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# Towards More Universal Wayfinding Technologies: Navigation Preferences across Disabilities

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## ABSTRACT

Accessibility researchers have been studying wayfinding technologies for people with disabilities for decades, typically focusing on solutions *within* disability populations—for example, technologies to support blind navigation. Yet, we know little about wayfinding needs *across* disabilities. In this paper, we describe a qualitative interview study examining the urban navigational experiences of 27 people who identified as older adults and/or who had cognitive, visual, hearing, and/or mobility disabilities. We found that many navigation route preferences were shared across disabilities (e.g., desire to avoid carpeted areas), while others diverged or were in tension (e.g., the need to avoid noisy areas while staying near main thoroughfares). To support design for multiple disability groups, we identify four dimensions of navigation preferences—technology, route, assistance, experience—and describe how these might usefully inform design of more universally usable wayfinding technologies.

## Author Keywords

Accessibility; Navigation; Visual Impairment; Mobility Impairment; Cognitive Impairment; Deaf; Older Adults;

## CSS Concepts

• Human-centered computing~Empirical studies in accessibility

## INTRODUCTION

For people with disabilities, navigation in public—to and from school, the workplace, the grocery store, and government offices—is a hard-won legal right, and yet still replete with challenges. Effective navigation can be hindered by inaccessible signage and maps [15], physical spaces that do not comply with legislation (e.g., the US Americans with Disabilities Act [3]), or social factors [2],

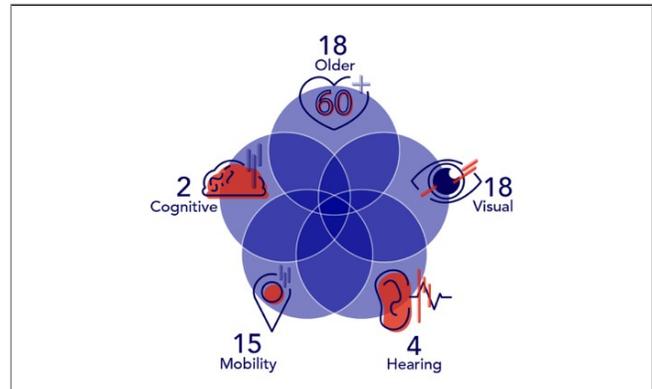
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**Figure 1. Most studies of accessible navigation focus on one disability community. Our study draws on interviews with 27 people who identify as having one or more disability identities (represented by the overlapping segments of this abstract diagram), including from older adults (18 people) to people with vision impairments (18), hearing impairments (4), mobility impairments (15), and cognitive impairments (2).**

rendering them unnavigable. To overcome and route around these and other impediments, many research efforts have sought to support indoor and outdoor navigation for a variety of disability communities. The vast majority of prior work has focused on people with visual impairments (e.g., [2,6-9,15,17,20,24,31,33-35,43-46]), to the near exclusion of people with mobility [12,19,22, 23, 26], hearing or cognitive disabilities [4,38], older adults, or people with multiple disabilities [4,40,41]. While Froehlich et al. [14] call for modeling needs of people with different disabilities, to date there is little information about the shared and divergent navigation needs of people *across* disability groups.

Accessible and assistive technology (AT) researchers often advocate for systems that exhibit universal usability [1,25]. Such systems can be mainstreamed, reducing stigma [38] for people with disabilities, while supporting the widest possible range of users. However, most user-centered design methods do not include people with disabilities except in the rare event that they are a specified “target user,” nor do inclusivity-oriented methods tend to recommend studying more than one disability community at once [42]. These practices seem to run counter to the reality that 12.7% of the US population has one or more

disabilities [26]. So, while the likelihood that a technology will be used by a person from any one disability subpopulation (e.g., people who are blind) may be relatively low, the likelihood of it being used by people with disabilities in general is fairly high.

The present research study answers a recurrent question with an unconventional user population: what navigational challenges do people with varying disabilities encounter, and how can navigation technologies be more effectively designed to meet needs of people *across* disabilities (i.e. are there common preferences among individuals with different disabilities?). To address this question, we conducted an interview study with 27 participants residing in urban environments, regarding their experiences with wayfinding. Each of our participants had one or more of the following disabilities: visual, mobility, cognitive, d/Deaf, and/or identified as an older adult<sup>1</sup> (Figure 1). Participants were asked questions about their travel habits, techniques they use to orient and navigate, challenges they have encountered, and suggestions for future wayfinding technologies.

Interviews revealed the diverse navigation strategies and challenges. Interestingly, people with different disabilities often shared similar route preferences. We present a discussion characterizing wayfinding preferences in design. Four dimensions identified from the analysis—technology, route, assistance, experience—offer promise to the design of universally usable wayfinding technologies.

## **RELATED WORK**

### **Wayfinding for People with Disabilities**

Most studies of wayfinding regarding people with disabilities focus on people with visual impairments. These studies have well-documented the importance of not only technological aids to wayfinding, but also the role of the navigator's low-tech AT (e.g., white cane [43]), skills (O&M training [24,43]), personalities [43], and myriad elements of the context of travel. Navigation strategies and needs vary depending on whether the site of travel is familiar or unfamiliar [8,24,34,43,45]. Especially when the location is unfamiliar, people with vision impairments will plan trips ahead of time, by viewing websites [8,20] or calling ahead [20]. Because people in this population tend not to have access to driving, public transportation is important. Accordingly, many studies have explored how to support access to bus stops [8,15,20,34] and rideshare services [7]. Trust in one's driver, and their ability to drop you off at the correct location is a common issue [7,34].

In wayfinding, people with vision impairments need information about their current location and orientation [17,24]. Positioning with respect to streets and intersections

is one useful cue [8,20]. Challenges arise regarding navigating in a straight line and avoiding obstacles [15,34,43,44,46], especially in large indoor spaces [34,43].

Many visual informational cues along routes can support indoor and outdoor wayfinding. These include street signs [15,17], store names [2,15,35], local area maps [15], bus numbers [15], curbs [8,15], steps [15,35], walking surface texture [24,44], slopes / ramps [35], traffic patterns [15], doors / elevators / escalators / restrooms [2,35], and room numbers [15]. Excessive noise, crowds, and bad weather (especially snow) along routes should be avoided [34,43]. Specific landmarks can be particularly helpful [8,20,24,35]. Because many of these cues are inaccessible or dynamic, it is common for people with vision impairments to either travel with a sighted guide or consult with passersby for assistance [8,43]. Unfortunately, not all others are helpful; frustrating or unsafe situations can arise when others do not understand visual disability or seek to do harm [6,43,44].

Beyond navigation for people with vision impairments, a smaller subset of studies focuses on supporting those with mobility impairments [12,19,22,23,26]. These studies collectively identified information critical for effective indoor and outdoor navigation: presence of curb cuts, leveled ground, steepness of inclines, narrow pathways or obstacles, elevators, ramps, presence of a sidewalk, construction, crowds, and people's attitudes [12,19,22,26].

While we can already see some overlapping needs across users with vision impairments and users with mobility disabilities, there are relatively few studies documenting needs of the latter, not to mention needs of people with other disabilities, like hearing or cognitive impairments. Interestingly, Giudice and Legge [15] observe that: "where an environment can be made accessible for somebody in a wheelchair by removing physical barriers, such as installing a ramp, there is no simple solution for providing access to environmental information for a blind traveler." So, there appears to be an assumption that the nature of navigation support for other disability populations is fundamentally different and requires fewer features. The present study offers empirical evidence to rebut this assumption.

### **Wayfinding for People with Multiple Disabilities**

Few studies explicitly discuss wayfinding needs of multiple disability groups, and those that do tend to focus on people with two disabilities (as opposed to different people with different disabilities). One set of studies is concerned with developing a power wheelchair interface for independent navigation by people with both a cognitive and mobility disability; the authors identified the need for smart collision protection, support for driving in a straight line, and help navigating through narrow, crowded, and unfamiliar areas [40,41]. A study of blind and deaf-blind bus transportation found that users have challenges accessing transit websites, knowing when to get off a bus, using digital wayfinding apps without sacrificing privacy, concerns of safety, need

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<sup>1</sup> While being an older adult is not in and of itself a disability, older adults often have one or more disabilities and unique needs, so we place them in their own category.

for human assistance, challenges communicating with others, and obstacles in streets [4].

Studies regarding older adults or members of a single disability group may include participants who do indeed have a variety of other disabilities. For example, studies of people with vision impairments often include older adults, and vice versa. Giudice and Legge [15] describe the wayfinding needs of people with vision impairments, noting that most vision loss is age-related, so this user population is more likely to have additional needs. However, we have not seen papers like this specify just how these different disabilities alter the needs or experiences of navigation.

### **Accessible Navigation Technologies**

Most research on accessible wayfinding technologies has again focused on people with vision impairments (with exceptions [7]). Technologies used by this population range from mainstream apps like Google Maps or Lyft, to specialized or experimental AT like NearbyExplorer [28], BlindSquare BPS [5], Seeing Eye GPS [17], RightHear [32], pathVu [29], and NavCog3 [35]. While turn-by-turn directions are a common feature in navigation apps, there is a growing understanding that simply providing awareness of nearby Points of Interest (POIs) better supports independence [45]. Accordingly, several apps provide such features. A range of accessible wayfinding apps have been examined by Karimi et al. [21]. The researchers argue for the inclusion of experience-based approaches to navigation (e.g. crowd-sharing accessibility notes about a location) to better support individuals with disabilities.

Due to the technical limitations of indoor environments (e.g., lack of GPS signal), there is a bias towards solutions for *outdoor* navigation. These systems can aid in finding walkable routes through urban areas as well as identifying access points to public transportation (e.g., bus stops [8,20]). However, navigation aids in indoor environments are equally important for users to navigate (e.g. hospitals, schools, federal/state buildings, banks, etc.). To address this need, indoor navigation research has been an area of rapid growth in recent years [2,9,16,27,33,35]. Often these solutions are beacon based [35] and may leverage crowdsourcing to lower the burden of implementation [16].

Apps that are in widespread use, as well as those being built for research purposes, both tend to focus on the needs/preferences of users with one disability. However, considering users with differing disability needs offers the potential to identify overlaps which could be utilized by interface designers to ultimately serve a more diverse audience. We aim to address this gap by conducting a study with individuals with differing disabilities.

## **METHOD**

### **Study Design and Procedure**

We conducted a qualitative interview study examining the urban navigational experiences and preferences of individuals with different disabilities, both indoors and outdoors. We asked participants to specifically reflect upon the places they go, the tools and technologies they use, strategies they employ, and features of (dis)preferred routes, and what improvements they would like to see in future technologies to aid navigation.

We used a semi-structured interview protocol. Questions (see auxiliary materials) were generated iteratively through pilot interviews conducted with individuals recruited through personal and professional networks, who self-identified as older adults (i.e., aged 60 and over), having visual impairments, and/or having other physical impairments. A 36-question interview protocol was developed to probe participants' experiences of planning routes, identifying preferred routes, navigating both indoor and outdoor environments, and the current technologies they utilize. Interviews were conducted in person, by phone, or by Skype audio. Interviews were recorded and fully transcribed.

### **Participant Demographics and Sampling**

A total of 27 participants were recruited for the IRB-approved study. We recruited participants via mailing lists of local disability organizations, followed by snowball sampling. Interviews lasted 60-90 minutes and were fully transcribed. Individuals were carefully screened to ensure that they met the criteria (i.e., being aged 60 or over and/or having a visual impairment and/or physical impairment and/or other disability). All participants were based in the US. Participant demographics are described in Table 1.

### **Analysis of Transcripts**

Inductive thematic analysis was iteratively performed across all interviews. The first and second author met for multiple 1-hour meetings to collaboratively code the first transcript. The first author continued coding individually and generated a codebook after reaching saturation. Six other researchers were trained on the code book and given one interview to code. Then, the first author met with the coders to review the coding for quality and consistency before assigning additional transcripts to each researcher. The first author confirmed that no new codes were emerging from additional transcripts. The number of coded incidents for each discussion point described in the Findings section are included under each subheading. We also note the number of participants from each disability category that expressed each finding; totals may exceed the number of participants (27), as many participants had more than one disability.

ID	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27
Age	23	33	75	86	36	74	62	69	60	33	79	30	67	78	60	47	32	23	66	37	37	29	63	48	36	63	27
GR	M	M	F	M	F	F	F	F	M	F	M	M	F	F	F	M	F	F	M	M	M	F	M	M	F	F	F
VI		✓				✓			✓			✓	✓		✓				✓*	✓	✓*		✓*	✓	✓*	✓	✓
MI	✓				✓	✓*	✓		✓	✓					✓*		✓	✓*		✓		✓		✓			
HI				✓*		✓*									✓*	✓											
CI								✓*						✓*													
OA			✓	✓		✓	✓	✓	✓		✓		✓	✓	✓				✓				✓			✓	
FDT	D	D	D	D	D	D	D	FD			FD		FD	W	FD						FD			FD		FD	

**Table 1. Participant demographics.** GR = Gender, VI = Visual Impairment, MI = Mobility Impairment, HI = Hearing Impairment, CI = Cognitive Impairment, OA = Older Adult, \* = Late Onset of Disability FDT = Frequency of Day Trips (Where Described), D = Daily, FD = Every Few Days, W = Weekly.

## FINDINGS

### Gathering Route Information

#### Planning for Unfamiliar Environments

(71 incidents. 14 VI, 12 MI, 4 HI, 1 CI, 12 OA)

26 participants shared that they conduct research before visiting locations to obtain information, both about the planned route and the accessibility of the location. These information gathering techniques include: calling building personnel to ask about the accessibility of the location and planned route, visually assessing the building beforehand in person, or searching the building online. Participants indicated that they use many techniques when searching online out of necessity, as the information is not always readily available. Techniques include visiting: the official website of the space to receive information from the source; crowd-sourced review forums (e.g., Yelp, TripAdvisor) to analyze what others have experienced; and Google Street View to visually assess the accessibility of the entrance.

However, even when these measures are taken, many participants felt the information gathered was insufficient or incorrect. 17 participants expressed that accessibility information was often out-of-date, vague, or nonexistent.

“I have to just go and hope for the best because that feature [locating accessible entrances] of Google Maps is not accessible to me.” – P12 (VI)

This has resulted in some cases where participants were unable to reach their destination, causing frustration. Participants indicated that they use a variety of technologies in order to circumvent situations such as these. When asked about their receptiveness to experimenting with newer navigational technologies, 6 participants preferred exploring these newer technologies, and 21 participants expressed a preference for familiar technologies.

“If it works after time, then it decreases my stress and it becomes easier and easier to use. [Adopting a new technology] is difficult and more challenging, so I’ll be less motivated to use it.” – P06 (OA+VI+MI+HI)

In contrast to the 26 participants that indicated planning ahead when venturing to new environments, only 16 participants stated that this is their preferred method of travel; they enjoy planning and/or are comforted by conducting the research themselves. 11 participants (10 of whom expressed their experience of extensively planning for visiting unfamiliar environments) articulated that they only do this planning out of necessity. They would prefer to take more spontaneous trips (e.g. opening a navigation application when beginning their trip).

#### Planning for Familiar Environments

(64 incidents. 14 VI, 12 MI, 4 HI, 1 CI, 12 OA)

The section above highlights what was said about visiting unfamiliar locations. Participants shared that these techniques often shift once they become more familiar with an environment. Rather than calling ahead, usually no research would be done. 12 participants indicated that they would continue to do a quick online scan if there is a possibility an event being is held at that location or construction is ongoing that could disturb navigation.

#### Others’ Misunderstanding of Accessibility

Participants reported that others’ lack of lived disability experience can lead to large gaps in communication between those with and without disabilities that affect mobility.

#### Misleading Accessibility Information

(39 incidents. 14 VI, 11 MI, 2 HI, 8 OA)

Participants indicated many situations in which they asked for route information in the form of a general overview or step-by-step directions and received answers that were misleading and/or unhelpful (n=20). Places would often claim to be fully accessible when, in fact, they were not. Barriers that seem small to some are impassable for others:

“Sometimes they will say ‘it’s accessible’, and then there’s a step to the entrance. If there is one step, that means it’s not accessible.” – P17 (MI)

#### Nonsensical Directions

(44 incidents. 11 VI, 8 MI, 3 HI, 1 CI, 9 OA)

When navigating in a new and/or complex space, directions are often necessary to reach a destination. Participants indicated asking others in the vicinity questions when they are disoriented or when they are unable to find their destination. Some participants shared that this is something that comes easy to them, while others stated that asking others for directions makes them uncomfortable and it is used as a last resort.

“I hate asking people for help. I only do it when I need it. [Only after trying several times to reach a destination] I get so frustrated that I will ask somebody for help... I feel so embarrassed when this happens.” P09 (OA+VI+MI)

However, regardless of if they fell into either category, a significant number of participants spoke about the low quality of directions that they have received. 15 participants recalled situations where directions received from others were not suited to their needs. One participant, an older adult with a visual impairment, recounts:

“I had an Amtrak person say to me ‘oh, the train is right over there.’ I mean it’s sort of funny. People don’t think about the language they use, you know. Words matter.” – P06 (VI+MI+HI+OA)

These situations force the navigator to either keep prompting for more specific directions, or find someone else to aid them. When asked about what directions would be meaningful to them, 24 said that using landmarks (see ‘Landmarks’ section) and/or east-west directions (see ‘Preferred Layouts and Floor Textures’ section) were best. 14 participants prefer to rely on directions from known people for this reason. They know that they will receive specific and meaningful directions. However, when asked about what they would *prefer* to do rather than what they *need* to do in order to receive proper navigational instructions, only 9 participants expressed that they would prefer to receive directions from others whereas 18 would like solely technological assistance.

#### *Lack of Empathy/Understanding*

*(80 incidents. 12 VI, 9 MI, 4 HI, 2 CI, 9 OA)*

19 participants relayed that they felt others without apparent disabilities were not empathetic in certain situations. One recurring situation was when a participant would have to find a workaround to a type of inaccessibility that is inconvenient, and sometimes unsafe, to them and the people around them. One participant, an older adult who is a wheelchair user and double amputee, recalls a perfect example of this:

“I recently used the Metro, and I had to get to a presentation. The elevator was out of commission, so I had these guys stand behind me and support me on the escalator. They almost tripped, which almost made us all fall down. People in the Metro were screaming at me, and I’m like ‘Fix your damn elevator!’” – P07 (OA+MI)

Another aspect of this lack of empathy is when business/building owners do not respond to complaints from visitors about accessibility issues. 11 participants felt that for larger organizations (e.g., the Washington D.C. metro, chain stores) it was difficult to report their claims of inaccessibility and be certain that their concerns are being heard and taken seriously. These participants felt that for smaller organizations (e.g., boutiques, mom-and-pop stores) it was easier to voice their opinions, but the lack of oversight from a larger company made it much less likely that the business/building would modify themselves based on the complaint.

#### **Infrastructure Features that Affect Mobility**

##### *Preferred Layouts and Floor Textures*

*(53 incidents. 12 VI, 9 MI, 2 HI, 1 CI, 8 OA)*

Carpeted areas were a source for much frustration for participants across groups. 9 out of 12 participants with mobility impairments shared that the presence of carpet on a route can cause struggle when using both manual and power wheelchairs. A manual wheelchair on carpet causes the user’s arms to tire and get strained very quickly, and power wheelchairs’ batteries would be put under much stress and lose power quickly.

“Carpet is my enemy... Rolling on carpet is the worst no matter what form of wheelchair you have. It’s either killing my shoulders or killing my battery.” – P10 (MI)

12 of 14 participants with visual impairments claimed that carpet deafens the echo of their white cane. Many white cane users use the echo of that device in order to orient themselves and develop a mental model of their surroundings. Without this echo, it is more difficult to pick up on certain elements of the building (e.g. doors, large rooms).

16 participants also shared a preference for grid layouts, both indoors and outdoors. Those with visual impairments stated that it is simpler to navigate in this type of environment rather than one with curves and foot traffic circles. Many of these participants spoke about how it is hard for them to continue moving in a straight line when walking, so the lack of complexity that a grid layout provides is a welcome constraint. Navigating using cardinal directions is also something participants were taught in orientation and mobility training. Those with mobility impairments articulated that it is easier to maneuver their chairs in a grid layout, though with the stipulation that there must be enough room for maneuvering:

“I tend to stay in more urban areas that have more angular street setups; where there’s an identifiable North-South-East-West kind of thing. Whereas in suburbia you have street curves and street circles.” – P20 (VI+MI)

Older adults without these disabilities echoed this claim that grid layouts are easier to understand and more intuitive to navigate within.

***Insufficient Accessible Infrastructure***  
(93 incidents. 11 VI, 12 MI, 3 HI, 11 OA)

Because of legislation such as the Americans with Disabilities Act, public buildings in the US must meet a certain threshold of accessibility [3]. Participants felt that most did not go beyond minimum compliance standards when designing the layout of buildings. Several stated that the infrastructure of most buildings would not support mobility of many more than a single person with the same disability in a space. For example, one participant recalled an event with many mobility impaired and visually impaired visitors. With only one elevator in the small building, many had to be escorted to the freight elevator that was used for the kitchen. This participant recalled this experience as being inconvenient and humiliating.

Along with the emotional toll, lack of infrastructure can also pose a significant inconvenience and safety threat. When infrastructure that the navigator was previously relying on fails (e.g., an out-of-order elevator), it creates an extra burden, as they must adapt their route. On-the-fly route adaptations can be especially difficult to those with disabilities. There are some instances when that piece of infrastructure was the only step allowing them to reach their destination (e.g., a well-lit hallway, a working elevator). There are other instances when this failure or lacking poses a safety threat, as we saw with P07 when a broken elevator required a dangerous balancing act on the escalator. This concern was related often to small, privately-owned businesses that do not have oversight or cannot afford to continuously attend to infrastructure issues. Older buildings that were built when there was not a general understanding of accessible design are also regular culprits. Again, this oversight can cause instances of failures to reach certain destinations.

***Stairs vs. Ramps vs. Elevators***  
(102 incidents. 14 VI, 12 MI, 4 HI, 1 CI, 12 OA)

One area of great importance to navigation is the ability to navigate buildings with multiple floors. Participants varied in their response to questions about their preferences of how to accomplish this feat. A general consensus was reached on stairs; most participants avoid stairs. Most with mobility impairments cannot physically use stairs, 13 with visual impairments shared a concern for safety when using stairs regardless of if they have functioning vision, 3 older adults reported feeling winded, and 1 older adult with a cognitive impairment expressed that her troubled balance makes utilizing stairs dangerous. Two participants (P05 and P09) compounded this statement by adding that they avoid even going *near* stairs out of concern for their safety:

“I have a fear that... [if a passerby bumps my hand and] I have the joystick accelerate near [stairs], that I will roll off the stairs.” – P05 (MI)

One way participants avoid using stairs is by seeking out alternatives. Participants emphasized that they will seek out ramps even if this takes more time or draws attention to themselves. However, 8 participants with mobility impairments avoid ramps that are steep. Another approach to avoiding stairs is through the use of elevators.

Conversely, 4 participants with visual impairments and 1 with a cognitive impairment preferred the use of stairs because of their efficiency.

“I’m fine on stairs... most people assume I’m not, and that’s kind of frustrating. Routes with stairs can oftentimes be more direct...and I do whatever’s easiest.” – P19 (OA+VI)

Therefore, many stated that they would like to be notified of the locations of stairs, ramps, and elevators upon entrance to a building.

***Crowds***  
(57 incidents. 12 VI, 9 MI, 3 HI, 1 CI, 10 OA)

18 participants with visual, mobility, hearing, and cognitive impairments and older adults expressed an avoidance of crowds. Participants in all categories explained that the presence of a crowd causes many moving obstacles that can be difficult to navigate around. Those with mobility impairments stated that these moving obstacles create a space in which it is difficult to maneuver a wheelchair. Those with visual impairments further shared that the noise from crowds disrupts their ability to hear the echoes of the white cane and thus causes disorientation. Visually impaired participants also stated that they have encountered more cases of others intrusively offering unwanted help during these situations. Participants with hearing impairments found that the noise resulting from crowds disrupts their functioning hearing and can interfere with their hearing aids, causing a loss of that sense. The participant with a cognitive impairment relayed that crowds can be cognitively overwhelming and can cause a lapse in ability to functionally navigate. Older adults without these disabilities expressed their desire to avoid crowds as a matter of aesthetic preference rather than need; quieter, more scenic routes may be preferred even if they are longer.

Conversely, 5 participants reported that they would rather travel on a crowded route than a route without anyone else. This is due to a concern for personal safety. Some participants also expressed that, in case of confusion or failure to find their destination, they like having the option of asking for navigation assistance or guidance about features of the building.

***Obstacles***

***Construction***  
(53 incidents. 10 VI, 11 MI, 3 HI, 1 CI, 12 OA)

Participants often reacted with much frustration when explaining their experiences of encountering construction during navigation. Many remarked that construction is very

disruptive, as it is something for which one cannot always plan. The presence of construction brings about many problems. The first being that often one's planned route of travel is blocked. This causes the need to backtrack and find another accessible route, thus creating an extra burden on the part of the navigator. One participant, an older adult with a mobility impairment, recalled such an incident:

"I mean you can't ever get to downtown K Street with all the construction... they get rid of the curb cut.... They've got all the cones, so you've got to go backtrack, go around and find something—whereas everybody else just steps down and keeps going." – P07 (OA+MI)

This quote highlights both the inconvenience and inequality associated with this construction. Further, many participants with visual and/or hearing impairments explained that the noise resulting from some construction can impact their ability to navigate. It can inhibit them from using their sense of hearing for navigation (e.g., listening to traffic, hearing audio instructions), and it can disrupt the effectiveness of their hearing aids.

#### **Other Obstacles**

*(78 incidents. 14 VI, 6 MI, 3 HI, 8 OA)*

There are many objects, stationary or mobile, that can create physical barriers from navigation. Indoor examples include: furniture, decorations, or any small objects that do not appear on maps of the building. One type of area, in particular, that participants indicated struggling with, are food courts. These spaces have many moving objects (e.g. chairs, tables, people), and there is often little assistance available. Outdoor examples of obstacles described included: tree roots, food carts, and garbage bins. The presence of these obstacles requires the navigator to maintain constant vigilance, as the positions can vary.

#### **Landmarks**

*(84 incidents. 14 VI, 12 MI, 3 HI, 1 CI, 11 OA)*

Most participants, 24 out of 27, emphasized landmarks as imperative aspects of their navigation. In fact, many relied mainly on landmarks for orientation. Landmarks include: significant buildings, changes in floor texture or lighting, sounds, etc. P27 used the example of a mall to describe this (e.g. echo of cane at store openings, smell of the food court). Another participant, an older adult, recalls how they use landmarks during their daily navigation:

"I like to look at a map and memorize where major streets and landmarks are. [When navigating] I'd say 'go straight at this tall building, turn right at this fountain.'" – P11 (OA)

6 participants went as far as to describe landmarks as more meaningful to them than distance-based instructions (e.g., "take a right turn at the corner after the bright, blue building" as opposed to "take a left in 300 ft.").

#### **Inhospitable Conditions**

##### **Weather**

*(44 incidents. 9 VI, 8 MI, 2 HI, 6 OA)*

The impact of inclement weather includes a set of issues that can affect those with disabilities in a much more significant way. One important aspect of accessibility is the presence of curb cuts (i.e., purposeful dips in the sidewalk that lead to the road). 9 participants indicated that these curb cuts and other accessible features are often blocked after snow falls and the sidewalk/streets have been plowed.

"They cleared the snow on the sidewalk by putting it all into the curb cut. It's amazing! They also tend to do this in parking lots. They clear the snow in the parking lot, mounding the snow in the accessible parking [spaces]." – P10 (MI)

8 participants also shared that they avoid outside travel when there is ice on the ground. This was particularly mentioned by many older adults with visual impairments, who expressed a fear of not sensing the ice and having the potential of a bad fall.

##### **Noise**

*(49 incidents. 14 VI, 6 MI, 3 HI, 1 CI, 7 OA)*

As mentioned in the section on 'construction' above, noise can be very disruptive in navigation. 17 participants with visual and hearing impairments indicated that they avoid paths with significant noise as it hinders their ability to use their sense of hearing to orient themselves.

"I avoid [navigating near] highways. It's the noise factor. I can't hear the cross... That throws me to pieces and then I'm just about deaf." – P15 (VI+MI+HI+OA)

The 2 participants with both visual and hearing impairments emphasized this disruption significantly. 4 older adults added to this by sharing that they are more likely to take a quieter route out of preference even if it is longer. This preference is related to a desire for a more pleasant experience.

Conversely, 8 participants with visual impairments and 1 older adult stated that sounds, like the traffic discussed in the previous quote, can help, rather than hinder, their orientation.

"[When travelling] traffic is a good cue to keep me straight. I have the building on one side, and the street on the other." – P13 (OA+VI)

#### **DISCUSSION**

While accessibility researchers have run numerous studies on wayfinding technologies [2,4,6-9,15,17,19,20,24,31,33-35,40,41,43-46]), the vast majority have considered the needs of individuals with only one disability. Even when the populations we study include additional dimensions of disability, we rarely discuss the impact of these in our findings, though there are some notable exceptions (e.g.,

[4,40,41]). Consequently, researchers have a relatively limited understanding of how navigation technologies designed for one disability might (fail to) support the needs of another.

As described in the Limitations section below, some disability groups, like people with cognitive impairments (CI) or hearing impairments (HI), were underrepresented in our participant population. Despite this, 6 of 14 themes included perspectives of people with CI, and all 14 themes included perspectives of those with HI. For participants identifying with multiple disabilities, just like people with either HI and visual impairments (VI), the presence of HI altered their experience. For example, traffic sounds that were reported to be an orientation aid to people with VI proved to be a disruption to hearing aids and mask already limited hearing for those with HI. Generally, the navigation experiences of people with CI, HI, or multiple disabilities were captured by the themes in our findings, yet each group had slightly different embodied experiences. The experiences of those participants from underrepresented groups also point towards the creation of additional themes, such as a need expressed by participants with CI to be repeatedly reminded of next steps, that were not captured in our findings because of the low code count. In future work that includes more people with CI and HI, we might expect to see existing themes further supported, as well as the emergence of new categories altogether.

In sections below, we distill our findings and put them in conversation with prior work to demonstrate that (1) despite divergent experiences, there are a surprising number of shared mobility needs across disabilities, though (2) sometimes needs are divergent and conflict. We end with thoughts on (3) how and (4) why we ought to further explore navigation needs across disability in design, towards more universally usable wayfinding technologies.

### **Shared Preferences Across Disabilities**

We were surprised to find that, despite the wide range of disabilities of our 27 participants, many of their challenges and preferences were aligned. Moreover, because of this overlap, prior work focusing on singular disability groups has surfaced most of the high-level navigation needs that we describe here. The difference, and part of the value added by our study, is that in several cases, the *experiences* behind the challenges and preferences varied widely. We describe some of these below.

As previously documented regarding users with visual impairments and mobility impairments [4,15,19,43,45], we found that planning routes was common when preparing to navigate in unfamiliar environments; this included making visits to the site in advance, giving a call ahead, and looking online for more information. However, information is often out-of-date, and some circumstances—like elevator outages, construction noise, or snow embankments—can change status rapidly with significant consequences for travel (previously documented regarding individuals with

visual impairments [18,44]). Accessibility means different things to different people, so our participants found others, particularly those without apparent disabilities, to be unreliable sources of accessibility information (noted in prior work regarding individuals with visual impairments [18,44]); some avoided asking others for information altogether. Because of this and various personality factors, 18 participants stated that they would prefer to rely solely on the instruction of technology. Relatedly, when accessibility issues do arise during travel, potential allies often fail to empathize and act, or worse, become hostile (also known to be an issue for individuals with visual impairments [44]). These findings are in line with initiatives like Project Sidewalk [7], which seek to provide more timely, reliable updates and to educate the public about disability and access.

When navigating routes, participants encountered many “features” about which it would be useful to have more information. Like prior work [24,43,44], we found that people who use white canes value navigation signposts regarding transitions in flooring textures, as when the tile gives way to carpet. Extending prior work [19,20], we found that flooring information is valuable to power and manual wheelchair users. Across populations, carpet tends to be the “enemy,” but the experience differs based on disability. For wheelchair users, carpet takes extra energy to traverse, and for those with visual impairments, it dampens the echo of their white cane.

Many participants also preferred to avoid stairs, which has been thoroughly documented in studies of people with visual and mobility impairments [18,19,46]. However, the reasoning behind this preference varied across disability: they are inaccessible to wheelchair and walker users, they can aggravate knee pain or make older adults winded, they can affect the balance of people with cognitive impairments, and they can be dangerous to people with low depth perception, particularly when the person is travelling downstairs. Interestingly, we also found that people wanted to avoid routes that are merely *adjacent to* stairs, to reduce the risk of increased injury if they fall or are incidentally pushed by passersby.

As a final example, crowds along routes were a pain point for many participants, a fact that has also been documented in the context of navigation for people with visual, mobility, and cognitive impairments [8,19,20,32]. Crowds encroach on space needed for wheelchair passage. They can nudge a walking cane out from under someone, interfere with power wheelchair controls, or occlude or damage white canes. The noise from crowds can disorient people with vision impairments, limiting the use of an important alternative senses, and can be particularly harmful for people with both visual and hearing impairments. Further, it can generally make a route unpleasant, as stated by participants from all disability groups. They can ultimately

put people with various disabilities in uncomfortable or unsafe positions, often requiring them to backtrack.

### **Divergent Preferences Across Disabilities**

As described above, people across disabilities want to plan their routes around common “features,” like carpet, stairs, and crowds. However, they did not universally want to avoid or seek out such features. Rather, needs varied from person to person, and sometimes an individual’s own preferences were in tension. For example, participants with mobility and visual impairments, and older adults, expressed a preference for ramps over stairs. Reasons cited included wheelchair access, increased risk due to low depth perception or blindness, and joint pain, respectively. However, and somewhat counterintuitively, some wheelchair users preferred to *avoid* ramps because of the prevalence of ADA-noncompliant ramps that are too steep or texturally uneven.

Landmarks that make sound (like fountains or speakers playing noises) were reported to be particularly useful by people with vision impairments, but they also mask other sounds that are important for orientation. Furthermore, features like signposts or planted trees are “landmarks” for some users (e.g. older adults and people with vision impairments) and “obstacles” for others (e.g. users with mobility impairments or more significant vision impairments).

As a final example, findings suggest that participants prefer scenic or more peaceful routes that avoid highways and busy intersections. This was particularly true for people with hearing impairments (including those who also have vision impairments), as traffic sounds can be overwhelming, limit their functioning hearing, and disrupt their other senses (like smell and touch of the white cane). Yet, well-trafficked streets also provide utility to visually impaired participants who use their hearing to walk a straight line.

In sum, a “route feature” that provides accessibility for one can simultaneously pose a safety risk for another. Moreover, trade-offs exist when choosing routes that seek out or avoid certain features. These findings highlight the need for customization within navigation technologies to tailor the experience to users’ specific preferences, contexts, and changing abilities.

### **Characterizing Users’ Wayfinding Preferences in Design**

A primary insight gained from this interview study is that navigational preferences and needs transcend singular disabilities. This suggests that representations of users in an accessible wayfinding design process might center about something *other than* disability (e.g., the visually impaired navigator, the mobility impaired navigator, etc.). For example, user representations might focus on cross-cutting characteristics that impact preferred wayfinding activities (the technophile, the planner). Inspired by the approach taken by Williams et al. [44], we have derived four pairs of

opposing traits that differentiate the various “characters” or “personas” we encountered in our study: technology (familiar vs. latest), route (planned vs. spontaneous), assistance (human vs. technological), and experience (enjoyable vs. efficient). We systematically assigned traits to each of our 27 participants according to preferences they shared in their interviews. We believe these traits produce a sort of wayfinding preference schema that may usefully guide design. We define each pair of traits briefly below.

#### *Assistance: Human vs. Technological (H vs. T)*

This describes from where the user prefers to receive their navigational information. Do they like to call the front desk of a building, utilize personal guides, or ask for assistance from nearby pedestrians? Would they rather utilize navigational apps or online websites? 9 participants tended to prefer using human assistance, and 18 preferred technological assistance.

#### *Route: Planned vs. Spontaneous (P vs. S)*

This trait explains how and when the user would like to receive their navigation assistance. Do they research various routes and schedules in advance, or would they prefer to quickly utilize their navigational application on the way out of the door? 16 participants preferred planned routes and 11 preferred spontaneous routes.

#### *Technology: Familiar vs. Latest (F vs. L)*

This reflects users’ willingness to adopt new navigational technologies. Would this user be inclined to learn new forms of navigational technologies, or would they like new features to come as an extension to familiar applications? 21 participants preferred familiar technology and 6 preferred the latest technology.

#### *Experience: Enjoyable vs. Efficient (En vs. Ef)*

Does this user prefer a route that is more tailored to their specific needs (e.g. without stairs, less crowded), or are they more concerned with reaching their destination in the shortest amount of time? 10 participants preferred efficient routes and 17 preferred more enjoyable routes.

We found this schema easy to apply to our participants based on our interview data. For example, we characterized P01 as a TPLeF (technological assistance, planned route, latest technology, efficient experience) because he likes to plan routes multiple days in advance to account for his needs (e.g. accessible public transportation, accessible buildings), is eager in adopting new technologies and enjoys doing so, and puts more value on taking the most efficient route vs. the most enjoyable. Note that these classifications denote general preferences that can change based upon the situation. For example, even though P01 sometimes preferred the most efficient route, he stated “[The efficient route] only works if I’m going by train or bus, or else there are a lot of [accessibility] problems”. Across all 27 participants, only seven unique profiles emerged from the possible 16 unique trait combinations. The most prevalent characterizations (representing more than two participants) were HPFEn (9 participants), TSFEf

(8 participants), TPFEn (3 participants), and TPLEn (3 participants). We are currently developing four user personas [10] based on our interviews and the four most prevalent preference profiles listed above. Our drafts<sup>2</sup> of these personas are available for use and adaptation.

### **Towards More Universal Wayfinding Technologies**

The most prevalent mobility applications used by our participants were Google Maps and Nearby Explorer. Although Google Maps is not strictly an application for accessibility, it does contain a feature that allows for the choice of a wheelchair accessible path, but these only work through transit hubs, and our participants found them inaccurate. Not all of our participants with vision impairments were familiar with the Nearby Explorer app. While it does support both turn-by-turn and point of interest navigation, it does not currently include other features to support people with different disabilities. Our findings identify opportunities to expand on features in current wayfinding technologies such as these.

While the default behavior of these apps is to route users according to efficiency, many of our participants indicated that they are willing to take a longer route, both in distance and time, if that route avoids certain features (e.g., stairs, carpet) or is more pleasant (e.g., scenic, less noisy). New customization features might support distance-based directions as just one option, while also offering general orientation directions (like Nearby Explorer) that leverage landmarks (e.g., significant buildings, shifts in elevation). Beyond identifying pathways that are accessible, apps should indicate whether routes can accommodate multiple people with disabilities, which may especially be beneficial when members of the disability community want to congregate. Routing apps generally stop navigation instructions at the exterior of a building, but people with disabilities want to know where stairs, ramps, and elevators are when entering a building. Finally, routing apps might prefer routes with grid layouts, both indoors and outdoors.

Some recommendations provided above are simple to implement, while others require significant technological, infrastructural, and social innovations. But, often the most challenging aspect of realizing accessible applications is making it a priority within corporate settings where robust products can come to market ([30,36,37]). Wentz et al. [42], citing Maskery [25], identify misconceptions among industry professionals as a significant impediment; among these misconceptions is a belief that accessible interfaces will (1) “only serve a small market,” (2) “never meet the needs of each different disability,” and (3) “make the product worse for all other users.”

Perhaps the approach used in our study—to include people from multiple disabilities—can help rebut these rationales during design scoping in industrial settings. As an example,

our study found that avoiding crowds was not only important to people with vision impairments (at present, roughly 2% of the US population), but also for older adults and people with mobility (~6.5%), hearing (~3%), and cognitive (~5%) disabilities [13]. These subpopulations are not mutually exclusive, but collectively they represent a sizeable market (rebutting claim 1 above). This one feature may help members from multiple disability groups, improving the product across several user groups (rebutting claims 2 and 3 above). Running studies that engage members from within a single disability group may entail a simpler recruiting strategy, require less breadth of disability expertise for researchers, require fewer accommodations and modifications to study methods, etc. But, a strength of studies that investigate usability across disabilities may well be the ability to prioritize and advocate for features that are likely to benefit a broad range of users.

### **LIMITATIONS**

Many of the limitations of this study arise as a result of the nature of research involving participants of many disabilities. Although 27 participants comprise a fairly large sample for a qualitative interview study, one or two members of a disability subpopulation cannot represent the diversity of all members of that population. For example, we only had two participants with cognitive impairments, and this population includes an estimated 15 million people with extremely diverse needs in the United States alone [13]. Additionally, due to gaps in our recruiting networks, our participant sample is imbalanced, such that we had significantly more participants who were older adults or who had visual impairments or mobility impairments, as compared to hearing and cognitive impairments. This distribution does not proportionately represent the population as described by the US Census [39]. We also did not include interview questions about unique issues arising from intersectional [11, 36] disability identities, although it became apparent during interviews that having multiple disabilities constitutes a unique experience of wayfinding. Consequently, our findings speak to high-level needs regarding wayfinding routes, and there is much to be explored in future work.

### **CONCLUSION**

Our study has focused on the navigational experiences of 27 individuals with varying disability identities. Through a structured set of interviews, a range of themes have been identified that, if considered by designers, may benefit a broader range of individuals. The work has highlighted that similar route features are valued by those across disability groups. In future work, we plan to broaden our understanding of navigational challenges for individuals with cognitive impairments and individuals who use different forms of walking aids (e.g., rollators, electric mobility scooters), as strategies may vary from wheelchair users, as these aids may be used for specific tasks (e.g., navigating around stores, etc.). We also plan to explore, specifically, the navigational needs and challenges of users

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<sup>2</sup> <https://www.ics.uci.edu/~sbranhm/data/personas.zip>

with intersecting disabilities, and emergent theme from this work.

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