Mind Your Step: A diary study about navigating a city with a smart cane by a visually impaired person

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Abstract. Several studies have documented the navigation requirements and preferences of people with visual impairments. The primary methods used in such studies were interviews and surveys. With the same goal, this study employed a diary-based approach. A visually impaired person recorded daily navigation experiences with a smart cane for three months. These first-person diary entries were analyzed, and the findings are reported herein. The paper sheds some light on the challenges people with visual impairments face in navigating an urban city. The study shows some limitations with smart canes for urban navigation and suggests that more consideration should be given to the visually impaired for navigating in public environments.

Keywords: navigation · experience · accessibility · blind · visually impaired · urban city · smart cane · diary.

1 Introduction

One of the challenges faced by people with visual impairments is independent navigation and mobility. People with visual impairments have been using various traditional navigation aids such as white canes, guide dogs, and assistance from sighted human guides [4]. But still, many people could have concerns about navigation-related activities that intimidate them from going out for social events and interactions [11].

Independent navigation is *sine qua non* for a self-sustaining living of human beings [6]. Subsequently, additional information regarding obstacles and scenes could make navigation easier and seamless for the visually impaired [3, 12]. Various tools and systems are introduced commercially or as research prototypes to assist the navigation of the visually impaired [11]. However, many of these technology-based aids could not fully meet the needs and requirements of individuals with visual impairments either because of portability-related issues or the absence of some particular feature support (such as obstacle identification)

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[13, 19]. Moreover, the usage of such assistive systems is still a moot point on how helpful they are or whether they will work as they claim when the user with visual impairment navigates even in a modern urban city [11].

Several national and state governments worldwide have systems and guidelines to provide a universally accessible navigation environment [5]. Moreover, various associations, such as World Blind Union (WBU), promote various global campaigns to advocate for inclusive and accessible Urban Development [25]. However, people with visual impairments still face difficulties navigating even in an urban city [7, 22]. In the Sustainable Development Goals (SDGs) 2030 Agenda, the United Nations emphasizes universal and equitable access. All SDGs are interconnected and hold implications for inclusive, safe, resilient, and sustainable cities, which require improving access to navigation, public transport, etc. [24].

To understand the distinctive user interface requirements for indoor navigation, Puikkonen et al. [17] conducted a user study involving 23 visually impaired participants. This case study presented a few recommendations for the design of indoor navigation systems. A formative research was conducted by Williams et al. [26] to learn how people with vision impairments navigate using technology. The findings from interviews with vision impairments gave insights into everyday navigation challenges, perspectives about technologies, and the role of social interactions while navigating. A qualitative study was done in [16] involving 14 people who are legally blind to understand the experiences and strategies used when navigating a metropolitan area. The study suggested that designers should be aware that infrastructure shortcomings and environmental factors might be considered while designing assistive navigational technologies in some geographical regions.

To develop technologies to support independent navigation for the visually impaired, it is indispensable to understand the facts and actual issues that users experience and what behaviors and strategies are used to overcome such problems [2, 18, 20]. Several studies reported using white and smart canes in controlled environments with constrained periods [14, 15, 23]. For a contextual understanding of user behaviors and experiences over time, it can be not easy to appropriately create scenarios in a lab setting to gather valuable insights in a real-life environment [10]. These reasons led to choosing a diary-based approach in our study to understand the navigation challenges faced by a person with visual impairments in real-life indoor-outdoor environments. In a diary study, participants self-report data longitudinally or over an extended period ranging from a few days to even a month or longer. During the defined reporting period, study participants are asked to keep a diary and log specific information about the studied activities.

Qualitative data can be collected in several representative ways, including observations, surveys, and interviews. Nevertheless, people with visual impairment tend to be reluctant to be observed for fear of infringement of privacy [9]. Furthermore, researchers find observations to be time-consuming. Also, it is more difficult to collect detailed experiences from surveys than from diaries.

An interview may limit participants' ability to recall past experiences within a limited time frame. Also, interviews might make it hard for them to remember problems from the experiences to which they have become accustomed [1, 8]. The context and period in which data is collected for a diary study make them unlike other standard user-research methods, such as surveys or usability tests. Although the diary method is practical for gathering experiences from people with visual impairment, using it without considering their characteristics could be inefficient and difficult to generate meaningful findings [9].

Through our diary-based study, the daily navigation experience of a person who is legally blind navigating an unfamiliar city using one of their familiar navigation tools, a smart cane, is presented. Recently we have been witnessing some drastic changes in the urban navigation environment due to the emergence of micro-transportation amenities such as e-bikes and multitudinous structural changes to the public environments such as road maintenance and cable works. In addition to considering all those transitions, this diary-based also reports challenges faced by the user during navigation with the smart cane, what the participant thinks to overcome those challenges and possibilities for further development of assistive navigation solutions. We believe that the results from this study can be beneficial while designing and developing a navigation assistant since it considers the design requirements from the perspective of a visually impaired based on daily life experiences.

2 Methodology

This study uses the diary method as a *first-person research* to provide a detailed account of user behavior, actions, thoughts, and experiences [1, 8]. The study is conducted in an urban environment in the capital city of Oslo, Norway. One of the authors (now onwards known as *participant*), who is visually impaired and unfamiliar with the city, recorded her experiences while traveling around the city. Although the diary belonged to one of the authors, its contents have been processed by the individual authors and discussed to prevent misinterpretation and bias. During the study, the participant used a smart cane as the primary navigation aid while roaming around. Our diary-based study consists of five phases [21]:

Planning and preparation: We defined the focus of the study, routes, and the timeline of three months in this phase. The route selection was the participant's choice, as it comes along during typical daily situations. The participant was informed that she could use any navigation aid she was familiar with and advised not to use any other supporting assistance during the period. The smart cane was thus finalized, and since it came with an associated app, it is also considered a part of this study.

Pre-study brief: We had meetings to discuss the details of the study. We walked through the schedule for the reporting period and discussed expectations. Created clear and detailed instructions for the study. We discussed some relevant

examples from the literature. Discussed that the main focus should be hindrances faced during navigation and positive thoughts about the navigation accessibility across the city.

Logging period: We discussed potential options to support effective activity logging. During our discussion, we agreed on what information the participant must log without stifling natural variability and differences. For logging, we agreed to follow the *snippet technique*, where the participants only record short snippets of information about activities as they occur. Then, at the end of each day, or when the participant has time, she elaborates on each snippet by providing additional details about the activity. The 2-step approach ensures that relevant information is captured in situ before it is forgotten, without the participant having to provide extensive detail at the time of capture, which can sometimes be inconvenient and unnatural. The participant recorded her experience in voice snippets using her smartphone during navigation. Then at the end of each day, these records were elaborated in a document.

Post-study interview: After the completion of the study, all the data documented by the participant was evaluated. A follow-up interview was conducted to discuss logs in detail. If something was unclear, we sought clarity from the participant by asking for specific details to complete the story.

Data analysis: The study was conducted over three months, and these studies are longitudinal and generate a large amount of qualitative data. From these, we extracted, organized, and analyzed the whole data by including the participant in the process.

Once the data was organized, we also took demonstration photos in a few instances to give more clarity to the readers about the experiences encountered by the participant. The demographic profile of the participant is as follows: The participant is 32 years old female. Commonly used navigation tools include a smart cane, a white cane, and a few mobile apps. Everyday navigation tasks include going to work, home, shopping, visiting restaurants, walking in parks, attending dance classes, etc.

3 Experiences

This section describes the participant's major experiences with the smart cane and various everyday situations where the participant faced challenges while navigating indoor and outdoor environments in Oslo for three months. The experiences are reported under various headings.

Smart cane

The participant used WeWALK[1] for navigating around. WeWalk is a smart handle that can be attached to any long cane for navigation assistance. It uses an

[1] www.wewalk.io/en/

ultrasonic sensor to detect obstacles by warning users about impending danger or obstacles via vibrations. WeWalk also has an associated smartphone app to assist in navigation. The participant shared some experiences using WeWALK smart cane for navigation. According to the participant, WeWALK is not waterproof, but the leather pouch attached to the handle of WeWALK protects the handle from bad weather, rain, snow, etc. The participant expressed concerns that the cane handle was too heavy and oversized, which could disadvantage people with smaller body physiques.

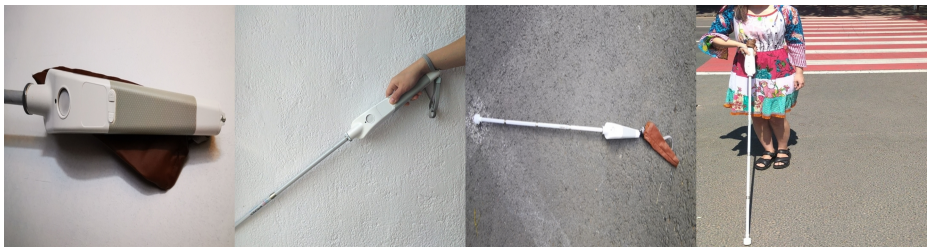


Fig. 1: The WeWALK design. The leather pouch is used to protect the sensors from extreme environmental conditions. The sensors in the handle will vibrate when there are some obstacles nearby. The participant needs to swipe the smart cane to identify the obstacles along the path.

Another limitation the participant pointed out about WeWALK is its battery capacity. The battery life may not be enough to get someone through an entire day of traveling. This could be overcome by charging through an external battery that users could carry in their backpacks. However, that could increase the device's overall weight, adding more inconvenience to the user. In addition, the participant observed that the app of the cane consumes a lot of battery compared to the cane. Half of the smartphone battery goes down in 15 or 20 minutes if the app is used.

Sometimes, the vibrations from the cane create confusion for the participant in identifying obstacles and acting accordingly.

> *"I'm not sure if the vibrations that I feel in my hands are from the handle from the sensor for detecting an obstacle or they're just vibrations from the bolt from the cane on the pavement. Because it feels like almost the same vibration, and it's hard to differentiate it."*

Besides having a few limitations, the smart cane has notable advantages, according to the participant. The other features supported in the app, such as a geolocation identifier for the phone and also to save favorite places to visit regularly, are helpful for the users. Also, it can find the phone if it is connected to a cane but lost somewhere. Another feature of the cane is the horn that can be used to warn other pedestrians or animals on the way during navigation. According to the user, it is possible to adjust the sensitivity of vibrations.

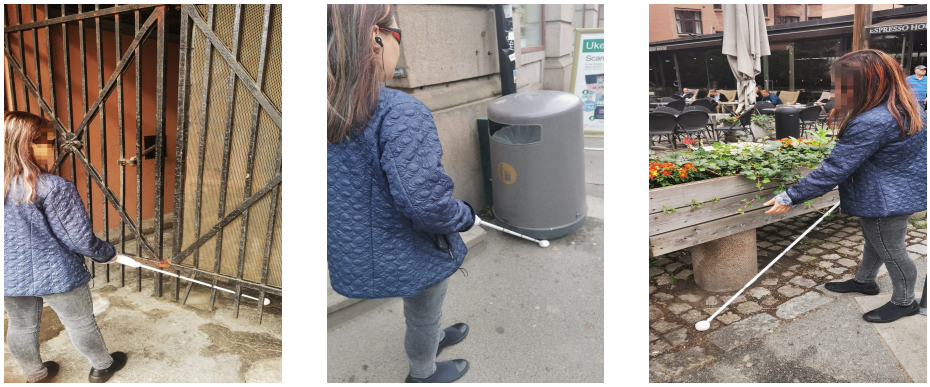
Walking and crossing the street

The participant reports the experience of crossing the roads with traffic signals. This could be one potential issue that must be considered while designing an accessible public environment. Figure 2 shows the situation when the participant is waiting to cross a traffic line. But due to an issue with audio delivery from the traffic signal point, the participant felt difficulty understanding the green signal to cross the road.

> *"Even though there has a traffic light in an intersection, I couldn't detect the color change because it has no functioning audio signal."*

Fig. 2: Difficult situation when there is no audio signal from traffic lights while crossing roads.

Figure 3 shows various instances the participant felt difficulty while navigating with the smart cane. In one case, the cane got stuck in grill lines. In the second case, the participant got a hint about an obstacle with vibration from the smart cane but could not identify the type of obstacle. Here, the participant wanted to use the trashcan but couldn't use it because of the unavailability of information in identifying the object. In the third case, the participant feels difficulty crossing the flower barricade to find a way to get inside a restaurant. But after spending so much time and touching along the barricade, the participant managed to resolve the tiresome issue.



(a) (b) (c)

Fig. 3: Challenging situations when the type of obstacles or objects are unknown during navigation.

Constructions on roads

The outdoor environments were complex and challenging for the participant. During the daily navigation, the participant experienced challenges with construction works in pedestrian pathways (see Figure 4).

> *"If there is some construction on the road on my path to my destination, I don't know exactly how to avoid this construction and to go around."*

Fig. 4: A challenging situation when construction works happen in the middle of the pathway.

Because of the lack of accessibility guidelines in maintenance/construction routes, the participant faced few accidents while navigating. The participant reported that it was difficult for her to detect road signs when there were some constructions in the area. Because of this, sidewalks were blocked, and she hung her shoulders in one of the sharp corners of the pathway. Since there were no serious repercussions, she continued her way home.

On the public transport

The participant also conveys various challenging situations when navigating around public transportation points. Even though many of those points have blind trails for easy navigation, there are no accessible directional clues about a service point, such as ticket vending machines or platforms.

> *"If it is a mall, railway station, or bus station, if the opening is too big, then it's tough to find the path. On the other hand, if I need to find a toilet, then it is almost impossible to find it without asking people around."*

> *"It is easy to reach a destination such as a railway station or bus stop with my cane app. Also, I can know which platform to use to catch my train, bus, or metro. But it is not easy to find the right platform since there are no accessibility clues. Also, it was challenging to locate ticket vending machines."*

Walking in the park

While walking around parks, sometimes the participant felt lost. Also, when there were wet leaves around the park which caused a difficult time identifying the asphalt path for comfortable navigation.

> *"I remembered that I needed to go to an alley between some trees to get out of the park. It was tough to keep on the right path because there were stones on the ground, and I didn't know if I was on the right path. I tried to orientate by the sounds made by the card on the road I was walking to, but there were few of them, and because of the distance, I couldn't hear them well. Luckily, someone passed, and I could ask for help to get out of the 'trees labyrinth.' "*

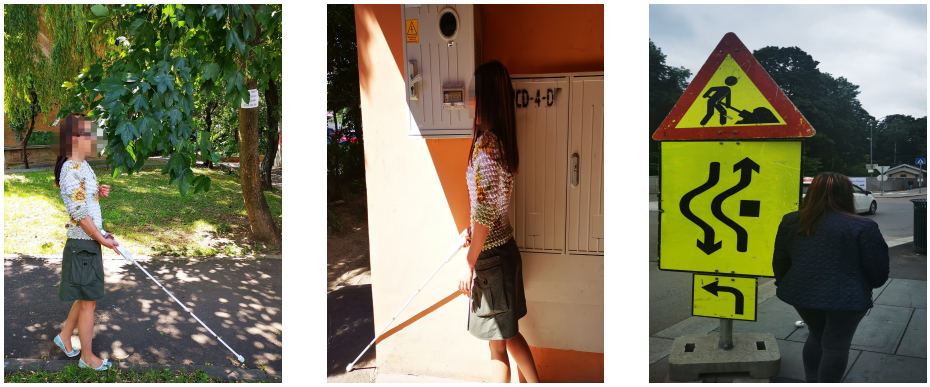
> *"It was not my first time going on this route, but there was something different: it was full of wet leaves on the ground, so there were places where I could not identify the asphalt/path."*

Hanging obstacles

The participant experienced difficulties when there were hanging obstacles along the path. According to the user guides given on the website, WeWALK detects obstacles at head and chest level (such as low-hanging tree branches and light poles) and informs it through vibrations. But the participant faced a different case scenario while passing through hanging obstacles.

> *"If there is a tree or hanging obstacles, the cane will vibrate, but I don't know exactly how tall the obstacle is. And I can't know the exact position of the obstacle if it's hanging. If it's really on top of my hand, I can put my hand on my head to save me from getting hit by it."*

The examples images in Figure 5a and 5b show the inconvenience faced by the participant and the obstacles that were hit on the head. Figure 5c presents a similar situation of getting hit by an obstacle with a prolonged part (yellow) not detected by the smart cane.



(a) (b) (c)

Fig. 5: Challenging situations with hanging obstacles.

Finding a restaurant

The participant expressed difficulties in getting inside a shop or restaurant. Even though she could reach in front of the restaurants with the smart cane, she found it challenging to find the entrance doors.

Also, the lack of accessible information to identify various obstacles, such as stairs or elevators, was always exhausting for the participant.

> *"If I'm entering a building other than my home that is already known, for example, a new restaurant, I have no idea where the stairs are or where the elevator is because there was no guidance on the floor."*

Open spaces

When there is open space such as ground or park without directional cues, it is arduous to find where to move without losing track.

> *"When I am traveling in a wide-open space, I have no clue where I am and what is there in front of me because there is no point of reference to guide me. Sometimes it creates panic, confusion, and frustrations."*

The associated app sometimes confuses the participant while giving directional information.

> *"I usually keep my smartphone in my pocket. So, it always confuses me with the position guidance given by the WeWALK app. I'm unsure if the cane has a gyroscope sensor, so I assume the positioning depends on the*

gyroscope sensor from the app. And the directions that I receive from the app to go at 9:00 or 12:00 o'clock depends on my position on the phone."

At work

The participant shared challenges experienced while walking inside the university (work).

"There is always a challenge to find the card readers and the door opening buttons in the university buildings."

The participant was optimistic about the accessible indoor pathways at the university, and it helped her to navigate without much trouble. But, according to the participant, the signboards are not accessible to a visually impaired person.

Wrongily parked bikes and scooters

The participant had experienced hitting a parked bike with her leg while passing nearby (see Figure 6). Even though the smart cane could detect the presence of the obstacle, after passing, it was not enough to give information about the length of the obstacle.

"While going on the sidewalk next to a supermarket close to my home, I hit perpendicular to a bike parked on the sidewalk. I hit it down because I was very close to its back wheel while passing, and my cane was moving in the other direction when I hit it. An issue during my travel, I did not go straight on the sidewalk parallel to the road. I usually go next to the curb, but it is impossible because of some trees."

Fig. 6: Irregular parking of e-bikes and bikes is a threat during navigation.

Coping strategies

The participant mentioned that it could be more beneficial for safe and smooth navigation if it is possible to know where exactly she was or which scene was

nearby (like a river, a park, or a construction area). The participant also mentioned that it was hard to know the scene of the navigation environment. For this, coping strategies for detecting sounds helped to infer location and environment. For instance, sounds from birds helped to identify the current scene as a park. Also, the wind sound in the trees helped as well. But when it is winter, it is challenging to use coping strategies. The participant had some experiences by using various senses (such as hearing (sounds from the environment) and touch (steepness of the road) to reach the destination.

> *"On my way to the pharmacy,* ***there are steep streets, so those are guiding steps for my navigation****. Having a map in mind, I could easily recognize if I was going right* ***by focusing on the car's sound and identifying the street's direction****. For example, hearing cars coming from the left side and going to the right, by a distance of about 100m, helped me identify where the* $\langle streetA \rangle$ *was. So, I calibrated my route perpendicular towards* $\langle streetA \rangle$*. A challenge to this approach is that the street is in the two intersections of some narrow streets with different angles. To continue on the same lane after passing the intersection, I needed to adjust my route some meters to the left/right because the street was out of the phase, and* ***I did that by the voice/sounds of the people/cars passing****. All my way to* $\langle streetA \rangle$*, I was going on the road because there were very few cars on those streets. I felt more secure than on the sidewalk because, on the main road, there might be fewer obstacles or impediments to my navigation (leaves, scooters, bicycles, pillars, construction signs, etc.)."*

Need of environmental information

The participant emphasized the need to get environmental information to help understand the navigation environment.

> *"When I am exploring a new area, I will create a map of myself and where I am. I even do it in my own home. I do it subconsciously. This mapping would help me when I travel there next time. It can help me identify obstacles such as doors, walls, and other things."*

The participant mentioned a few situations where it felt like having an obstacle or object identification feature could be helpful to understand what obstacles are on the path or if there is anything near which could be beneficial in that situation (such as a bench to rest sometimes). But the smart cane can only indicate the obstacle, not its type. And it gets more challenging to find something in a large open area or a park.

On the way to the COVID test station

The participant explained the experience of going to a COVID-19 testing station near work. The lack of accessibility guidelines during the pandemic is challenging

for all people with visual impairments. Even though the participant used help from a friend via video calls, it was not enough. People at the testing stations were also unaware of arranging the testing location accessible and giving proper guidance to people with visual impairment. The priority of the pandemic test stations was given to the general public, and maybe consideration of people with impairments has been missed.

> *"I was trying to follow the margin of the sidewalk close to the street to have guidance, feeling the direction I needed to go. My friend warned me when I was close to an obstacle (e-bikes, pillars, etc.). Still, it was challenging for her because of the direct sunlight coming from the direction I was moving. I had to cross three crosswalks, two of which had traffic lights. My friend told me when it was green (a few traffic lights have an audio signal when it is green, but there are not always working)."*

4 Discussion

The results from the study support the need for a navigation assistance solution with more features than the smart cane used for the experience. It also advocates for improving accessibility in transportation and mobility when a city considers its urban planning. As a result of the experiences described in this study, some recommendations are evolved.

- Both portability and convenience in a navigation assistance tool are essential requirements for the users.
- Able to give information regarding the type of obstacles and distance to them while navigating. Also, the tool should be able to identify the presence of both hanging and ground-level obstacles.
- Able to be used uninterrupted for at least an entire day without recharging.
- Should work even in challenging climate conditions without affecting its performance.
- Supports user preference settings to choose an appropriate output modality in giving information to the user.
- Good to have a scene identification feature to inform about the environment/scene while navigating.

Furthermore, the study suggests having more accessible environments in public spaces such as roads, shopping malls, universities, railway and bus stations, open spaces, etc. When pedestrian pathways are closed for construction or maintenance works, the concerned authority should consider providing an accessible navigation path for those with motor or visual impairments. There should be accessible information boards regarding stairs/elevators/help desks etc., in indoor environments. Like any research method, diary studies have several benefits and potential drawbacks that researchers should be aware of from the beginning. The principal advantage of this study is that the researchers can get an opportunity to discover how people with visual impairment use an assistive navigation aid

such as a smart cane in a natural environment. Many research studies intentionally strip away outside factors to create an environment free of variables so the user can focus solely on the product or service. But this diary study could reveal external factors that affect an end user's experience (such as inaccessible city designs and badly parked bikes/e-scooters). Researchers can also learn what social situations might affect usage patterns using the aid in a real-time environment. One potential shortcoming of this approach is that the conclusions drawn from the study highly depend on a single participant and the environments they usually visit. Hence, it could miss some typical experiences that other people encounter. Relying on a single participant might question the accuracy of the results. But the in-depth analysis of various issues over a long period in different real-life environments has advantages over other user experience methods such as surveys or interviews.

5 Conclusion

This diary-based study describes both the positive aspects and the challenges faced by the visually impaired while navigating in an urban environment using a smart cane. Also, it evaluates some facilities offered today for public navigation in a modern metropolitan city like Oslo. The study emphasizes that a navigation assistance system could perform better if a universally accessible public environment exists, especially in a crowded place like a city. Portability and convenience for the users need to be considered in designing a navigation assistant system. Also, people with visual impairments prefer to have some feature support from the navigation tool, such as knowing the scene, identifying obstacles, etc. The lessons learned from this diary-based study could help researchers design and develop a universal accessible navigation solution for the visually impaired. We also believe the results would be helpful for improvisations needed for a universally accessible public environment in an urban city to support people with visual impairments.

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