Navigating the 21st Century Without Vision: How the iPhone changed the landscape for assistive technology and fueled the movement fighting for digital accessibility

by

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ABSTRACT

In 2009, when Apple released the iPhone 3GS, it was the first accessible touchscreen smartphone. This centralized platform, with its built-in GPS, high quality camera, powerful processor, and continuous connectivity, paved the way for new approaches to making a whole range of activities more accessible and convenient for the blind and visually impaired. Where once a blind person might have filled an entire shopping cart with expensive devices that had very specific functions, they could now get nearly all of those services in one device.

But even as the iPhone pushed accessibility forward, every door it opened led to another one bolted shut. A blind smartphone user can access mobile apps and social media platforms, but when those applications are not designed to be interpreted by Voiceover, they hit a brick wall. Full accessibility is still either entirely absent from apps, websites, and new devices, or it is thoroughly misguided. The iPhone blurred the line between assistive technology and mainstream technology. It raised the bar for digital accessibility, adding fuel to the fire of the blind community's movement for inclusive design.

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Roberto Manduchi is the first to admit that his initial foray into navigation for the visually impaired was a fool's errand. At the time, he had just landed a teaching position at the University of California-Santa Cruz and was excited to have the freedom to choose his focus. As an engineer who specializes in computer vision—the art and science of teaching a computer to make sense of images—he saw a parallel between his skillset and the needs of blind people. "We made robots see. Why can't we make blind people, if not see, why can't we help them with cameras?" So he jumped into the field of assistive technology and fell flat on his face.

Manduchi is a humble Italian with dark hair, friendly wrinkles around the eyes, and a prodigious nose. He grew up in TK, Italy and earned his PhD in electrical engineering at the University of Padua in 1993. He then moved to California and, after a stint at Apple, got a job at NASA's Jet Propulsion Laboratory where for several years he worked on autonomous vehicles for the military.

In 2001, he moved to Santa Cruz to open his own lab at the university and started thinking about where to take his research. Sensitive to issues of disability, he got the idea that he could use computer vision to help the blind. But he made a classic engineering mistake, one that he's now dedicated to teaching his students not to repeat. He went straight to the solution, without really understanding the problem he was trying to solve.

This blunder, a project completed in 2005, was a replacement for the standard white cane that blind travelers use to navigate safely through the environment. Under the impression that some users found the cane ill-suited for crowded settings, Manducchi invented a laser cane. He thought the laser would not only be more discreet but could potentially provide additional information to the user, like feedback as they were approaching a staircase.

"That was the wrongest move ever," Manduchi said. "The white cane is a fantastic thing that works all the time! It doesn't have batteries! Constantly people like me try to beat it, and you don't because that's just the wrong problem to address. If something works, let it work."

After that, Manduchi started to do his homework. He began to collaborate with another computer vision scientist, James Coughlan at the Smith Kettlewell Eye Research Institute in San Francisco. And as he got to know the blind people in his community and learn what their life was really like, he began to find what he called "usable problems, rather than made-up problems."

One of these usable problems has to do with navigation. While the white cane and guide dog are unbeatable assistants for travel in familiar environments, there are myriad situations in which additional information would be advantageous. Today, GPS devices are only effective up to an average of sixteen feet from the entrance of a building. For that last stretch to the entrance, a blind person has to navigate with a bit of trial and error or ask where the door is. Indoor environments are an even bigger black box. When I arrive at an unfamiliar building or need to find my gate at the airport, I look for maps and signs, and still often get confused. Without access

to these visual cues, I would have to wander the halls or find someone to ask for guidance.

These are age-old problems that people in the field of assistive technology have long been trying to solve. Past solutions often involved an expensive device that worked for a limited range of scenarios. For example, the Smith Kettlewell Institute is known for developing "Talking Signs" in the early 1990s, which were deployed in several cities around the United States. A Talking Signs installation consisted of infrared transmitters placed at different points of interest around a building or public space. With a Talking Signs receiver, priced at $200 in 1993, a blind or visually impaired person could pick up the signals of nearby transmitters, and the receiver would read the sign out loud for them. The sound became louder as the user got closer to the sign. Case studies found that Talking Signs were incredibly well-received.

During the rulemaking process for the 1991 Americas with Disabilities Act, members of Smith Kettlewell provided oral and written testimony describing how Talking Signs could be used to make overhead signage in public spaces more accessible. They thought that infrared remote signage should be required under the ADA. Although that didn't happen, when the Act was signed a note was included in the Federal Register saying that the Architectural and Transportation Barriers Compliance Board (ATBCB) planned to further study the issue for future revisions of the guidelines. No rule regarding audible signage has been included in subsequent amendments to the act.

The problem with Talking Signs is a key problem with some of the assistive navigation solutions being proposed today. The Signs required building managers, transportation hubs, and city workers to maintain the technology. And it required users to purchase a specialized device to access information that was only available in a limited number of settings. Without the widespread adoption that an ADA rule would bring, Talking Signs slowly faded away.

Then in 2009, something happened that completely changed the landscape for assistive technology. Apple released the iPhone 3GS, the first touchscreen smartphone that was fully accessible right out of the box. Where once a blind person might have filled an entire shopping cart with expensive devices that had very specific functions, they could now get nearly all of those services in one. The phone came with Apple's signature screen reading software, Voiceover, which recites the contents of the screen out loud to a user as they navigate through the device. Since then, blind and visually impaired users have embraced the iPhone almost to the exclusion of all other smartphones.

With a small computer now in the pockets of anyone who could afford it, problems that had long seemed intractable started being considered afresh. This centralized platform, with its built-in GPS, high quality camera, powerful processor, and continuous connectivity, paved the way for new approaches to making a whole range of activities more accessible for the visually impaired. And although the perfect navigation system has yet to be created, engineers like Manduchi and Coughlan were presented with a new toolkit with which to approach it.

And they aren't the only ones. In the age of the smartphone, artificial intelligence, and the internet of things, the creation of a navigation system for the blind has become the holy grail for computer engineers in universities all over the country. Even more significant, major tech companies such as Microsoft and Google now have teams dedicated to developing better navigation tools. This level of investment was unprecedented before Apple took the first step toward inclusive design with the iPhone.

Inclusive design, also referred to as "universal design," is an approach that aims to create a product that will work for anyone, regardless of their abilities, rather than designing a product that is engineered specifically for people with disabilities. Claire Rowland, a user experience consultant, says that everyone experiences a disability sometimes. "It might be that you've got your hands full because you're carrying children and shopping. Or it might be that you're in a very noisy place," she said. When designers consider users who have these impairments all the time, it makes the product better for everyone.

But even as the iPhone pushed accessibility forward for the visually impaired, every door it opened led to another one bolted shut. A blind smartphone user can access mobile apps and social media platforms, but when the software is not designed to be interpreted by Voiceover, they hit a brick wall. Full accessibility is still either entirely absent from apps, websites, and new technology, or it is thoroughly misguided. The iPhone added fuel to the fire of the blind community's movement for inclusive design. To see why, it's essential to understand what assistive technology used to be like and how the iPhone changed the playing field.

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A Magical, Wonderful Thing

The history of assistive technology for the blind and visually impaired mirrors in some ways the history of mainstream technology. The lightning pace of innovation in the late twentieth century bore fruit for everyone. But, more often than not, accessibility for all was an afterthought. Frequently, the blind were expected to come up with their own adaptations as workplaces became more high-tech. One person who lived through these developments is Jerry Berrier, the Director of Education Technology at the Perkins School for the Blind in Watertown, Massachusetts.

When Jerry was a kid in western Pennsylvania, he loved tinkering with radios. He was blind from infancy, and the radio, with its switches and knobs, was a mini-universe of touch and sound. By the time he was ten he learned Morse code. When his parents picked up a short-wave receiver in a thrift store, he strung up a simple antenna system between his house and a tree in the yard to listen to the radio.

That was in the early 1960s, when the world was a very different place for the blind. Jerry was
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fascinated by technology, but there wasn't a lot of it available. At his school for the blind, the encyclopedias, more than 100 volumes engorged with Braille type, took up an entire wall of the classroom. Accessing information independently was laborious.

By the time he got to college in 1970, things started to change. He was an early adopter of the Optacon, a device that translated regular text into a tactile signal. With one hand, he glided a small camera across a page, while the index finger on his other hand rested in a little trough. The camera converted the text into electrical impulses that Jerry could "read" with his finger. The Optacon cost $3450, the equivalent of almost $20,000 today. Jerry was lucky to acquire one with the help of funding from a foundation as well as his church. He found the device revolutionary. "The letters would come up exactly as they were on the page," he said.

The world was on the brink of a new era of technological advancement, and Jerry had a prescient feeling: "I knew, instinctively. This stuff is going to open up the world to me."

At Perkins, Jerry is the tech guru, in charge of acquiring adaptive technology for students and supporting other staff members if they run into trouble with their devices and software. In 2017, he won a Carroll Center Award, which honors blind employees who have made outstanding contributions to their workplaces in the state of Massachusetts. Outside of work, Jerry is a devoted birder and outdoorsman. He has written guides for people who want to learn to identify birds and their songs, and in 2016, he worked with Massachusetts Audubon to add accessibility features to trails that enable the blind to be alone in nature.

I met Jerry on a snowy winter morning in the Perkins History Museum, a grand medieval-looking hall on the collegiate red-brick campus. We sat at a table surrounded by glass cases displaying some of the essential artifacts of blind technological history, like the Perkins Brailler, one of the first Braille typewriters. I asked Jerry to take me through the list of things he considered revolutionary for blind accessibility in his lifetime, and for a technophile like Jerry, the list was long.

In the early 1980s the same company that made the Optacon developed a new product called the Versa Braille. It was a primitive computer about the size of a boxy briefcase. Jerry used the Versa Braille while he was working for Verizon as an employment interviewer. The device had a mic and a braille keyboard so he could record interviews while also taking notes. It stored everything on a floppy disc, allowing him to search for candidates in the system later on. He said it was extremely useful, but also extremely expensive. "I remember thinking, that's about as much as a car costs!" Jerry said.

Later in the 1980s, there was the portable braille note taker, sort of like a personal digital assistant with a Braille keyboard that cost around $1000. It could record notes, maintain a calendar, and store contacts. An even more radical shift came with the invention of new software that could read the screen of a computer out loud, commonly known as a screen reader. Suddenly, information was at his fingertips. He could quickly use the dictionary. He could do research without asking for assistance. "It just changed the world. Changed my life," Jerry said.

Skipping ahead to the present, I asked him if he considers the iPhone to be one of these

revolutionary devices. At that, Jerry's tone shifted, and his voice became rapturous. "The iPhone is one of the most magical, wonderful devices for a blind person that has ever been created," he said.

To the sighted, that might seem paradoxical. I was surprised when I first learned how popular iPhones were among the blind and visually impaired. Even though Voiceover and other screen readers had already been available for computers, using a computer with a keyboard and mouse is a tactile experience. How could a touchscreen, which lacks any topography, let alone buttons, be considered magical to people for whom touch has been so central to the user experience? But again and again, every blind person that I interviewed emphasized the significance of Apple's iPhone. Several used the term "game changer."

On the one hand, the iPhone has been revolutionary for blind people in the same ways that smartphones have changed the world for every person that has one—the way we socialize, the way we access information, the way we do our jobs, shop, watch movies, travel. But the key difference was that, starting in 2009, a blind person could purchase an iPhone, take it out of the box, and have their world change instantly, without any additional expense. There was no need to buy screen reading software, special devices, or adaptors. Because Voiceover was embedded in the phone's software, blind users could almost immediately navigate through apps, and read emails and webpages, as long as accurate text was available for Voiceover to interpret.

If you've never used Voiceover, here's how its works: With Voiceover turned on, you tap the screen once to highlight an app, which prompts Siri to read the name of it out loud. If that's not the one you're looking for, tap again, and Siri will read the next app on the screen. Swiping left and right allows you to scroll more quickly through the list, and if you drag your finger around the screen, it will read anything that you glide over, allowing for a more exploratory approach. Once you land on the app you're looking for, tap twice to open it.

Voiceover had been a feature on the Mac operating system since 2005, so some blind users were already familiar with it. But computers have keyboards to tap on and mice to click. Using Voiceover on a touch screen like the iPhone was not intuitive. For Jerry, there was a real learning curve. He downloaded an audio how-to guide from the National Braille Press and used that as a reference for months until he got good at it. Now it's second nature.

Others were able to pick it up more quickly. Like Jerry, Lindsay Yazzolino, a millennial who works as a freelance assistive technology consultant in the Boston area, has always been a total technophile. She got her first iPhone in college, and said she had no problem learning how to use it on her own. "I'm that type. I just picked it up, kind of figured it out. I've exchanged tips with friends about cool apps, but mostly it was just me," she said.

Since then, Apple has expanded its accessibility features on the phone immensely. There is now an entire language of taps and swipes that allow for expedient navigation through the device.

Vision loss is not always a congenital condition, so the age at which someone loses their sight can be a major factor in their ability and willingness to change the way they do things. According to the CDC, the majority of blind people are 65 or older, and the prevalence of age-related eye

diseases is expected to double over the next three decades. That's why organizations like the Lighthouse for the Blind and Visually Impaired, a nonprofit in San Francisco, offer technology training programs as one of their services.

Erin Lauridsen, the Access Technology Director at the Lighthouse, said that a big part of technology training is the buy-in from the individual—the belief that they can adapt and the courage to try. For someone who has been sighted their whole life, the shift from looking at things to listening to them can be overwhelming. I consider myself a tech-savvy person, but when I tried out Voiceover on my phone, I was completely lost. I opened my GPS app and tried to look up directions to the grocery store, but I pretty quickly became frustrated and gave up. Voiceover doesn't just convey text on the screen. It can also narrate the layout of a page, like the headers and sidebars, and identify every digital object, like distinguishing buttons from links. Accessing a news article is not just listening to a story. It's navigating a maze of menus, ads, videos, and photos, in search of the text.

As you might imagine, real-time playback of all of this information can be intolerable to endure. Many users train their ears to listen to Voiceover at a faster and faster rate. To the uninitiated, this makes Siri sound like gibberish. When I was in a room full of veteran Voiceover users, it reminded me of hearing a chorus of Alvin and the chipmunks, if their voices were sped up by a factor of three. But for Voiceover users, the speed becomes natural—simply a way to make the experience more seamless and convenient.

Wynter Hingel, a musician who lives in Boston, was resistant to changing the Voiceover speed on her phone at first. "I used to hear other blind people do that and I would think, 'don't be one of those weird blind people that listens to their voice thing super fast,'" she said. "And then I realized one day that you can get more information if you do that. So I started to put it a little faster and a little faster. Eventually you can understand it."

Wynter was the first person to demonstrate the iPhone's accessibility features for me. She got her first iPhone in 2011, and it soon replaced several of her older assistive devices. She used to carry around a heavy, clunky GPS tracker and a currency identifier that cost around $200. Now she just has one pocket-sized machine that serves both of those functions, and does a lot more. Her favorite feature is the Braille keyboard, an option that allows her to type in Braille by touching her fingers to the screen in the formations of Braille letters.

"That was the second game changer," Wynter said. It allowed her to do things, like send messages, much more quickly. It used to be that if she was on the bus and received a text as she was nearing her stop, she wouldn't have enough time to respond to it using Voiceover. But by holding up the phone horizontally like it was a videogame controller, Wynter showed me how she can type on the Braille keyboard, touching the screen with three finger tips from each hand. "Now I can just, boop boop boop! It's really clever."

When I asked her to tell me which apps she uses on a daily basis, I expected her to expound on the amazing apps that have been developed to serve blind users. But her list was pretty much the same as anyone else's. She uses the alarm clock to wake up in the morning (me too); she uses a real-time transit app to look up train departures (same here); she uses a GPS app to get directions

(who doesn't?); she looks up recipes when she wants to cook something new (naturally!).

There are a few things that she's grateful to have access to without being forced to purchase another device, like an app that can scan barcodes. "If I wanted to make sure that I wasn't accidentally putting re-fried beans in a pumpkin pie, I can scan the can and it will tell me what it is," Wynter said.

That feature is included in a powerful app developed by Microsoft called Seeing AI, which came out in 2017. The app accesses the phone's camera and thanks to machine learning, it can read documents and signs, identify people's faces, describe a scene, tell you what color something is, or tell you if the lights are off or on. When I asked other blind smartphone users about the best assistive apps, Seeing AI was always at the top of their lists.

But when it comes down to it, the most magical, wonderful thing about the iPhone for the blind community is just being able to use the same apps that everyone else uses.

For Lindsay Yazzolino, participating in social media is a big piece of that pleasure. "I think some of the consequences of social inaccessibility, they're kind of insidious, but hard to pin down," she said. She gave the example of a group message. If a bunch of your friends are in a chat group on Facebook or Slack, and you can't access that group because you don't have a smartphone or that particular chat program is not compatible with your screen reading software, "it's like the equivalent of everyone sitting around the table and you're sitting in the corner," she said. But thanks to features like Voiceover, blind smartphone users are just as active as everyone else on (and addicted to) Facebook, Twitter, and Instagram. For better or worse.

The iPhone blurred the line between assistive technology and mainstream technology. It raised the bar, forcing other smartphone companies to catch up and make their devices more accessible. For Wynter, the inclusive design and ease of use of the iPhone makes her wonder why there's still so much technology that's *not* accessible. "It really shows me that if enough money and enough interest is put into accessibility, so much can be done," she said. "And so I look at other companies and I think, how dare you?"

What made the difference was not that people who were blind or visually impaired could use the phone. It was deeper than that. It was the fact that Apple expanded its definition of who its customers were, of who its users could be, and designed the product to be accessible to all of them.

Sassy Outwater, the Executive Director of the Massachusetts Coalition for the Blind, put it this way: "There is literally nothing in print anymore that is not accessible to me, if I take the time to access it. There's really nothing right now other than driving and flying a plane that I can't do without the proper time, and apps, and technological support. And that all started when someone said, I think that disabled people can have equal access, and better access, if I start building possibilities into a product that is in *everybody's* hands."

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A Thousand Ways to See

On a chilly Saturday morning in December 2018 a group of about fifteen men and women gathered in a classroom at the Massachusetts Institute of Technology. This was the last meeting of the year for ViBUG—the Visually Impaired and Blind User Group, and it was Jerry Berrier's final meeting as president. He sat at the front of the room, taking notes on a Braille keyboard and leading the group through the agenda.

ViBUG convenes once a month and meetings run about three hours long. The group's official mission statement reads, "ViBUG is dedicated to advancing access to computers and other assistive technology by the blind and visually impaired community." During a typical meeting, members will share updates on new technology, both assistive and otherwise. There's also a question and answer session for people to give and receive advice with different tech problems. Some of the questions are things that any technology user might need help with: How do I use track changes in Microsoft Word? Should I buy a Mac or a PC? Other questions require more specialized knowledge, like troubleshooting the Braille screen input on the iPhone.

The end of the meeting is often reserved for product demonstrations and presentations. Tech start-up developers and entrepreneurs sometimes join, looking for feedback on new assistive devices or apps they are working on. The afternoon I attended, the founders of a company called Mediate presented a computer vision app they were working on that would help blind people locate objects in space.

"When you ask where a table is, it can say, there's a table fifteen feet away, there are two chairs in front of it, and there are a couple people around the table," explained one of the presenters. Well, that level of detail was the eventual goal, but for now the app functions more like a homing device. He held up the phone to demonstrate.

"Find a person," he instructed the app, and then pointed his phone at the whiteboard on the wall. As he slowly turned the phone toward Jerry, who was sitting nearby, it started to beep. As he moved it away from him, it went silent again.

One of the ViBUG members, Mika, left the room to beta-test the app in the hallway, while others asked questions and made suggestions.

> "Does it recognize just the stairs going up, or will it recognize ones going down?"
>
> "Right now it makes a beep, are you able to change that to a vibration?"
>
> "One thing you might want to include in the things that it looks for, is bus stop signs. That is really, in a lot of places, a huge issue."
>
> "Along the same lines, traffic light buttons might be useful."
>
> "Yeah, those are really difficult to find sometimes."

Soon, Mika came back into the classroom with a report:

"A lot of people come up with ideas of things we don't need. They don't really talk to blind people before they make them. Or they come up with ideas that are so far down the road that you don't know if it will ever come to fruition," Mika told the developers. "But this one does seem to be more advanced than a lot of things that we see. I would definitely download it and play with it some more."

Although the proposed app from Mediate is more of an object-finder than a navigation tool, these comments and concerns brought up by ViBUG members provide a pretty comprehensive roadmap of the challenges in improving navigation apps for the visually impaired.

First of all, what should the system detect? Should it access a map of the building and give you directions based on that, like a GPS app? Should it look for signs in the environment, like bathrooms and room numbers, and direct you based on those? What if you don't have a destination in mind, and you just want to see what's nearby? Should it process an entire scene captured by the camera, and list out everything around you? Does "everything" just mean business names and points of interest, or should it include public benches and garbage cans?

Second, how should the information be conveyed? Should the app employ continuous narration of the environment? Provide turn by turn directions? Users might want to limit these cues so they can keep their ears open to the environment while they are in transit. Should the directions be felt instead, like a vibration on the side of your body that you need to turn toward?

Third, offering a partial solution is a recipe for abandonment. An app that only works in some places and not others, or can detect some things and not others, does not ultimately solve the problem. If Google Maps gave detailed driving directions on the interstate, but became useless once you got off at your exit, would it be any better than an old fashioned map?

In fairness, there are several outdoor wayfinding apps that have been widely adopted by blind smartphone users. Apple Maps and Google Maps are popular, as are two apps designed specifically for blind users called Blindsquare and Nearby Explorer. A few months ago, Microsoft put its hat in the ring with an app called Soundscape. What's different about Soundscape is that it provides a 3D audio signal in addition to optional turn-by-turn directions. The app emits a steady "ping" that sounds like it's coming from the direction of the user's destination, helping to keep them oriented.

Each of these programs takes a different approach, whether it's offering turn by turn directions, guiding the user with stereo sound, or giving directions in reference to the clock face. They also provide different kinds of information, like notifying the user of street crossings or mentioning points of interest along the way.

But each app disappoints in some way. "A lot of the apps are fun to play with, and there are certainly apps that can at least tell you which way to go based on GPS. But that's only part of the equation," Jerry told me. Some apps give too much information, some not enough. And when you've got something talking in your ear, it distracts you from being able to sense what's going

on around you.

When I asked about indoor navigation, Jerry was doubtful that a reliable solution was even possible. "I can't imagine any app that would guide me through this building," he said, referring to the labyrinthine Howe building at Perkins. But that doesn't mean he's given up on the idea. Earlier in his life he wouldn't have thought the iPhone was possible, so he enjoys seeing what people come up with. "I just think we're still a long way from having something that's the panacea for blind people," he said.

"What we really need is the same information that everyone else already has, right?" said Erin Lauridsen, the Director of Access Technology at the San Francisco Lighthouse. "What businesses are around me, what streets are around me, what's the signage?"

This is at the heart of the challenge, according to Josh Miele, a blind scientist and designer who works at Smith Kettlewell. What blind people really want out of a navigation tool is to simulate the visual experience. "I mean, that's kind of the joke—what blind people want is to be able to see," he said.

But that's not, in fact, the case. "Most blind people who are good at being blind are perfectly happy in their lives—don't envy sighted people, don't wake up every morning wishing they were sighted. But at the same time, if you asked somebody to list all of the things that they want in their ideal wayfinding technology, what they want is to be able to see."

Josh believes what's really needed in these apps are better ways to filter information. Navigation is rarely an activity with a singular goal, and the filters that sighted people use to sort through visual information as they travel are key to the convenience and opportunism with which they move through the world. These filters might differ depending on the day of the week, the time of day, the neighborhood, or some other circumstance. If a sighted person is walking around with a check they need to deposit, they might home in on a bank that they would have otherwise ignored. So perhaps a navigation app should include the option to notify the user when they are near a bank. But the key word is "option," because if the traveler didn't have a check in their pocket, they may not want to hear about every bank they pass by.

To Josh, the ideal navigation tool would learn his behaviors and preferences, and then apply them as filters to feed him more pertinent information. "If I'm walking from here to city hall, I would like turn by turn information," Josh explained. "But I'd also like to know if there's a sushi place on the way because I'm hungry. And by the way I also like barbecue, but I don't want barbecue today. But if I found out about the barbecue place, then I would know that the next time I walk to city hall."

There is one assistive technology company that has found a solution that goes much further in approximating vision—one that Erin, Jerry, and others spoke positively about. The company is called AIRA, and while the solution has been enabled by technology like the iPhone, at its center is good old-fashioned human interaction. The name AIRA combines the acronyms for Artificial Intelligence and Remote Assistance, and the company employs trained agents who are available any hour of the day to help customers with, well, pretty much anything.

When a user calls up AIRA, the app provides an agent with a live video feed from the user's device. It also works with proprietary glasses that have cameras built into them. When connected to an agent, the user's needs serves as the filter: AIRA Agents help people sort through mail, explore a new place, or get them that last few feet to the door of their destination. Amy Bernal, the Vice President of Customer Experience at AIRA said that the only constraint on the service is users' imaginations. Of course, that's not entirely true—there are a few limitations for legal reasons. For instance, an agent is not allowed to tell you when something is safe or unsafe. They can't tell you when to cross the street, but they can tell you when the light is green.

When I first met Wynter Hingel, she had been a subscriber to AIRA for about eight months but had hardly used it. She felt there was something strange about it. "Being so used to trying to do everything I possibly could independent of human interaction, I find that I'm still kind of struggling with, how is this going to fit into my life?" she said. "I feel like when I'm calling up that service, I need to have a really specific idea of what I want."

But there was one thing that she couldn't wait to use it for: navigating the airport. Wynter was about to fly back to Wisconsin for the holidays and planned to call up AIRA during her layover. When I checked back with her a few weeks later to see how it went, she said the experience was liberating. She connected to an agent as the plane was taxiing, and they helped her exit the plane. The agent read the signs in the airport and led her to her gate in a different terminal. Then she realized she still had some time before her next flight, so she asked the agent to find a bar and guide her to an empty seat. "Honestly I wouldn't have ever done that on my own with the airport employees because I feel like it's not their job...I wouldn't have ever asked them to get me a drink."

If you decided to call up AIRA every time you wanted to borrow someone's eyes, it would get expensive. Wynter said she was connected to the agent for about 40 minutes, which used up a little more than a third of her $89 per month plan. AIRA is beginning to partner with airports, grocery stores, pharmacies, universities, and museums to offer complementary access to guests once they connect to the wifi in those locations. The company's ultimate goal is to make the product free to users in as many locations as possible—especially in educational institutions and workplaces. (There's actually another app called Be My Eyes that works similarly to AIRA, except instead of being connected to a trained agent, you are connected to a stranger—a sighted volunteer who has signed up to help. Be My Eyes is free to use.)

Eventually, many AIRA calls might not even require an agent. One of the most interesting aspects to AIRA, and the most concerning, is the "AI" portion of the equation. Every single call that a user initiates on AIRA is recorded and retained by the company. They are collecting what's probably the world's largest data set on what blind people want assistance with and what the solution to each call looks like. The service includes a digital assistant named Chloe, sort of equivalent to Apple's Siri. For now Chloe's abilities are limited. She can tell you how many minutes are left on your account, she can translate text-to-speech when you point your camera at a document. But the company is using the data collected from the human interactions to make Chloe better. Amy Bernal from AIRA said that they want Chloe to get smart enough so that she's as close to an AIRA agent as possible.

For now, the company does not have plans to replace live agents. Bernal said the goal is to give users a choice of who to work with. One situation where Chloe could come in handy is in going to places where the agents cannot go, like a public restroom. "We're not going to infringe on other people's privacy with bringing that live video stream into a public place. That'd be a great place for Chloe to shine," Bernal said.

But the burden of this solution is not just financial. Calling up an agent or a volunteer comes with what Erin Lauridsen described as a generosity cost—the energy expended in taking the time to be nice to someone. "It's not that I'm mean," she said, "but I don't always want to be like, 'Hi, how are you today? Thank you *so* much for your help,' for just some basic tasks."

The cost and privacy concerns that come with AIRA illustrate just how difficult it is to create a one-size-fits-all solution. But no app is going to satisfy everyone. AIRA may become a favorite option for many users, indeed it seems like it already has, but it would be wrong to assume that an effective assistive technology needs to work for everyone. The same can be said of any technology. Some people find that PCs suit their needs, others choose Macs.

The whole idea of creating a "perfect" assistive technology for the blind and visually impaired detracts from a larger issue. If mainstream developers considered a wider range of end-users for their products, the need for many of these specialized solutions would be greatly reduced. And often, what's really holding developers back is ignorance, indifference, and fear.

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Design Without Fear

The challenge of recreating the experience of vision in navigation has not stopped countless developers from trying. These start-up hopefuls often go to people like the ViBUG members or to Erin Lauridsen, looking for feedback on their product. And as Mika from ViBUG described, it's often clear that these people have never spoken to a blind person in their life. Just like with Roberto Manduchi's laser cane, there's always people coming up with technology for the blind that isn't needed. "They design based on their fear of how hard it would be to be a blind person, versus talking to blind people and finding out what the needs of the community are," Erin said. She cited ideas where the developer thought that blind people needed some sort of medical alert app or device—something that vibrates when you're about to hit an object, or comes with a button to call a loved one for help. "Those are the types of ideas where I go, oof. Build something else. We don't need that."

Even when their idea is on the right track, assistive technology developers face another hurdle: market size. The Census Bureau's 2017 American Community Survey included the question, "Is this person blind or does he/she have serious difficulty seeing even when wearing glasses?" and reported that 2.3 percent of the U.S. Population has a visual disability. That's why historically, standalone assistive devices have been so expensive. Specialized apps can be cheaper to build, but their profit margins remain limited.
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When accessibility is built into devices, apps, and systems that exist for the entire population, however, it can bring added value to everyone involved. One thing that Erin is optimistic about is the potential benefits for blind people as the Internet of Things proliferates. Commonly referred to as IoT, the Internet of Things is the idea that everyday objects will eventually become smart, connected objects that can communicate with you, receive verbal or remote cues, learn about their environment, and respond in helpful ways. Amazon's Alexa, Nest, and other "smart home" devices are considered IoT technology. Smart homes are actually built on technology that was originally intended to help the blind and visually impaired. Voice assistants like Alexa are made possible by the same types of text-to-speech algorithms that underpinned screen reading software developed in the 1980s—a perfect example of how products designed for accessibility can benefit all users.

One IoT-style solution that has already been tested for blind wayfinding is the bluetooth iBeacon. These are a modern version of Talking Signs, small sensors that you can put up around the environment that receive and transmit information. In general they have been well-received by users, but ultimately, they suffer from the same infrastructural problems as Talking Signs.

"Anytime that infrastructure is a high cost or high maintenance thing that's *just* for blind people, I don't think it will scale up. Because that's a really big ask," Erin said. But her thinking is that more and more, everyday objects are going to get hooked into the IoT for all kinds of reasons. For example, a trash can that notifies the garbage truck when its full, or a public restroom with a sensor that notifies the city when it needs toilet paper. That trashcan and restroom are geotagged, and those tags could be helpful for someone who is blind, not to mention anybody else looking for a trash can or a restroom. "If it can benefit the whole population, there's less of an argument of why someone should spend the time and money to do something," Erin explained.

In order for Erin's vision to become a reality, though, the interests controlling these smart devices, whether its a private vendor or a local municipality, would need to provide public access to their data. That would create an ecosystem where other businesses could build new services based on that data to meet other needs. This isn't completely unheard of—think of real-time transit apps that provide bus and train times. These services wouldn't be possible without local transit authorities opening up their data.

Alexandra Deschamps-Sonsino, a London-based product designer and Internet of Things expert, said that despite this example in public transit, she doesn't see this happening on a larger scale without legal requirements. "This isn't public information. It is ultimately a private supplier of the garbage can that holds that data," Deschamps-Sonsino said. Transit apps benefit transportation companies by driving up use. But not every IoT company is going to benefit from opening up its data, and it's unlikely they would choose to do so voluntarily.

Even without opening up their data, IoT companies can still design products that are accessible to disabled users. But Deschamps-Sonsino said that in her experience, the average startup in the IoT space does not think about accessibility. One reason could be that the majority of these companies are no more than three years old. "Within that timeframe, a wider array of users is not your primary concern. Your primary concern is to get any users at all," she said.

For more than a decade, the iPhone has provided an accessible interface that comes with a wide array of tools to make any app available to people with disabilities. And yet, shockingly few developers consider these tools today. Claire Rowland said that accessibility is still considered a niche market, reserved for products that are made to specifically help people with disabilities rather than taken as a tenet of good design.

"There's a concept called digital segregation," said Sassy Outwater, the executive director of the Massachusetts Association for the Blind. "There shouldn't be an experience that is workable for me, and then there's one that's workable for you." She is not downplaying the importance of disability-specific tools like Braille or sign language, or the uniqueness of the disability experience. But in order for there to be more "game changers" for the blind and visually impaired community, it's going to take mainstream developers doing what Apple did—expanding their definition of who their customers can be, and building accessibility in from the start.

When people ask Sassy for app recommendations, she finds that she's naming disability-specific apps less and less. For example, when I asked her which navigation tools she endorses, her first choice was Siri. I found this confusing, because Siri is not even a GPS system. But Sassy's response was a testament to the reliability of Voiceover, and the unreliability of most tech companies when it comes to designing accessible software.

"Apps change. Apps go out of business. Apps get sold and then become inaccessible," she said. When she first tried Google maps it didn't work at all with Voiceover, and then after an upgrade it worked great. Over the course of several more upgrades, though, it was unpredictable whether or not it would work. She's hesitant to make recommendations, because if someone becomes reliant on an app to do something like go to the grocery store, and it suddenly becomes inaccessible, what are they going to do? "It's bigger than the apps," she said. "It has to be about the mindset of designing accessibly, and keeping it accessible."

What Sassy would ultimately like to see is for Siri to become something similar to AIRA's Chloe—an artificial intelligence-powered voice assistant that can be drawn upon in any situation. "Voice activated services are really the future of where this is going," she said.

Right now, Siri's capabilities are limited to Apple products. When you ask her for directions, she can find them on Apple Maps, but not Google maps. You can't ask her to use your barcode scanner app, or to post a picture you took onto instagram. Sassy's preference would be a further consolidation of assistive technology, and more fluidity between apps. She wants to be able to say, "Siri, scan the barcode on this can of soup and tell me what it is," or "Siri, tell me if the lights are on or off in my room." The Microsoft app Seeing AI can perform those tasks, but in order for it to be controlled by Siri, Apple would have to collaborate with one of its rival companies. "That's not going to happen because of economics, but if they talked to each other more it would make my life even better," she said.

How did Apple become this role model of accessibility, anyway? It's proven to be a difficult question to answer. When I reached out to the company to ask what led to the inclusion of Voiceover on the iPhone in 2009, they declined to comment. I asked several of the people I

interviewed for this story if they had any insight into it, and responses were speculative.

Amy Mason, a colleague of Erin's at the San Francisco Lighthouse, suspects that Apple's efforts to improve accessibility in its products can be traced back to the company's settlement with the National Federation for the Blind (NFB) in 2008. At the time, even though the Mac operating system included Voiceover, the iTunes software and iTunes University educational materials were not compatible with screen readers. When the NFB brought this issue to the Massachusetts attorney general Martha Coakley, she admonished the company for violating the Americans with Disabilities Act and the Massachusetts Equal Rights Act. But instead of bringing litigation, Coakley suggested that the company rectify the situation voluntarily. Apple agreed, vowing to make its iTunes University service accessible by the end of the year, and the rest of the iTunes Store accessible to both Mac and Windows users by June of 2009. Sure enough, the following June, they did more than fulfill their promise. That's when the iPhone with Voiceover was born.

Sassy had a different explanation. "It came right from the top," she wrote in an email. "Steve Jobs wanted his products to be used by everyone. It's as simple as that."

Whether or not it was as simple as that for Apple, today, it's hard to see why it isn't as simple as that for everyone else. The technology is there, but the mindset is not. The problem is in fact much bigger than inaccessible apps and devices—it spans to appliances like microwaves, treadmills, and washing machines that come with touch screens and no voice-activated option. It spans to electronic medical records and payroll software and job application portals. It spans to every website on the internet that uses flashing animations, buttons that aren't coded as buttons, links that aren't coded as links, photos without alternative text, videos without description, Captcha tests—all features that make a website inaccessible to blind users. When buttons and links aren't coded as such, screen readers can't identify them. "There's nothing like spending an hour filling out a form and then not knowing which one is the submit button," Sassy said. When I asked her how often she comes across an inaccessible website, she said it happens multiple times a day.

Addressing these problems requires a shift in perspective; a willingness to learn about other people's experiences, and a sense of duty to account for them. Or, it may require legal action. The Americans with Disabilities Act was created in 1990, long before the proliferation of online education or commerce, and does not yet include any requirements for websites. But many are arguing that businesses are required to make their websites accessible under Title III of the act, which says that the disabled cannot be denied public accommodations that are available to the able-bodied population. In 2018, more than 2,000 web accessibility lawsuits were filed in the U.S. As a wave of litigation against all kinds of businesses—the Blick Art Supply store in New York, Winn-Dixie grocery stores in Florida, Domino's Pizza, Hobby Lobby, and even major universities like Harvard and MIT—has made its way through the lower courts, opinions have been split. All this may change if one of these cases manages to reach the Supreme Court. In March, the law firm Seyfarth Shaw reported that the case against Domino's could soon be headed there.

Making the world a more accessible place for people with disabilities is never going to have a purely technological solution. Technology reflects the culture and beliefs of its creators.

Accessibility doesn't just mean being able to use an iPhone app or navigate through a building independently. It means having equal access to education and jobs. It means being respected and trusted by the able-bodied community, instead of feared. "If people are sitting around thinking about how to stop blind people from running into things, or how to keep us safe, they're not going to hire me, right?" said Erin. "Society is still kind of stuck on either pity or inspiration, and hasn't, in some ways, moved beyond that."

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Selected Sources

Manduchi, Roberto. (2018, November 12). Phone interview.

Pingel, Wynter. (2018, December 6.) In person interview.

Yazzolino, Lindsay. (2018, December 7.) In person interview.

ViBUG Meeting attended December 8, 2018

Coughlan, James. (2018, December 7) Phone interview.

Pingel, Wynter. (2019, January 7.) Phone interview.

Bernal, Amy. (2019 January 8.) Phone interview.

Outwater, Sassy. (2019 January 9.) In person interview.

Berrier, Jerry. (2019 January 10.) In person interview.

Manduchi, Roberto. (2019 January 14.) In person interview.

Jones, Kat. (2019 January 15.) In person interview.

Coughlan, James. (2019 January 16.) In person interview.

Miele, Joshua. (2019 January 16.) In person interview.

Lauridsen, Erin. (2019 January 17.) In person interview.

Rowland, Claire. (2019 April 11.) Phone interview.

Deschamps-Sonsino, Alexandra. (2019 April 12.) Phone interview.

Berrier, Jerry. (2019 May 1.) Phone interview.

"Blindness and Vision Impairment | Gateway to Health Communication | CDC." *Gateway to Health Communication & Social Marketing Practice*, Centers for Disease Control and Prevention, 2017, www.cdc.gov/healthcommunication/toolstemplates/entertainmented/tips/Blindness.html.

Bray, Hiawatha. "Coakley, Apple Agree on ITunes Access for Blind." *Boston.com*, The Boston Globe, 27 Sept. 2008, www.boston.com/news/local/massachusetts/articles/2008/09/27/coakley_apple_agree_on_itunes_access_for_blind/.

Disability Statistics, K. Lisa Yang and Hock E. Tan Institute on Employment and Disability at Cornell University, 2017, www.disabilitystatistics.org/reports/acs.cfm?statistic=1.

Duenas, Michael. *Improving the Nation's Vision Health: A Coordinated Public Health Approach*. Centers for Disease Control, 2010.

Feingold, Lainey. "Digital Accessibility and the Quest for Online Equality." *Journal of Internet Law*, Oct. 2017, pp. 3–12.

Feingold, Lainey. "Big Win for Web Accessibility in Domino's Pizza Case." *Law Office of Lainey Feingold*, 15 Jan. 2019, www.lflegal.com/2019/01/dominos-ninth-circuit/.

"Introduction to Talking Signs." *Source Material on REMOTE INFRARED SIGNAGE*, The Smith-Kettlewell Eye Research Institute Rehabilitation Engineering Research Center, 2007, web.archive.org/web/20070220122805/http://www.ski.org/rerc/WCrandall/introts.html.

Koestler, Frances A. *The Unseen Minority: a Social History of Blindness in America*. D. McKay Co., 1976.

Manduchi, Roberto, and James Coughlan. "(Computer) Vision Without Sight." *Communications of the Association for Computing Machinery*, 1 Jan. 2012, cacm.acm.org/magazines/2012/1/144819-computer-vision-without-sight/fulltext?searchterm=Decipher%2BInc%2BData%2BCollection%2BMarket%2BResearch.

Vu, Minh. "Domino's To Ask Supreme Court To Consider Whether ADA Website/Mobile App Accessibility Lawsuits Violate Due Process." *ADA Title III*, 21 Mar. 2019, www.adatitleiii.com/2019/03/dominos-to-ask-supreme-court-to-consider-whether-ada-website-mobile-app-accessibility-lawsuits-violate-due-process/.