Introduction

Eyes have always been a crucial sensory organ, used constantly in our daily lives. Yet, according to the World Health Organization (2019), “at present, at least 2.2 billion people around the world have a vision impairment, of whom at least 1 billion have a vision impairment that could have been prevented or is yet to be addressed.” Although we cannot fully grasp the experiences of individuals with visual impairments, we experimented to better understand how they navigate using a white cane. Our goal was to gain insight into the challenges they face and to inform the design of products that better serve their needs.

Spatial Challenges and Interactive Strategies

Before beginning the experiment, we considered the typical daily routine of a visually impaired individual and identified a route that one would likely travel each day using a white cane—the pathway from an apartment door to the main road, as our navigation task. We selected the apartment with the lowest rent among the three of us, assuming it would be more accessible. The pathway includes walking down the stairs in front of the apartment door, passing through a park with plants, and walking down a footpath etc, according to Figure 1. It involves multiple challenges and may test the capability of a white cane. By putting ourselves in the position of individuals with visual impairments, we identified five major concerns along this pathway:

1. **Manhole Covers on the Ground:** As shown in Figure 2, numerous manhole covers were scattered along the path. Many of them were uneven with the surrounding ground, and the slits in their surfaces posed a challenge for standard white canes, which could easily get stuck in the gaps—creating a serious safety concern. When the stick is stuck in the manhole, we immediately experience “panic”. The white cane is

not simply a tool that "helps" with any specific needs; it embodies the functions of multiple senses, it provides us with feedback about the surrounding environment. When the white cane is restricted, tactile impression is restricted, one of our most significant sources to replace "visual" is blind again. When the white cane is stuck, our feedback of the surroundings is deprived. For this problem, our strategy is to stay calm and take actions carefully when uncertain. The sensory system collaborating together creates a "sensation-action loop" that helps us perceive information.

2. **Edges Between the Pathway and Grass Fields:** As shown in Figure 3, although the grass fields appeared to be level with the stone pathway, they were slightly lower and softer. This subtle height difference, combined with the narrowness of the path, increases the risk of tripping for individuals with visual impairments. We first experience a sense of weightlessness the second we step outside of the narrow pathway, then we take action to make sure we regain the balance, and we need to use the "white cane" to detect the environment around us in order to regain our sensation-action loop. Looking at ground texture-related concerns, we noticed that it is not enough to use the white cane to "tap" the ground, moreover, our strategy is to "hit" the ground before taking the step, as an interaction to cope with this challenge.
3. **Stairway to the Apartment Entrance:** As shown in Figure 4, before reaching the apartment door, there was a long stairway that was both steep and narrow. Even with full vision, we felt uneasy getting through it. This experience made us reflect deeply on how careful such stairs are for someone who has never seen them before. Our interactive strategy is to "be slower and use a foot to explore before actually taking the step." This action helps us perceive the environment, predicting our next step.

Design of the Cyborg Artifact

While all the identified problems are worth addressing, we chose to focus specifically on the second issue: the edges between the pathway and the grass fields.

This issue is mainly about one concern. Most white cane is primarily designed to detect obstacles above ground level, but here, the challenge lies in detecting a subtle change in ground texture and height, and is specifically, lower than the ground level. While the grass field may appear level with the pathway, its surface is softer and slightly lower, creating a potential danger. The problem we aim to solve is how to enhance the cane's ability to detect changes in ground texture and height that could affect a user's stability when stepping onto a different surface.

Based on findings in neuroscience, the use of tools such as the white cane can induce significant changes in the brain’s representation of the body. Maravita and Iriki (2004) explain that “this extended motor capability is followed by changes in specific neural networks that hold an updated map of body shape and posture (the putative ‘Body Schema’ of classical neurology)” (p. 79). This finding is significant since it shows that when a visually impaired person uses a white cane, their brain progressively incorporates the cane into the internal model of their body. The cane is no longer treated as a separate object but becomes an extension of the body itself. Therefore, to support this neuroplastic adaptation, it is necessary to design white canes that offer delicate tactile feedback and high functional reliability, allowing users to navigate with greater confidence. Maravita and Iriki (2004) further mention that “such vRF expansions may constitute the neural substrate of use-dependent assimilation of the tool into the body schema” (p. 80), reinforcing the importance of designing assistive tools that seamlessly integrate into users’ sensory systems. They also conclude that “tools, by enabling us to extend our reaching space, can become incorporated into a plastic neural representation of our body” (p. 84). It stresses that careful tool design directly supports users' ability to safely interact with their environment.

In addition to the neural integration emphasized by Maravita and Iriki (2004), Hutchins (2010) highlights that tools such as a blind person's cane function as extensions of the user's cognitive system itself. Through the framework of cognitive ecology, Hutchins illustrates that perception and cognition extend beyond the skin, flowing through tools into the surrounding environment. Thus, improving the white cane's sensitivity and reliability not only supports the user's bodily schema but also strengthens their embodied interaction with the world; it creates a seamless cognitive ecosystem.

To address these challenges, we propose adding two enhancements to the white cane, improving its functionality while maintaining its original shape and core use, as shown in Figure 5 (Section 1). Both additions would be on the cane's tip. The first design is an ultrasonic drop-off detector, mounted at the front of the tip, as shown in Figure 5 (Section 2 and 3). The second is a highly sensitive tactile tip, either attached to or replacing the existing tip material, as shown in Figure 5 (Section 4).

Traditionally, white canes rely on physical contact to sense ground conditions. However, they often fail to detect sudden drops, such as stairs or steep slopes, in time to allow for safe navigation. To solve this, we suggest installing an ultrasonic drop-off sensor at the front of the cane. This sensor would continuously send out ultrasonic waves to monitor changes in distance between the cane and the ground ahead. If a sudden drop in height is detected, such as at the beginning of a staircase, the sensor would alert the user through a slight vibration. This system effectively extends the sensory capabilities of the cane, translating visual information (height differences) into tactile signals. It allows users to adjust their movement strategies based on sensory feedback more accurately and immediately.

In addition to improving the user's ability to recognize different surface materials, we propose the "Ultra-Highly Sensitive Tactile Tip." Made from a finely engineered tactile material, this tip can distinctly detect the difference between soft surfaces (such as grass) and hard surfaces (such as flagstones). As the user pushes the cane forward, subtle changes in resistance are transmitted to the hand, providing immediate information about the terrain. This mechanism forms a "sensation-action loop," allowing users to create a picture of the environment through direct bodily perception without needing external translation. The design aligns with the theory of "embodied cognition" and significantly enhances environmental awareness while walking.

Conclusion

In conclusion, after experiencing navigating through challenges from the perspective of an individual with visual impairments, focusing on a route from an apartment door to the main road of the community, our understanding of the importance of “vision” and the cooperation between different senses had deepened. Through direct experimentation with a “white cane”, we identified barriers such as stairs, uneven surfaces, and subtle height differences between pathways and grass fields. Specifically for the challenge about subtle height between pathways and the grass field, we designed a solution that improves the function of the white cane with an ultrasonic drop-off detector and a highly sensitive tactile tip, aiming to extend the user's sensory capabilities without replacing human decision-making.

Navigation relies not only on environmental structures but also on real-time sensory feedback between the body, tool, and the surroundings. Facing challenges without vision reinforces how cognition is situated and how thoughtfully designed tools can participate directly in these processes.

References

World Health Organization. (2019). World report on vision. World Health Organization. https://www.who.int/publications/i/item/9789241516570

Maravita, A., & Iriki, A. (2004). Tools for the body (schema). Trends in Cognitive Sciences, 8(2), 79–86. https://doi.org/10.1016/j.tics.2003.12.008

Hutchins, E. (2010). Cognitive ecology. Topics in Cognitive Science, 2(4), 705–715. https://doi.org/10.1111/j.1756-8765.2010.01089.x

Figures

Figure 1. Pathway Record and Sign of Challenges

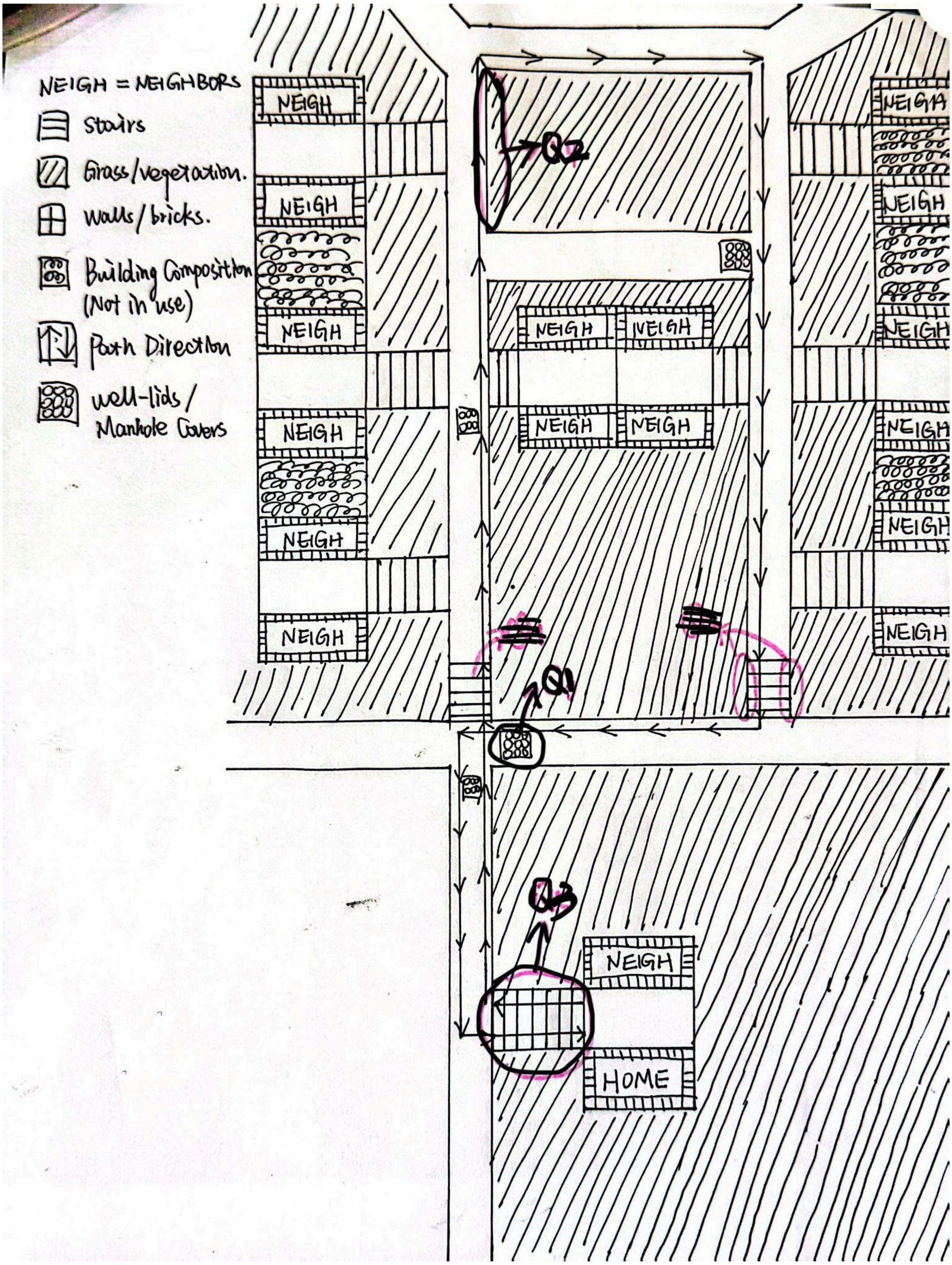

Figure 2. Manhole Covers on the Ground

Figure 3. Edges Between the Pathway and Grass Fields

Figure 4. Stairway to the Apartment Entrance

(Figure 5 on the continued next page.)

Figure 5. Design of Improved White Cane based on Spatial Challenges