# “Just Let the Cane Hit It”: How the Blind and Sighted See Navigation Differently

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## ABSTRACT
Sighted people often have the best of intentions when they want to help a blind person navigate, but their well meaning is also often coupled with a lack of knowledge and understanding about how a person navigates without vision. As a result what sighted people think is the right feedback is too often the wrong feedback to give to a person with a visual impairment. Understanding how to provide feedback to blind navigators is crucial to the design of assistive technologies for navigation. In our research investigating the design of a personal pedestrian navigation device, we observed firsthand the ways that sighted people seemingly misunderstand how many blind people navigate when using a white cane mobility aid. Throughout our qualitative end user studies that included focus groups and observations (including couple-based observations with a close companion) we gathered data that explicitly shows how the language and understanding of sighted vs. blind pedestrians differs greatly and even how it can be dangerous when people interfere in the wrong way. From our findings we discuss why it is difficult for a blind person to navigate like a sighted person to ensure designers are aware of the difficulties and designing with new training in mind, not simply designing from their own point of view. We also want to encourage advocacy and empathy amongst the sighted community towards this activity of walking around independently.

## Categories and Subject Descriptors
K.4.2 **[Social Issues]**: Assistive technologies for persons with disabilities

## General Terms
Design; Human Factors

## Keywords
Blind navigation; white cane; empathy

## 1.1 INTRODUCTION
Navigation without vision is difficult. Common successful strategies include using additional aids ranging from low-tech solutions such as a white cane to high-tech solutions such as handheld GPS devices. Our eventual research goal is to contribute to the high-tech solutions, however we are first interfacing with end users to study the current strategies, techniques, and products.



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To help us learn about this task and avoid incorrect assumptions we conducted immersive, in-depth qualitative research for over one year and developed an understanding of navigation from the perspective of individuals with visual impairments. Our observations have revealed diverse navigation strategies directly impacting how instructions should be given to someone walking independently. We found that the strategies taught in Orientation and Mobility (O&M) training often conflict with the type of information that sighted people and/or new technology provide, which makes comprehension more difficult for the visually impaired. While we do not propose to cease innovations beyond the traditional navigation strategies, we thought it important to note the differences. Dramatically changing the way a blind person walks has serious safety implications and other implications impacting the likelihood of adoption and success, which do not seem to be currently accounted for in literature.

It’s important to note that not every blind person needs a mobility aid and that not everyone obtains O&M training. However, for those that use a cane or seeing eye dog, there are certain techniques that are taught and relied upon to ensure safe travel. There are also certain non-visual cues that are universal for people with vision impairments that provide substitutions for visual cues used in navigation. Based on responses from our visually impaired participants we believe more people with vision could use a better understanding of using a different modality for receiving the same environmental feedback.

In this paper, we present our findings from several research studies that have explored how assistance from sighted people often creates complications for people with vision impairments. Through interviews and observations with independent blind travelers, we identified mismatches between information provided by sighted assistants and information needed by blind travelers. We also conducted a study in which blind participants explored a location along with a sighted companion, and found these mismatches even when the individuals knew each other. Since the majority of the participants in our study (and in the visually impaired population) were cane users, and using a cane presents a very different navigation strategy than using a seeing eye dog, we focus primarily on cane users in our findings and discussion. Based on these insights, we discuss design implications for creating automated navigation tools that provide information best suited to independent blind travelers.

## 2. RELATED WORK
In order to understand how best to design navigation tools to support blind travelers, our research is significantly informed by prior research in designing navigation aids for blind people. In addition, our research is also informed by prior studies examining social interactions during navigation activities.

## 2.1 Blind Navigation Devices

For over 40 years researchers and practitioners have been applying the latest technology trends to aiding people with vision impairments with more accurate orientation, obstacle detection and avoidance, and real-time as well as virtual wayfinding [4]. In the latest available systems, users are able to use either a handheld GPS device such as Humanware's TrekkerBreeze[1] or applications on their smartphone devices such as Google Maps[2] to hear landmarks they are passing, receive turn-by-turn directions (for walking and taking transit), and simply regain orientation in space with compass-style features. While the latest technology has presented marked improvements in the available features and streamlined hardware, there are still open challenges for technology designers to undertake. For example, there are outdoor locations not available on a GPS device for which users could still use support, such as a park or college campus. Also, commercially available indoor wayfinding applications such as Talking Signs[3] have not been widely adopted; thus, indoor navigation devices are still primarily a focus of current research but not available to users at the present. Given the continued opportunity to improve the availability of technology for visually impaired navigators, we are building upon the current research and commercial devices but also ensuring we take a user-centered design approach to address the most pressing issues in the most usable interface.

## 2.2 Blind Navigation Training and Strategies

In proposing an algorithm for indoor navigation, Swobodzinski and Raubal provide a comprehensive description of what is generally taught in Orientation and Mobility (O&M) training, focusing on training for people whose vision requires a mobility aid [5]. This intensive and extremely detailed training helps people learn how to use their other senses to discover information about their environment as well as walk safely. Techniques include listening for distinct environmental sounds, using the white cane to trail (glide) along a wall to walk straight and keep one's orientation, and the differences between "obstacles, hazards, clues, and landmarks" (referring to the many objects one encounters in the environment). Using the O&M training strategies, the researchers built a system specifically for blind pedestrians that chose the "optimal route by trading off distance and the number of landmarks and clues along a route". They compared their routes to those generated by algorithms assuming a sighted traveler and asserted that their distinctive approach was more appropriate and optimal. Taking into account the substantial differences between how a blind and sighted person approaches a navigation task underscores our desire to involve end users in our development process and to include many different research probes to ensure we have a full understanding of the technology needs and interface and interaction requirements.

## 2.3 Collaboration in Navigation

By examining how humans interact during a navigation task, we can better understand user information needs and the shortcomings of existing navigation technology. Even though navigation is an activity frequently performed within a group, there is little research exploring group interactions – whether for blind navigation or more general navigation studies. One noted exception is work by Forlizzi, *et al*, where they observed pairs of people navigating in a vehicle [2]. The person driving navigated with directions from a passenger (deemed the "navigator") who was able to familiarize themselves with maps and directions prior to starting the journey. They found interesting dynamics about the teamwork employed by the participants such as negotiating the optimal timing of giving out upcoming maneuvers, determining when to give solely directional cues versus more details (such as which lane to move into), and analyzing the tangential conversations they carried on outside of the navigation tasks (such as reminiscing based on passing landmarks). This study provided insights for in-car GPS devices based on the human interaction; thus, much like this study we set out to examine similar human interaction behaviors for pedestrian navigation. We conducted a similar study with blind participants and sighted companions, finding many of the same teamwork negotiations and social interactions. Following we explain the findings from this study as well as findings from single-person observations and focus group discussions related to navigation technology needs.

# 3. RECALLING NAVIGATION EXPERIENCES

We sought to understand the current navigation challenges experienced by people with vision impairments through several studies. Our prior work detailed findings from over-the-phone interviews conducted with 30 adults with vision impairments [6]. We added to that data with other collection methods including focus groups (which included regular diary entries) and observations of everyday navigation with a person with a vision impairment. Each study allowed an opportunity to identify, and even see firsthand, remaining challenges despite the prevalence of navigation technology. We also learned that some of these challenges stem from the environment but others from people.

## 3.1 Focus Groups and Observations

### *3.1.1 Participants*

We recruited 20 participants for the focus groups and observations – 17 focus group participants and 5 observation participants (2 participants participated in both). Table 1 details their ages, genders, and visual impairments. "FG" denotes a focus group participant, "O" an observation participant, and note 2 participants conducted both studies and thus have 2 identifiers. FG5, FG15, and O3 were guide dog users; all others were cane users.

### *3.1.2 Methods*

We convened 2 focus groups in 2 different metropolitan areas. The first group of 8 (6 female, ages 31-63) met once a month for 6 months in Washington, D.C. The second group consisted of 7 participants (4 female, ages 30-66) who met once in Atlanta. Both focus groups were led in guided discussions of past navigation training, current navigation challenges, and ideas for future navigation technology.

Participants were also asked to type "diary" entries during the month after the session(s). Diaries are a freelance journal entry related to the study, in this case related to navigation experiences or technology ideas. Diary studies provide a means for capturing anecdotes not recalled or shared during the meeting, chronicling day-of experiences, and relaying ideas upon further reflection.

[1] http://www.humanware.com/en-usa/home

[2] https://www.google.com/maps/preview

[3] http://www.talkingsigns.com

**Table 1: Focus Group and Observation Participants**

| ID | Age / Gender | Vision Impairment | ID | Age / Gender | Vision Impairment |
|---|---|---|---|---|---|
| FG1 | 30/M | Glaucoma age 4; gradual vision loss; no usable vision | FG10 (O4) | 58/M | RP age 27; gradual vision loss, some light perception |
| FG2 | 31/F | Legally Blind: Myopia and Nistagmus | FG11 | 61/F | Blind since birth |
| FG3 | 38/M | Gradual vision loss from age 5 | FG12 | 61/M | Blind from birth, ROP |
| FG4 | 44/F | Lost vision age 31 | FG13 (O5) | 63/F | Blind from birth, ROP |
| FG5 | 48/M | Retinitis Pigmentosa (RP) | FG14 | 63/F | Lost vision age 23 |
| FG6 | 48/M | PR, low day vision, no night vision | FG15 | 66/F | Blind from birth, ROP |
| FG7 | 51/M | Choroidermia at 12 | O1 | 25/F | Blind since birth |
| FG8 | 57/F | Stills Disease age 5, gradual vision loss, little usable vision | O2 | 29/F | Low vision, requires magnification |
| FG9 | 58/F | Glaucoma age 38; low vision | O3 | 29/M | Blind from birth, some light perception |

Observation participants were accompanied on diverse everyday tasks including running errands (using public transit), mall shopping, and commuting home during an evening rush hour. The participants chose the task for observation and were followed by one researcher for one session. The researcher asked questions during and after the observations.

## 3.2 Findings

The studies provided us with valuable overall navigation insights concerning a breadth of topics including what participants found useful as navigational cues, what they wanted to know about their surroundings, and obstacles they encounter. However, discussions also often led to the unexpected topic of difficulties they have with strangers as they navigate. For this paper we will focus primarily on these interactions between blind and sighted people, particularly because participants indicated they are often treated differently (and in many ways awkwardly) by sighted individuals.

### *3.2.1 Navigation Techniques – Actual vs. Perceived*

Visually impaired individuals use many environmental characteristics to recall and confirm their path and help move along a path safely. When asked what is used to help with guidance participants would unanimously and emphatically exclaim, “Everything!” Those who have been trained to concentrate on feedback from their other available senses can detect even the smallest of features.

To expound, landmarks such as stairs and doors are often counted and used to trigger navigation cues. Tactile features such as the slope and raised bumps of a wheelchair curb cut can signal both an intersection and a step to complete along a path. And a variety of audio cues are also utilized for environmental awareness and navigation; for instance, elevators beep as they transition between floors, providing a clue as to their location.

Sometimes devices built to help supplement these navigation techniques don’t quite hit the mark for users. For instance, FG11 mentioned she once used a sonar cane to help her navigate, but found it often told her about things she already knew about including when she was near a wall (which she could sense on her own). She stopped using the cane because it wasn’t giving her enough valuable unknown information in relation to giving her cues of what she already knew.

More apparent than miscues in technology, however, were misconceptions by sighted people. FG1 and FG3 brought up the frequent misconception that blind navigation, like sighted navigation, is easiest in wide-open places. Visually impaired individuals actually benefit the most from navigating in areas where they have boundaries and many navigational cues such as walls. Since white cane users use the cane to connect with objects, fewer objects equates to less information about the surroundings and path.

An additional misconception that was mentioned by the participants was that they do not count paces (as many sighted people believe they do), because the size of the paces varies too much. Counting steps is also too difficult to do when walking with others and carrying on a conversation.

### *3.2.2 Unhelpful Assistance – Grabbing and Shouting*

Participants mentioned the hazard of sighted people trying to provide unnecessary assistance to them, even though they may have good intentions. We describe several examples of sighted people grabbing people while navigating, shouting directions, and surprising someone. While the sighted person may only be trying to help, they are not always aware of the type of information that is helpful to the visually impaired person, and can often create more dangerous hazards.

One repeated encounter, particularly for the white cane users, was being grabbed or having their cane grabbed while they are walking. Our participants theorized that sighted people are often under the impression that visually impaired individuals are not suppose to run into things with their cane. FG13 noted that people would grab her before she gets on the escalator, and she needed to explain to them how dangerous that is since it could make her fall. O3 mentioned that people will often grab him to stop him from running into obstacles, for instance puddles, but that a verbal warning would be much less surprising and less dangerous. Being grabbed unexpectedly is very alarming, and as FG8 mentioned, it can result in a feeling of loss of control. As FG5 noted, “it only takes one person grabbing you to make you fall.” FG13 and O3 said they actually purposefully walk very quickly and try to appear confident so that people do not try to reach out and grab them or provide well intentioned but hazardous assistance.

Another common occurrence was having directions shouted out, particularly when one is concentrating. FG10 takes the train and utilizes audio cues to know when the doors open and other boarding cues. However, he mentioned that people will often shout at him (such as, “Over here!”) as he stands listening for his cues. The sighted people who see him believe that he is just standing, is lost, or requires some sort of assistance; however, when they yell at him it actually “throws him off” and distracts him from the audio cues he needs to focus on. Multiple participants from the focus groups mentioned that they found that type of distracting assistance very irritating.

An additional comment about sighted assistance was that sighted people trying to help do not always give a verbal warning. People will also not make any noise, even when a person is running into them with their cane. For example, FG10 mentioned that often he will run into people when he is waiting to pay the fare for his metro card. FG11 explained that people will try to help, but that she is unaware of the help unless she is verbally told about it. For example, phrases such as “open door on your left” are very useful to visually impaired individuals, where as if the door is held open and the visually impaired person is not aware of it, it will most likely just cause more confusion.

#### *3.2.3 Walking With Others*

Participants explained that when walking with other sighted people they prefer the “sighted guide” technique. This is when a blind person grasps the elbow/arm of a sighted person and simply uses their body movement to navigate. (This is in addition to their cane but to a lesser extent, and guide dog owners will allow their dogs to simply follow along.) This is a more relaxed way of navigating for both people because the sighted person does not have to give verbal cues for every navigation occurrence and the blind person will walk under the assumption that the sighted person will avoid any hazards in the way.

O3 and many others in our groups prefer to use this technique because it doesn’t interrupt the conversation as much and is easier on the sighted companion. FG12 said he prefers it because he doesn’t want his sighted companions to feel bad for providing unhelpful information and doesn’t want to feel he’s training his companions on what information is most helpful to speak aloud. Others in the focus group agreed they felt like not using sighted guide was putting a sense of responsibility on a sighted companion. He also emphatically proclaimed that sighted people are often very bad at deciphering left from right when giving directions, to which other focus group participants also agreed. This preference for sighted guide actually had a large impact on our second set of user studies with sighted partner navigation.

## 4. SIMULATING REAL NAVIGATION

Continuing our investigation into the navigation technology device needs of people with vision impairments, we conducted observations of a blind participant navigating real environments with a known sighted companion. We anticipated we would learn how to best design navigation technology for independent travelers by noting (and attempting to mimic) the successes of the same interaction between people.

### 4.1 Partner Observations

#### *4.1.1 Participants*

Adults with visual impairments who used a white cane or guide dog were recruited for partner observations of navigating a real world environment. We recruited participants who had undergone navigation training and were comfortable enough to conduct the study without using the “sighted guide” approach - being led by a sighted person with the use of physical touch. We asked participants to identify a close companion to act as their guide (for instance, a spouse or friend).

Table 2 details the gender, age, and relationship of the participants. ‘N#’ indicates the visually impaired participant, while ‘C#’ indicates the sighted companion. The participants varied on the onset and state of their visual impairment but all but participant N3 had no usable vision and all were white cane users. All participant pairs had some prior experience navigating together (though not always in completely unfamiliar locations).

**Table 2: Partner observation participants. N=blind participant (i.e., the navigator); C=sighted participant (i.e., the companion).** ***Note N1 conducted the study twice with two different companions.***

| ID | Gender, Age | Vision Impairment Or Companion Relationship & Time Known |
|---|---|---|
| N1 | 36/M | RP, gradual loss age 3, most age 20 |
| C1a | 32/F | Wife, 10 years |
| C1b | 29/F | Friend, 3 months |
| N2 | 53/F | Accident age 6, lost all vision at age 9 |
| C2 | 19/F | Child, 19 years |
| N3 | 58/M | No vision left eye, poor residual right eye |
| C3 | 58/M | Friend, 30 years |
| N4 | 55/M | Glaucoma at 9, gradual loss until 18, now no vision (and hearing impaired) |
| C4 | 21/F | Volunteer, < 1 year |
| N5 | 19/F | Fully blind since 13 |
| C5 | 20/F | Volunteer, 2 months |
| N6 | 32/F | ROP, light perception in right eye |
| C6 | 48/F | Friend, 6 years |

#### *4.1.2 Study Method*

After considering several locations, we decided to conduct the study on our college campus (at least for the first iteration). In our prior work we identified several commonly encountered environments as well as noted differences about how to navigate in those places [6]. Our UMBC campus provided a variety of indoor and outdoor spaces in a very close proximity, which would be difficult to find in other locales. Having one location also allowed us to compare our findings across participants.

We designated four locations for participants to explore in different sections of campus: 1) a hallway art gallery, 2) a research laboratory, 3) a sculpture garden outdoor park, and 4) the bookstore and food court in a university center. The first stop simulated a gallery scenario, particularly useful for observing subjective environment descriptions as well as navigation; the second location simulated an office setting; the third highlighted navigation techniques in wooded areas (a particularly difficult terrain); and the last stop simulated a shopping experience as well as a food ordering experience. We intentionally asked participants to arrive in the morning or early afternoon while classes were in session and the food court was busy, again to simulate different environments including crowd density. Since most of these participants had not been to our campus before, it served as an unfamiliar environment for them, presenting the most extreme of navigation scenarios for which one would rely most heavily on a navigation device. Participant N1 is a student; however, he had only been a student a few months at the time of the study and was not familiar with many parts of the route.

In addition to the navigation tasks, participants engaged in three brief interviews during their tour. When participants first arrived on campus we sat them in the lobby of the nearest building to where they arrived and gave sighted companions a paper map with the buildings and suggested routes outlined. We then explained the overall structure of the study (we delayed explaining the study prior to their arrival mostly to gather pre-planning habits). The second interview was conducted in the research lab and we conducted a mini-interview of the blind participant regarding their navigation strategies and challenges as well as gathered each participant's feelings about the study thus far. We allowed participants to clarify if the navigation instructions had been helpful to receive and/or difficult to give out. If necessary, we then let the blind participant express how they would like to navigate in the second half (since usually there was some difficulty). Then participants moved through the final two destinations where they had a final interview after grabbing lunch in the university center.

## 4.2 Findings

Because most of our past data focused on strangers interfering with navigation, we believed our prior-relationship requirement would result in observing successful navigation strategies. However, not being able to use the sighted guide technique (that is, having the blind participant hold the sighted participant's arm) presented many more miscues than anticipated. Only one couple had ever navigated in the independent fashion we designated for the study. Thus, having to verbalize navigation cues that were typically simply inferred by their body movement brought to light many misunderstandings sighted companions had about how cane users navigate. In the end, however, blind participants were able to cope (much like they do with strangers they encounter on a regular basis) and the study resulted in an education for the companions.

### *4.2.1 Misunderstanding "Cues" vs. "Hazards"*

Most especially during the first part of the study (before the mid-interview at the research laboratory) sighted companions attempted to have their blind partners walk the way they would typically walk, or based on their understanding of what was safe.

#### *4.2.1.1 Walking a Straight, Wide Open Path*

Much like what was found in our focus groups and observations, the sighted companions thought navigating in big open paths was the easiest navigation portion. Thus, the sighted companions often told their partners to "just go straight" in a relaxed tone of voice (and used the time to look at their maps) when really this was the most difficult task to do. It was common for the sighted participants to jokingly scold their partners for not walking straight when they began to veer, not realizing that a lack of vision nearly prevents being able to reach a destination in an undefined path without some other form of tactile or verbal feedback.

Not realizing the difficulty of the task of walking in open space, the directions then became a cyclical round of instructions similar to the following: "Go straight, no come left, too far, ugh – just walk straight!" Rather than focusing on the overall directions, companions spent a lot of time and energy trying to nudge participants into walking down the sidewalk and in open spaces in the same straight lines they usually do.

#### *4.2.1.2 Avoiding Helpful Boundaries*

Many companions thought that boundaries were hazards or didn't recognize important navigation cues. Companions also often walked on the right of their partners (away from the natural boundaries) forcing partners to negotiate avoiding the oncoming pedestrian traffic. When we suggested to C5 that she let her partner walk on the right side of the sidewalk she said she didn't want her to walk into the grass (Figure 1). She didn't initially understand that the grass (even if it was lined with bushes for a while) was actually a good cue for keeping straight and also kept her partner from having people walking towards her direct path.

**Figure 1 – During the study, a sighted companion (C5) said she didn't want her partner to walk along the grass area (like as shown) because she saw it as a hazard (not a walking cue).**

At a sidewalk intersection C3 wondered how his partner would "know to turn" without reading the signage indicating the building was to the right. He didn't realize that the fence and the grass line surrounding the path would indicate a curve and upcoming stairs. Later C3 wondered about a slightly angled portion of the sidewalk (somewhat like an "L" shape) and said it was a falling hazard. But N3 clarified that in the sunlight he could see the contrast of the grass and sidewalk and there's no other obstacles that he'd run into anyway (like trees) so walking into the grass wouldn't harm him.

During the walk with N4 and C4 they encountered two trucks blocking a pathway (the path doubles as a driveway for delivery trucks) (Figure 2). While C4 tried to explain how to walk down the center of the trucks, N4 used his cane to tap between the trucks to gather the width. She saw he was hitting the cars and wanted him to stop and just follow her instructions but he instinctively (and correctly) ignored her to make sure he didn't run into any obstacles as he negotiated the path. The companion jokingly scolded him for hitting the cars.

N1 explained the importance of boundaries to his second sighted companion, C1b (Figure 3): "Boundaries are very important. Because when you don't find boundaries then you lose all your direction. I don't have any sign of where I am now, what I'm doing. *[C1b: "Yeah, you don't have a feedback mechanism, right?"]* A very flat area with no boundaries is a place where the blind can easily lose direction."

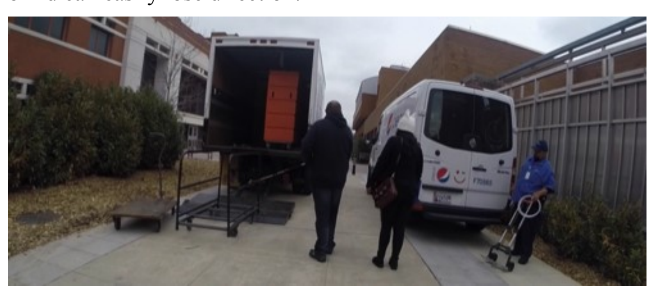

**Figure 2 – As N4 uses his cane to tap between the two trucks to understand the width of the gap, his companion (C4) laughs and admonishes him for "hitting people's cars". She didn't understand his strategy to understand his boundaries.**

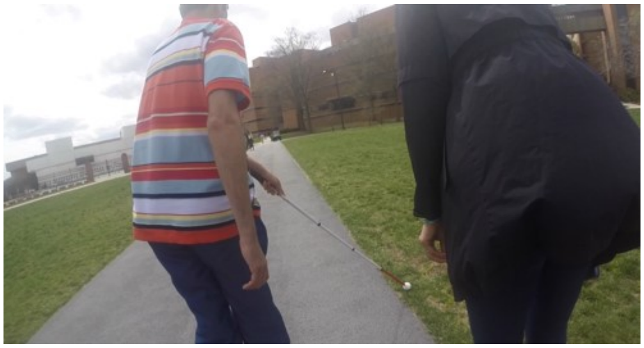

**Figure 3 – N1 shows how he uses a grass line to walk straight.**

### 4.2.2 Sighted People Give Wrong/Bad Directions

N3 put it rather bluntly when he said, "Never trust sighted people." While he was being sarcastic, we did notice that having vision didn't seem to help the companions give accurate directions. While we're mindful that many of the companions were experiencing an overload by having to narrate the navigation experience, there were still surprises in the miscues.

#### 4.2.2.1 Ambiguous Phrases

The companion's directions often incorporated ambiguous phrases such as "here" or "over there" along with the companion pointing in the general direction of the target object – obviously neither of which is helpful for someone who cannot see the visual references to which the phrases apply. Companions would also mix up saying "left" when they meant "right" (and vice versa).

#### 4.2.2.2 Timing

There was also a tendency with companions who were not used to giving verbal instructions to give directions as soon as they saw an item approaching. For example, saying, "We're coming up to some steps on the left" as soon as the sighted companion saw them would cause the blind participant to turn too early. When companions tried to compensate for this by giving distance estimates they were generally inaccurate measurement estimations and often presented with little confidence and in the form of a question, as in "In about 10, maybe 20 feet?"

#### 4.2.2.3 Missing and Misinformation

Companions also didn't know what alerts to give participants such as warning of pending stairs and then announcing the end of the stairs. Companions eventually learned to give this warning after seeing their partners slow down and explore at the junctures. However, C5 told her partner they were done with a flight of stairs while on a long landing, but there were actually 2 more flights. This discouraged her partner (who initially thought she was kidding because she so confidently told him they were done).

While companions did their best to provide their partners with relevant information, there were instances when the most relevant information was missed or what was needed was not understood. As a detailed example, C3 spent time explaining his concern about the handrail being close to the wall (Figure 4) (as opposed to the other hand railing which was more open). Instead he needed to warn N3 that the stairs shifted from normal wide to very long and spread out (information he needed to keep from falling). The companion also allowed him to walk up the left side of the stairs, which made him vulnerable to running into people (as people tend to walk down on the left and up on the right) and then walking next to him took up the entire staircase. Overall he was trying to see things from his visually impaired friend's perspective but missed the mark.

Then, once at the top of the stairs (Figure 5), N3 asks, "What's on the left?" but C3 says, "It's just up here," and points to the destination building and then names buildings in the incorrect order (based on his orientation, not that of his partner).

**Figure 4 – C3 expressed concern that the handrail was close to the brick wall, but didn't warn N3 about the unusual stair length or that he was walking on the wrong side of the stairwell for oncoming traffic.**

**Figure 5 – At the top of the stairs, N3 asks his companion, "What's on the left?" but their differing orientations causes the companion to give incorrect information based on his interpretation of "left" as they stand perpendicular to one another.**

#### 4.2.2.4 Speaking Their Language (Eventually)

Many of the visually impaired participants used the second interview (in the research lab) to educate their partners on what is most helpful to provide given they were not allowed to use the sighted guide technique.

N4 was the most vocal as he began his explanation as soon as we were seated. Their exchange was the most detailed in terms of how each person was feeling during the encounter:

> N4: "If there's something in my way on the ground as long as it's cane level I don't mind hitting it so you don't have to worry about – go to the left a little bit – I can just let the cane hit it and go around it. But the overhead stuff is a different story. "
>
> *[He explains how he uses his cane to trail a wall and uses the grass line to stay straight.]*
>
> C4: "I don't want him to fall over a trash can or something. I know his stick will hit it but I don't want him to fall." *[After more discussion…]* "Do you want me or the stick?"

*[N4 and the researchers explicitly tell her to switch her mode and don't think he's going to fall.]*

C4: "I'll just tell you left, right, and forward and if you hit a wall or a foot that's on you."

*[N4 tells her to clarify between saying "left" for a sharp turn vs. "veer left" for slight body adjustment.]*

C4: "Okay, I'll let you be more independent."

The conversation helped them. Once they left the research laboratory C4 let N4 use the handrail to walk down the stairs (which caused N4 to walk faster than she did). C4 also delayed speaking a landmark on the path (like the stairs) until N4 was very nearby but also pointed out upcoming parts of the path (such as describing a set of steps then a landing then another set of steps). During one exchange she told him "You're gonna hit a grass line" and shifted her position to let him find it to which he responded, "Oh cool." In the final interview he explained that her change in verbal direction cues and allowing him to use the environmental cues helped make the experience much smoother and more enjoyable for him.

Aside from one pair (noted below) all of the other companion pairs had the same type of shift from the first to the second half. Not only were explicit conversations had such as that with N4 and C4, but overhearing the answers to our questions about common navigation strategies educated companions (such as learning how participants hear audio cues or use the change in floor texture to know there's a pending navigation action).

Of note was the second companion pair – the mother/daughter team. Rather than having miscues along the way or a transformation between the first and second half, they grasped the independent navigation task right away. C2 let N2 (her mom) walk independently and guide off environmental cues such as hitting a fence, retaining walls, and grass lines. In the meantime with every new environment they encountered C2 explained the surroundings as they walked. C2 only chimed in with feedback on the mobility portion of the study when it was absolutely necessary (for instance her mom had trouble finding the automatic door opener on one of the doors). When we commented about how comfortable they seemed to be at navigating in this separated manner they explained that this is how they often walk together. The mother had to be independent in order to raise her children and her children have been around an independent blind traveler all their lives so it was a natural occurrence. It was nonetheless interesting to see this type of interaction happen seamlessly and naturally.

#### *4.2.2.5 Coping with Sighted People*

Multiple participants mentioned during the interviews that none of the miscues experienced in our study were different from what they experience with strangers on the street (further confirming our prior findings as well). Due to the common occurrences, they've learned to cope in several ways.

N5 mentioned that she's learned to cope with the incorrect left/right directions by listening for the direction in which a person's head turns, as people tend to look in the direction they want you to go.

Not completely tuning out their other senses, during the study both N3 and N6 heard the beeping sound of the elevator and were able to gather its direction while their companions looked down the hallway or had to first turn a corner to notice it.

N3 explained that he's learned to ask 3 different people for directions before he acts on their advice because he finds people are nice and don't want to tell you "no" so they'll give some information, even if it's wrong.

Much like having to cope in real life navigation as expressed by our prior study participants, partner study participants worked well with their sighted companions to probe for the information they needed, use their own instincts to override bad instructions, and educate their companions along the way.

## 5. DISCUSSION

Our research probes set out to inform the design of new navigation technology for people with vision impairments by first identifying current navigation challenges then exploring possible device features. Our focus group discussions and subsequent diary entries asked participants to recall past navigation occurrences, our single-person observations allowed us to experience the scenarios firsthand, and our partner observations provided device emulation without actual device prototyping and use. Our findings not only contributed to device design considerations but, somewhat unexpectedly, also pointed to broader social implications.

Many of the design considerations that can be inferred from the findings (particularly the partner observations) are similar to any navigation device and application. These include providing optimal timing of giving directions and determining the level of detail to provide (from simply what one is passing to detailed directional cues). Note this is not dissimilar from the findings (explained in the Related Work section) for the collaborative in-car GPS navigation study of Forlizzi, *et al* [2]. However, as expressed in prior work by Swobodzinski and Raubal (also detailed in Related Work), navigation without vision has very unique attributes from navigating with vision [5]. Thus, future systems will need to continue optimizing routes and become smarter about what is considered a "boundary" (such as the wall) versus what is a "hazard" (such as a hole in the ground).

To expand further, many systems are designing for obstacle avoidance but with a view that any object is an "obstacle" and the optimal path is one that is clear and wide open throughout. While this may be an ideal scenario for swifter navigation and less cognitive load in the amount of encounters one has in a given path, this also immensely changes the structure of how a person is taught to navigate and how they "see" the world. To make the point differently, in order for a person to see their environment, their eyes hit objects with light; similarly, in order to navigate without vision, currently a white cane user (literally) hits objects with their cane (and therefore their hand, wrist, and arm). Because the sensation is different, people with vision don't necessarily realize the similarity in needing object feedback in order to map out a path, but it is actually the same concept just experienced differently. Thus, future system designs should either take into account the need for a cane to "just hit" objects or provide enough sensory information to substitute for the lack of visual stimulus.

Our open-ended discussions in the focus groups as well as observations in the wild and with partners also revealed troubling findings around the lack of knowledge about vision impairments and the subsequent interactions that range from awkward to dangerous, particularly with strangers. It appears there is opportunity for more activities to build awareness, advocacy, and empathy within the sighted community. Numerous advocacy groups make great strides in this area in their everyday endeavors but it appears more voices need to carry the message. Social media coupled with multimedia presentation seems a very promising way to reach a wider audience for a group this is large but still a minority in their respective communities. Prior work with emulation software for people with disabilities [1],[3] has also demonstrated strides in building empathy between people with diverse abilities that can lead to better communication, patience, and overall better social interactions.

## 6. CONCLUSION

In our research to understand the needs of people with vision impairments in regards to pedestrian navigation technology, we have uncovered many ways in which blind and sighted persons see navigation tasks very differently. Through our interviews and observations of people with vision impairments, including observations of participants with close sighted companions, we see where assistance from a sighted person can be incorrect and even interfere with safe navigation. Often sighted people are overly concerned about non-threatening hazards and fail to communicate the needed guidance information. We hope that by bringing awareness to these situations we can begin to foster education, empathy, and ultimately better communication between the two groups. We also hope the examples assist other technology designers to prevent these misunderstandings from becoming interface mishaps.

## 7. FUTURE WORK

Our future work includes continuing to conduct partner observations. We wish to include different environments like major cities as well as move to locations outside of our state. This will likely reveal more findings on navigation strategies such as how street crossings are negotiated. We also plan to run the study with more pairings, including with two blind participants. Through continual iterative coding we plan to identify more specific guidelines to contribute for future intelligent navigation aids that build upon the lessons learned from the current human interaction, ensuring the device sees navigation the way the user does.

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