted how the 3D-style format provided a lens for BLIs to sense their surroundings more accurately than existing travel applications. Besides the few remarks on the levels of noise from the travel map, most participants appreciated the ability to interact with their surroundings while being able to pick up their coordinates and local activity: "[With the street view, I like] the different sounds [i.e., clicking, wood, swooshing]." In five codes, participants appreciated how there was an accessible menu that gave users options of where they wanted to travel, which provides an ease of use that is uncommon in other travel apps. Indicated by 12 codes, participants stated that this was the first time they were able to virtually navigate the world with such an immersive and informed experience that mimicked the real world, suggesting a tool like this would give them greater confidence while traveling.

Discussion

Social Barriers

The COVID-19 pandemic proved to be a period where extra precautions needed to be taken by everyone, particularly around social distancing to curb the spread of the virus. However in developing and enforcing COVID protocols, BLIs' experiences were not taken into account by their respective governments and businesses, especially around communicating new protocols and the design of protection measures. Although not explicitly explored in this study, it is important to point out that experiences of BLIs are not homogeneous; they not only possess personal goals and aspirations, but they are also parents, family members, and carers who are responsible for the support and protection of others. Therefore, it is important to note issues that were brought up by BLIs in this study may impact blind individuals and families alike, especially when partners are both BLIs. When mundane tasks such as grocery shopping have their physical environment changed, BLIs need to relearn the environment, which generally happens with an orientation and mobility instructor. This takes time, mental effort, money, and generally impedes autonomy and fortifies barriers that continue to marginalize them (Wiener et al., 2014). Asking strangers for help is one of the most important parts of orientation and mobility for BLIs, and when strangers ignore or refuse to help, it can leave the BLI disoriented. Agent-facilitated navigation applications are useful to some extent, but they entail significant disruption to navigation, require a hand to use, and can sometimes be dangerous, as the phone is prominently visible. The signage in most public spaces indicating to keep 6 feet apart was completely inaccessible, which created negative interactions between BLIs and other individuals in lines at the grocery store, for example. With environments completely changed, BLIs were forced to interact with strangers to navigate once familiar spaces, despite the hesitation on both sides. If some kind of tactile marker on the floor could have been used to designate the 6-feet distancing requirement, that would have been more inclusive. Apps are being made to allow BLIs to judge the distance to another person, but they are relatively new and require modern hardware (Coldewey, 2020; Lee et al., 2021). One possibility why spaces did not have a tactile element was because of the possible tripping hazard. This means that tactile tiles that have minimal tripping danger need to be created. Similarly, most businesses had no accessible signage infrastructure to indicate traffic patterns. Indoor navigation tools, such as auditory maps and turn-by-turn navigation systems, e.g., Goodmaps, should have been utilized to make signage accessible (Goodmaps, n.d.).

Physical Barriers

Though the implementation of plexiglass was made to reduce the spread of the virus, the lack of consideration for communication was apparent, despite the critical verbal communication needed in those environments. Instead of having BLIs shout through the glass, technologies such as intercom systems, used by many banks, should have been used. The difficulty of communicating with cashiers, gate guards, and other hospitality personnel significantly diminished the experience of BLIs in these spaces, making them undesirable destinations.

Opportunities and Challenges Caused by Remote Participation Tools

The ability to work remotely from home has greatly increased opportunities for BLIs, but challenges around exercise, traveling, and socializing have been exacerbated. Since BLIs are a low-incidence population, it is unlikely research or high-quality job opportunities will surface where a BLI is physically located. The paper authors live in multiple states, collaborate over video conferencing, and use collaboration tools, e.g., shared documents, which are accessible enough for BLIs to use professionally. This study is an example of how BLIs from around the world can also now collaborate in relevant co-designs and research, as further described in Biggs, Siu, et al. (2022). BLIs can also stay in places they know, reducing the cognitive load of moving and learning a new neighborhood, keep their existing support network and community, and use their own tools in a comfortable space rather than worrying about traveling to the office, using a computer configured by a company with limited knowledge of accessibility, or worrying about looking different. These benefits have also worked to further isolate BLIs from socializing and going out. It is difficult to hold side conversations and have spontaneous interactions when using video conferencing platforms (Rosedale, 2020). Virtual reality (VR) conferencing platforms do allow side conversations and serendipitous encounters, but are largely inaccessible to BLIs (Entry, ND; Maloney et al., 2020; Tanenbaum et al., 2020). The result of BLIs being able to participate digitally in the workplace is that physical travel is reduced, which was also compounded by the COVID-19 pandemic. The proliferation of delivery applications mean that BLIs can spend months independently living and working indoors with no meaningful physical human contact, which is unhealthy (Twohig-Bennett & Jones, 2018). Focus needs to be given to making outdoor experiences more desirable and safe to encourage BLIs to leave the house.

Access to Geographic Data

Participants commented that the lack of access to geographic information (e.g., COVID statistics, political maps, public transit, and detailed travel route information) significantly hampered their quality of life and access was greatly desired, which is similar to the experience of BLI participants in Biggs, Pitcher-Cooper, and Coughlan (2022) who increased their map usage from less than one to over 20 a year when inexpensive tactile neighborhood maps were made available. A BLI contact tracer in Biggs, Toth, Stockman, Coughlan, and Walker (2022) was unable to tell callers COVID-19 trends when asked, unlike their sighted colleagues, and participants wanted to view what a gerrymandered districting map looked like. Critical information from governments and news agencies, e.g., evacuation maps for hurricanes and fires (Cal Fire, 2019), disease data (Centers for Disease Control and Prevention, 2020a), legal jurisdictions (Doucleff, 2022), flood maps (Staletovich et al., 2022), and war maps (Sullivan, 2022) are ubiquitous, and no geographic information is provided in a non-visual format. With the political and climate instability around the world, maps have become crucial methods of communicating geographic data, and BLIs are excluded from these vital, often lifesaving, conversations.

Although BLIs found the map probes encouraging, participants wanted a mobile app they could use anywhere. The primary purpose of the maps was originally to be a pre-trip planning tool that could be used at home before embarking on a trip, but as participants in this co-design and other evaluations of these maps have stated, they want to use a map while traveling (Biggs et al., 2019; Biggs, Toth, Stockman, Coughlan, & Walker, 2022). To facilitate this usage, further evaluation needs to be performed on how, when, and why BLIs would use these maps while on route.

Participants brainstormed ideas to allow deafblind users to understand information from these map probes that consisted of vibrations. Another co-design with deafblind users needs to be performed, but it is more likely that a combination of braille display and vibration will be needed to communicate more complex concepts on the geographic non-visual map. BLIs in Biggs (2019) described their ideal navigational solution to be a dynamic, 3D, tactile hologram map, which would be more user-friendly than a braille display and vibrations, but is still beyond technical capability.

Several participants commented that the cello sound in the heatmap was unpleasant, and these comments are similar to other studies where different sounds were compared in an interactive sonification and pure sine tones were preferred (Mascetti et al., 2017). When Biggs, Toth, Stockman, Coughlan, and Walker (2022) replaced the cello sound with a procedurally generated grouping of several pure tones, including sine and square tones, participants made no comment on the sounds, and were able to use them effectively. One possibility for the desire to move away from music, instrumental, or other noise-based sounds and towards more pure tones is possibly because of the pitch accuracy purer tones convey. Utilitarian interactive sonifications should consider creating a simple synthesizer that is not unpleasant, like a pure sine tone, but is not as rich as a cello.

Implications for Practitioners and Families

These last 2 years have highlighted the critical importance of technology usage in all aspects of life. Practitioners should keep up to date on technology trends for indoor navigation tools and applications that can help social distancing and other navigation requirements during major emergencies, e.g., the COVID-19 pandemic. Learning technology, in particular screen readers, is critical for BLIs to maximize their opportunities working remotely, and independently shopping on delivery apps. Much of the focus in O&M

training has been how to get to the store, workplace, and school. Although this is still important, it’s less so now, as trips to these locations may be few and far between. Instead, focus should be shifted to exercise and motivation to leave the house.

Navigation and other geographic tools e.g., Goodmaps (n.d.) and Biggs, Toth, Stockman, Tupy, et al. (2022), are transforming access to geographic information. Digital non-visual maps, such as Audiom, should be considered when teaching BLI students geography, during O&M training, and when using data science maps. Tools like Goodmaps should be considered when teaching BLIs to navigate indoor spaces. Additionally, advocacy by parents, professionals, and BLIs should be performed both at schools and other locations BLIs navigate, to support inclusive navigation tools like Goodmaps and Audiom.

Implications for Government Officials and Policy Makers

Until now, BLIs have not been part of the geographic information system community. Accessible alternatives have been tables, nearby-address search boxes, alternate text, and turn-by-turn navigation systems, which primarily exclude the geographic information critical in maps (Biggs, Toth, Stockman, Coughlan, & Walker, 2022; Giudice, 2018; Sloan, 2020). As demonstrated by BLIs in this study and others, digital non-visual maps have the potential to increase greatly the accessibility of jobs related to data, political participation, and navigation (Biggs, Toth, Stockman, Coughlan, & Walker, 2022; Loeliger & Stockman, 2014; Zhao et al., 2008). Funding should be allocated for more research and development in non-visual digital geographic accessibility, and agencies should consider implementing an auditory and text non-visual map viewer like Audiom into their currently inaccessible digital geographic materials. Digital non-visual maps are now the “technically accessible” alternative to visual maps, and “best meets” exceptions for maps, such as tables, turn-by-turn directions, alternate text, and nearby address searches are no longer eligible under Section 508 (General Services Administration, n.d.-a). Participants pointed to the CDC COVID-19 maps (Centers for Disease Control and Prevention, 2020a), public transportation information, congressional district maps (Bureau, 2021a), and demographic maps (Bureau, 2021b) as particularly inaccessible. Geo-referenced COVID-19 information communicated by the government is not yet equally accessible to BLIs, despite it being critical health data. More generally, the onset of national or international emergencies, or major fast-moving events, tend to promote the use of predominantly visual information. What is needed is infrastructure that can be leveraged to render this information in a non-visual accessible form, not least because oftentimes data is so fast moving, people are too occupied with their own concerns to address the problem at hand. Once BLIs can access geographic information, they will be able to push for detailed data sets with critical information to BLIs, such as doors and sidewalks.

As described by the participants in this study, the voices of BLIs were not brought to the table or considered when COVID-19 protocols were developed. The rollout of many of the COVID-19 safety measures were clearly not in consultation with the U.S. Access Board or other disability advocacy groups. The COVID-19 tests that were purchased by the U.S. government were originally inaccessible for blind individuals to operate, both in professional testing settings and at home (United States Department of Health and Human Services, Administration for Community Living, 2022). When creating guidelines and recommendations for businesses to make safe settings for their employees, co-designs need to be performed with individuals from diverse backgrounds, who may be negatively impacted by different recommendations and guidelines, so that issues can be identified and tackled from the start. The results of the Flatten Inaccessibility survey highlighted, early on in the pandemic, many of the problems faced by BLIs, but limited guidance was provided to businesses and government agencies to minimize or fix these problems (Flatten Inaccessibility, 2020). The techniques, tools, and data were there for policy makers to consult, but this information was not utilized enough to reduce appreciably the negative impact of health safety measures on BLIs.

It is important to note that although much of the criticism of this paper is focused on the U.S. government, other countries similarly failed in their responsibility to protect BLIs from negative impacts. For example, it was the United States that funded the first accessible COVID tests in the world, and the BLI researchers personally experienced many of the same challenges posed by BLI participants in this study in European countries and in the United Kingdom. BLIs and other people with disabilities need to be part of the governmental response to emergencies and not be relegated to a low priority.

Conclusion

COVID-19 has had a dramatic negative impact on the traveling behavior of BLIs, but much of the impact stems from inaccessibility and conflicting guidance from the CDC with critical O&M behavior. Public transportation and ridesharing are the only methods of independent transportation for BLIs until fully autonomous vehicles arrive, so priority needs to be placed on making this form of transportation as inexpensive and safe as possible. All governments must bring BLIs in as co-designers to contribute as equal members in the emergency response process. Digital data also needs to be made accessible, especially when life or death health risks are being wagered on if it is safe to step out of the door. COVID-19 has brought to light systemic inequities that need to be fixed as soon as possible in both the physical and digital world. Further work on the map probes can be found in Biggs, Toth, Stockman, Coughlan, and Walker (2022) and later iterations of the non-visual maps can be experienced at Audiom (XR Navigation, 2021).

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Conflict of Interest Statement

Brandon Biggs is the chief executive officer and co-founder, and Christopher Toth is the chief technology officer and co-founder of

XR Navigation, a company commercializing Audiom, the platform powering the probes used in this study.

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Table 1

Participants

Participant ID	Age	Hispanic or Latino?	Racial category	Gender	Vision level	Ever read maps visually?	Travel aid	Independent traveling skill
P1	29	No	Asian	Female	See shapes	No	Dog guide	5
P2	82			Male	Totally blind	Yes	Cane	5
P3	19	No	Asian	Male	Totally blind	No	Cane	3
P4	43	No	Asian	Female	Totally blind	No	Dog guide	3
P5	74	No	White	Male	Light perception	No	Cane	4
P6	65	No	White	Female	Low vision	Yes	Cane	3

Table 2

Code Counts

Categories	Count categories	Theme	Count theme
Having trouble distancing during pandemic	21	Social barriers	62
Display more detailed data	18	Feature request	44
Ease of use	14	Liked	29
Change sound	13	Mobile app	18
Mask problems	13	Physical barriers	12
Enhance navigation experience	10	Disliked	10
Improve accessibility	10	Busy sound feedback	7
The inconvenience of travel	10	Wants	7
Use of travel during the pandemic	10	Outdoor travel experiences	6
Not enough data	9	Using social cues	6