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Perspectives

COVID-19 and Visual Disability: Can't Look and Now Don't Touch

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Perspective

The coronavirus disease 19 (COVID-19) pandemic has created cataclysmic repercussions in virtually every facet of life and has had profound effects on the practice of medicine. This is particularly true for providers who treat disability. Although all disabilities are unquestionably challenged in undue ways, this perspective is meant to draw special attention to those with visual impairment. COVID-19 is extremely contagious and has spread globally with unprecedented rapidity. The best current countermeasures include personal protective equipment (PPE), social distancing, and minimizing or avoiding touch or contact with surfaces and/or objects that may be contaminated with viral particles, all of which pose unique challenges for those with low or no vision. Co-authors Rizzo and Giudice, themselves visually impaired, are researchers who are investigating creative innovation to combat the untoward consequences of visual impairment, However, this situation transcends their professional interests, as it has directly affected their lives and the lives of other blind individuals close to them. This essay builds on the combination of their personal experiences and research expertise to motivate the current problem and pose some viable solutions.

When you cannot see what is around you, touch becomes the primary mode of both exploring and interacting with the environment. We rely on touch to support many tasks throughout the day, whether it be the movement of the keys as we type on our computer, the warmth and heft we feel as we pick up our morning mug of coffee, or the texture of our clothes. However, for blind and visually impaired (BVI) people, the sense of touch and use of haptics (ie, information that is perceived through active touch) transcends these "normal" uses of this modality. For this community, touch perception supports many of the same tasks that sighted people perform on the basis of visual perception. Although hearing and touch represent the principal modes of nonvisual sensing, touch and vision share the ability to accurately convey spatial information. Despite touch having a much smaller "tactile field of view" and lower sensory bandwidth capacity than vision, a growing body of evidence suggests that spatial information learned from both modalities develops into an amodal "spatial image" in the brain that functions equivalently in the service of action, irrespective of the input source.[1]

This functional equivalence (ie, statistically indistinguishable performance) between touch and vision has been demonstrated for a broad range of spatial behaviors.[2] Neuroscientific evidence also corroborates this notion because the same expert processing region of the brain, the parahippocampal place area (PPA), has been found to be preferentially involved during functional magnetic resonance imaging (fMRI) in the computation of spatial layouts learned through haptic and visual perception.[3] This study also found no difference in the pattern of neural activation between blind and sighted participants on the haptic tasks, which agrees with other neuroimaging research studying haptic spatial processing in "expert" brain regions between blind and sighted participants.[3-5] In aggregate, the evidence showing similarity of behavior after haptic and visual learning and common neural networks underlying spatial computations between blind and sighted individuals provides converging support for the similarity of these senses in the encoding and processing of spatial information, irrespective of visual experience.[3-5] One may think of spatial information as the "common denominator" of the senses, with haptic and visual inputs informing us about a common physical space (ie, our perception of the surrounding world).

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An important consequence of this sensory similarity is that BVI people rely far more heavily on their sense of touch to support spatial tasks than their sighted peers. These tasks may be small-scale, for example, exploring what is on a table, or large-scale, for example, navigating to work. Given the ubiquity of touch for BVI individuals, pandemic-related concerns around touch and the need to minimize contact with other people and public-facing surfaces impose significant challenges. Some of these COVID-19–related difficulties have been discussed previously,[6] but the impacts of the coronavirus on spatial awareness and spatial behaviors by BVI people are still poorly understood.

Given the importance of nonvisual spatial perception for this community, especially on the basis of touch, and that safe and efficient travel is critical for independence, any barrier represents a serious threat to the lives of millions of BVI people. Our focus here is on how COVID-19 limitations on touch and physical contact have led to unintended yet significant challenges to spatial perception, interpretation, and behavior for BVI individuals. These issues can be considered through the lens of spatial cognition, which is a broad field of interdisciplinary research that encompasses the knowledge and beliefs people have about the spatial properties of objects and events in the world, the manner that they explicitly acquire, mentally represent, and act upon this knowledge, and the spatial supports (eg, maps, simulations, language) used to represent spatial information.[7,8] A significant component of what supports spatiocognitive activities performed without vision is touch. Obvious applications of touch to environmental awareness and spatial cognition include detecting and identifying objects and localizing key features in the environment (eg, doorknobs, railings, and so on).[9] However, touch is also an important input for directly supporting safe and efficient navigation. For instance, BVI people may use their long cane or foot to track the edge of a sidewalk, the feel of the tactile domes at an intersection to correctly orient when crossing the street, the feel of a distinct brick wall as a landmark, and myriad other tactile cues to maintain accurate orientation and safe navigation.[10,11] Success in these endeavors inevitably involves physical contact with many environmental elements and frequent proximity to other pedestrians.[12]

For BVI people, following appropriate social distancing behavior is particularly challenging because nonvisual sensing is not conducive to accurate detection or maintenance of a fixed 6-foot separation or an egocentric geofence. In most cases, BVI people are within this "bubble" when using their long cane and the ability to maintain any type of fixed boundary is inconsistent at best. Although the cane affords a traveler with the ability to swipe in a circle, thereby providing a "bubble of protection," doing so is highly impractical. In normal use, the cane is used only as a forward-facing "probe," with its field of view limited to an arc sweep of 90° to 100°, within a 3- to 5-foot range.[13] Empirical data support that cane use is based on inconsistent sampling from this limited forward-facing region during travel.[13] If dog guides are used, there is no training in place to maintain this separation. Indeed, service dogs are trained to utilize all possible space when guiding, meaning that they will often bring their handler within 1 or 2 feet of a passerby, especially when navigating in busy or crowded situations. The net result is that BVI travelers will generally, albeit unintentionally, end up much closer to surrounding pedestrians than their sighted peers, especially when navigating on busy streets, subway platforms, line queues, and so on.

The following illustration may help elucidate some COVID-19–related navigation and spatial cognition challenges experienced by BVI people. Caitlin decides to walk to the nearby convenience store with her dog guide Sam. When she reaches the store, she identifies the handle by touch (with exposure regret) and goes inside. As she walks to the cooler in the back of the store, she inadvertently goes the "wrong" direction down the aisle as she cannot see (and is therefore completely unaware of) the newly demarcated directional arrows on the floor. Upon reaching the cooler, she feels for its handle (by necessity yet again) and then inside to find her beverage of choice, which she can recognize by the unique shape of the bottles. Approaching the check-out line, she is unable to see the floor markers indicating correct spatial separation and thus ends up much closer than she intends to a customer who is standing silently at the register who brusquely requests that she back off and stay behind the indicator, which she has no way of detecting. When making her purchase, she must touch the Plexiglas safety barrier that has been newly erected on the previously unobstructed counter to isolate the open area to place her 6-pack (an obvious massive exposure risk given the throughput of customers at this common point of purchase). Finally, as she reaches for her change, her hand makes inadvertent contact with the salesclerk's hand.

Normally, most of these instances of physical contact, proximity, and movement behavior are everyday occurrences as a BVI person interacts with their world and are neither noteworthy nor problematic. However, in the coronavirus environment, many of these activities are potentially dangerous and put both Caitlin and those around her at greater risk. Her journey to the store is navigated primarily through touch and exploration with the hand. Although a sighted person may engage the door with an elbow (lowering risk), this is not practical if you cannot see where the handle is. Thus the hand is generally the most efficient and practical effector for supporting such behaviors, which makes sense as it is also one of the body regions with the highest tactile acuity.[14,15] However, it is precisely these types of public surfaces that are most likely to be vectors of COVID-19 and what people are advised to avoid contacting. That advice, although well intentioned and of little consequence to most sighted people, is not practical for BVI people. One solution is to wear gloves, which would allow for touching without direct skin contact. However, gloves represent a barrier between the skin and external stimulus, and such intervening materials can result in changes to tactile perception.[16] Gloves may mask what is being felt and reduce tactile sensitivity, especially for discriminating high-resolution stimuli (ie, trying to read braille with gloves). Even for more general tasks, such as Caitlin experienced, most BVI people find gloves to be very distracting and disruptive to tactile perception, somewhat analogous to a sighted person walking around the world while wearing a pair of blur glasses or operating in a dense fog. Normally, instances of accidental contact, such as touching a salesclerk's hand or bumping into somebody in a line, are not problematic; a simple "excuse me" suffices. However, in the COVID-19 world, this type of accidental physical contact is frequently met with concern, fear, and sometimes hostility.

Given that increased reliance on touch and inadvertent physical contact with others is the reality for BVI people, and that gloves are not a practical solution for this community to mitigate coronavirus health risks, one alternative is to use a large amount of hand sanitizer or to frequently wash the hands to maintain hygiene.[17] However, this solution also presents challenges, as these methods when repeatedly deployed in short time windows lead to chapped finger pads that also limit sensitivity. It is analogous to the classic finger pruning that occurs when we spent too long in the bath as a child or take a few too many laps in the swimming pool. Indeed, even repeated, short duration exposure to water can negatively impact skin sensitivity.[18]

As BVI people will continue to use touch to experience their world, and the need to reduce physical contact will continue as an important form of coronavirus risk mitigation, a viable solution must be able to support both of these needs. There is a range of such solutions that could assist BVI people in the present situation. One obvious solution is to avoid exposure and increase isolation compensated by more services. Although this is potentially viable, it is not practical. Services are finite and unfortunately compromised in the present pandemic state, and like their sighted peers, BVI individuals are anxious to once again be able to go outside, walk around their neighborhood, and exercise agency over their life. A second solution is for BVI people to rely on a close contact with whom they already have exposure. This person could serve as a sighted guide when required, assist with getting groceries, or provide sighted assistance when needed during these unprecedented times. Although this approach could work in theory, it also is impractical as it means a BVI person must wait until their friend or family member is available, which is antithetical to independence because the process fosters reliance on others. The third and most promising solution employs the use of technological tools, called assistive technologies (ATs).

Throughout the last century, the long cane and dog guide continue to be the most commonly used tools for mobility.[19,20] However, limitations of these traditional ATs, such as their small range of operation and limited field of view, has led to the development of many electronic ATs and travel aids (ETAs).[21] Although these devices are often separated into those that help avoid hazards or that assist in orientation, the key features of a comprehensive AT solution are: (1) detecting obstacles in the travel path, (2) identifying travel surface information including texture and elevation discontinuities, (3) detecting objects bordering the travel path, (4) identifying distant objects and cardinal directions, (5) identifying landmark locations, and (6) providing sufficient spatial information to enable familiarity and mental mapping.[22] In our current era of self-driving vehicles and

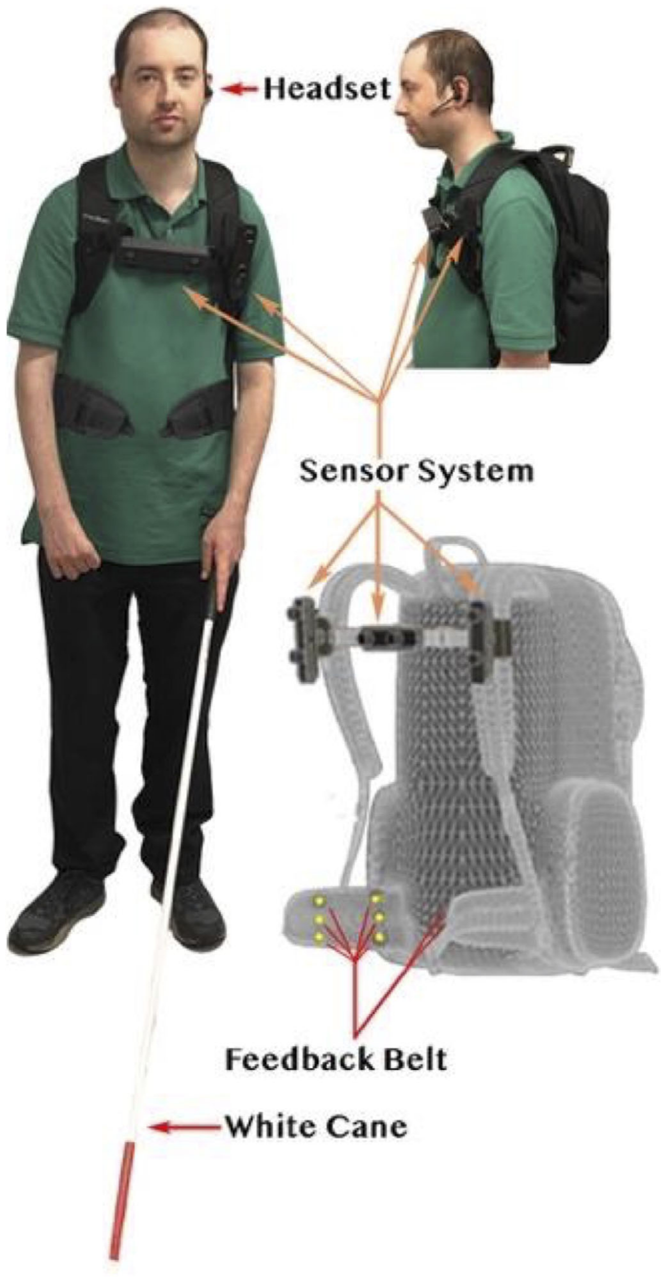

Figure 1. Proposed four-component mobility platform.

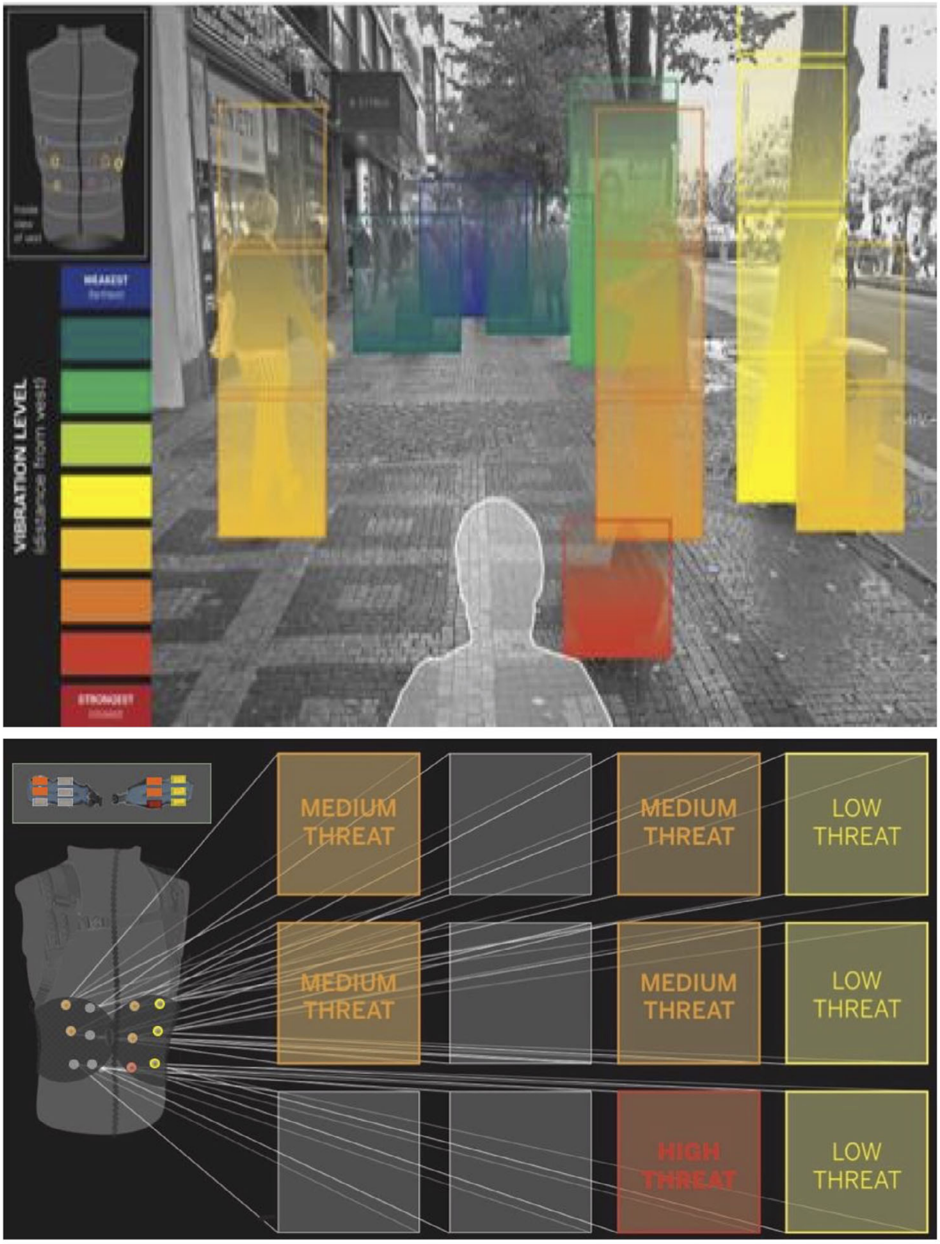

Figure 2. (Top) A simulated view of a scene decomposed into capture fields that spatiotopically correspond to actuators in the haptic interface. (Bottom) Color-coded depiction demonstrating the scene decomposed into a segmented grid for belt-based vibratory warnings of various threat level based on proximity and spatial position.

automated route mapping, there is clear need to move beyond the long cane or dog guide used in conjunction with a potpourri of limited-use gadgets, aids, and apps. What is required is a paradigm shift focused on developing comprehensive tools that make safe mobility a reality for BVI travelers and that augment the existing primary mobility solutions with useful AT that provides complementary information supporting robust spatial awareness and cognition. One such platform is the **VIS^{4}ION** system (Visually Impaired Smart Service System for Spatial Intelligence and Onboard Navigation). This platform (Figure 1) provides real-time situational and obstacle awareness in one's immediate environment, allowing individuals with visual impairment to travel more safely in three-dimensional (3D) space. VIS^{4}ION remedies some of the cane's shortcomings, and further augments the ability of BVI persons to both maintain balance and to localize objects in their environment.[23,24] The system also provides robust networked features, which expands computational power through connectivity.[9,25-28]

More specifically, VIS^{4}ION is a mobile platform capable of real-time scene understanding with human-in-the-loop navigation assistance; the smart service system has four components: (1) a wearable backpack with several distinct distance and ranging/image sensors, which extract pertinent information about obstacles and the environment;

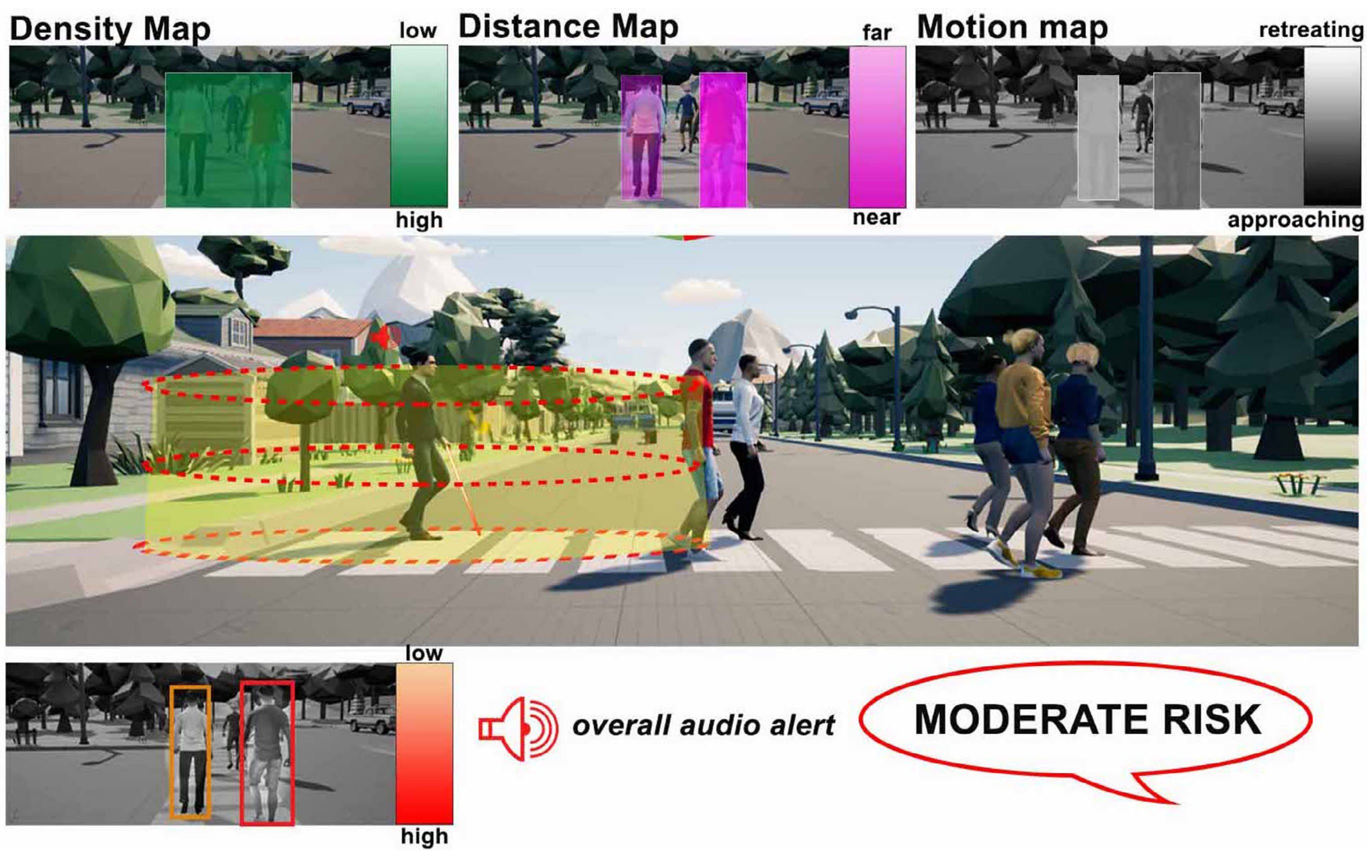

Figure 3. Crowd risk alert classifies crowds and sends the blind and visually impaired (BVI) user concise verbal alerts through audiobased prompts and notifications.

(2) an embedded system with both computing and communication capability (*inside backpack*); (3) a haptic interface (waist strap) that communicates the spatial information computed from the sensory data to the end-user in real-time via an intuitive, ergonomic, and personalized vibrotactile belt (waist straps of book bag) positioned on the torso[29-31]; and (4) a head set that contains both binaural bone conduction speakers and a microphone for oral communication.[23,24] Users of the VIS^{4}ION platform are alerted to environmental features of interest through the two human-machine-interface outputs: (1) audible messages delivered through bone conduction while leaving normal air-based audition intact; and (2) vibrotactile feedback whereby the scene that has been mapped is broken into a grid of segments and displayed to the end user in a crude pixelated form factor through the waist strap/belt. More specifically, the scene is decomposed into capture fields that correspond to the haptic interface in a spatiotopically preserved, intuitive, body-centered (eg, ocentric) fashion (Figure 2).

Although this AT tool was clearly not developed for pandemic-related risk mitigation, the potential to double down on embedded technologies to combat COVID-19 is certainly present. In fact, the team is presently exploring computer vision-based approaches for solving a number of critical issues raised in the literature[32,33]; although still under development, the wearable system is able to extract pertinent visual information from the user's surroundings, process the data through a series of parallel deep-learning techniques, and translate the results into pandemic-pertinent alerts and notifications. Spatial hazards are analyzed on three parameters: density (the population of the crowd), distance (from the user), and motion (relative to the user); subsequently risk is stratified for each parameter and an overall risk determination is rendered. Three maps are presented in Figure 3 to highlight these parameters: a crowd-density map (dens-map), distance map (dis-map), and motion map (motion-map). Higher density values are dark green in the density map, and lower density values are represented as light green. In the distance map, greater distance values are dark pink, and smaller distance values are represented as light pink. In the motion map, the faster a crowd moves closer toward the BVI user, the darker (black) the color is; the quicker a crowd walks away from the VI user, the lighter the color. As depicted in Figure 3, an end user is approaching a small crowd of pedestrians in a crosswalk and as the physical distance encroaches on what should be tolerated for an appropriate social distance, his risk is increased, and a moderate risk alert is delivered by the system. Additional spatial details are provided based on the evolving situation, and particular environment.

Although technological platforms are not presently optimized to aid with risk mitigation in the new era of COVID-19, much of what has been developed could be leveraged with simple pivots to successfully aid the BVI community. In fact, many computer vision–based neural nets are robust for accurately detecting pedestrians and could provide cueing and maintain a "safe" distance from others. Adapting alert routines to create a larger bubble of protection is reasonable and within reach given the depth sensing capabilities of many current embedded systems. A more practical deployable tool may just be the cellphone we already have in our pocket. There are a handful of applications that provide remote sighted assistance through live video-streaming. Several options include Aira.IO and Be My Eyes.[34,35] Although it has limited functionality, a remote guide may very well fill several of the gaps in this present pandemic.[35-38] The caveat is that limitations must be highlighted and clearly communicated, including but not being limited to compromised fields of view, basic functionality often focused on audio descriptions, restricted service ranges, and uninformed development that often fails to consider the perceptual and cognitive characteristics of nonvisual interface design.

In conclusion, the coronavirus disease 19 (COVID-19) pandemic has created cataclysmic repercussions in medicine while creating exceptionally difficult challenges and barriers for those with disabilities, particularly those with blindness and visual impairment. Social distancing and the minimization of touch are nontrivial for everyone, but for those with visual disability they are colossal. For a viable solution to be developed, it is critical that current ATs are surveyed and viable options are put forth to ensure the safety and agency of the BVI community. The simple truth is that the underlying problem is a basic one; it is a lack of information access. As a future direction, we must look to more comprehensive solutions that malleably adapt to environmental demand and user need. And always remember that "the world is full of suffering, (and) also full of the overcoming of it" (Helen Keller).

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Disclosure

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