Design research on tangible symbolic systems and wearable navigation devices for the changeable environments

By

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Abstract

Considering the threat of environmental change in the age of pandemics and the challenges that visually impaired people may encounter when using navigation aids, this paper integrates the design of tangible symbol systems and wearable devices into navigation aids. It seeks to explore the potential of navigation aids to be more interactive, practical, easy to use, and adaptable to the environment. The research aims to review and brainstorm existing literature on the subject, interviews with the target population, or design research methods such as conceptual design activities. This paper seeks to identify the vital role that the systematic design of tangible symbols and wearable devices can play in designing navigation aids for people with VI. The results of this research will be presented in the form of a wearable product design. It is hoped that this research will convey the idea that in the design of products today, consideration should be given to preventing threats from the future and making products more sustainable.

Keywords: Inclusivity, Interaction design, Wearable system design

Declaration

I hereby certify that this report constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

I declare that the dissertation describes original work that has not previously been presented for the award of any other degree of any institution.

Shiyan Zhang

Shiyan Zhang

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I wish to thank all of those who helped me complete my final year project. I would like to express my gratitude to my supervisor, Richard Appleby, whose advice and patience are invaluable to me.

throughout the year. Additionally, I would like to show my deepest thanks to my beloved parents and friends for their support, accompany, and encouragement.

I would also like to thank all of the participants in this study who took time from their busy schedules to contribute to this design research project.

Contents

Introduction

In an era of epidemics, frequent closures, quarantines, and nucleic acid testing have made our living space unpredictable, making it even more challenging for the VI to travel. For example, QR codes are required to enter and exit, daily nucleic acid testing is needed to ensure you are safe, etc. People with visual impairment are a diverse population, and society has taken steps to increase their inclusion and autonomy, not least through the provision of assistive devices to help the VI community. For example, building urban tactile paving, upgrading and optimizing traffic lights, and educating the public about visual impairment. The WHO also states that assistive products can enable people to lead healthy, productive, independent, and dignified lives, participate in education, the labor market, and civic life, and benefit people with visual impairments (WHO, 2018). Many scholars or designers have contributed to the field of research on accessible wayfinding assistive technologies, many of whom have proposed the use of sensory compensation for navigation of the VI, such as the use of touch, hearing, smell and taste to access spatial information. There is also a lot of research on highly technical devices such as Google's accessibility glasses, intelligent canes, and Braille typewriters. There are some daring researchers who, through innovative design, have provided many inclusive solutions for the visually impaired, offering them the same services as ordinary people. For example, Cooper Hewitt's exhibition 'Senses: Design Beyond Sight' offers the possibility of creating an inclusive environment, while others are providing opportunities for visually impaired people to 5 view the artwork.

Figure 1: The environment not conducive to travel for the visually impaired.

However, in the context described above, although scholars and designers have addressed these issues, there are still some urgent, unknown challenges. For example, while we know that improving the harsh environment in which VI people travel can increase their sense of social identity, how to give them independence and autonomy is still something that needs to be designed appropriately and studied; in the era of epidemics, frequent changes in urban infrastructure and urban routes make it difficult for VI people who rely on memory to walk; and how to create navigation aids able to mitigate various environmental In the era of epidemics, frequent changes in urban infrastructure and changes in urban routes have left VI people who rely on their memory to walk in an inch of their lives; and how to make navigation aids able to defuse the dangers posed by various environments, and how to adapt navigation devices to diverse social situations, for example, not being made fun of for carrying a strange-looking device when wearing a navigation aid to dinner, not feeling tired and inconvenienced by carrying a bulky device when taking public transportation, etc.; when talking about multisensory compensation, although there are now a lot of scholars and designers who have come up with a large number of valuable When it comes to multisensory compensation, although many scholars and designers have put forward a lot of valuable theories, there is still a lack of a systematic, integrated and standardized system, which leads to a huge learning cost for VI people to use these valuable theories, and this is not conducive to their use of "multisensory compensation". At the same time, the research on haptics as another "language" for VI people has the same problem as "multisensory compensation."

Figure 2: Changeable environments bring challenges for the visually impaired (Forest 2020).

To effectively research this topic, I have developed the following research questions:

How can sensory compensation and tangible feedback be used to enhance the user experience of navigation products? To what extent are wearable devices suitable as a vehicle for accessible navigation technology for the VI? How can the environmental resilience of accessible navigation products be increased? How can the design of tangible symbol systems be used to provide more inclusive and accessible navigation aids for the visually impaired?

Finally, this study aims to demonstrate that by designing wearable mobility aids that incorporate a tangible symbolic system, it is possible to improve not only the inclusivity and user experience of the product but also its performance and environmental adaptability. At the same time, futuristic and fashionable considerations are incorporated when proposing solutions for this study, allowing this research to meet the needs of the visually impaired while meeting the general population's expectations for mobility aids. Ultimately, this study hopes to provide possible directions on how to adapt assistive devices to people, environments, and products in the popular era based on design and hopefully increase the effectiveness and accessibility of assistive devices to the VI population.

Literature review

A study estimates that by 2050, 703 million people worldwide will have moderate to severe visual impairment (Ackland, 2017). Visual impairment affects health, psychological, social, and quality of life. The loss of vision affects the ability to access information about the immediate environment and makes independent and safe travel difficult. When it comes to travel, public transport is an unavoidable situation. Although many measures have been implemented in public transport, some of the needs of the visually impaired are still overlooked, resulting in increased costs and minimal utilization. Fürst (2013) pointed out that increasing the inclusiveness of existing public transport would make it more accessible to the visually impaired and provide additional comfort to other passengers. With the increased attention given by international organizations to the harmonious development of society, there has been a marked increase in the attention given to the VI worldwide. For example, the United Nations has made 'reducing inequality one of the 17 sustainable development goals. The WHO (2018) has called on countries to introduce welfare policies for disadvantaged groups. In addition to this, they emphasized the importance of improving the travel environment for visually impaired people, especially through assistive devices to support them in their travels (WHO, 2018). Wang (2017) notes that safe navigation methods can increase the willingness of visually impaired people to travel independently. At the same time, there are still many bulky and conspicuous wearable devices that plague visually impaired people. Overall, although the issue of inclusion of visually impaired people is increasingly mentioned worldwide, safe, autonomous, and independent travel is still an issue worthy of discussion.

Figure 3: Visually impaired people face a lot of difficulties when travelling.

Since 2020, the epidemic has created a more or less social environment, especially with the occasional epidemic recurrence, which undoubtedly poses a challenge for some VIs. On the one hand, the epidemic has led to the need for the government to change quarantine areas in different locations. Wiener et al. (2010) have suggested that orientation and mobility (O&M) techniques for visually impaired people during wayfinding are based on where they have already been to determine their location. However, due to the environmental changes caused by the epidemic, familiar environments became unfamiliar and walking memory was no longer helpful. They also have no way of knowing if they are at a safe distance from others and often encounter breaks on familiar roads that take longer to reach their destination (CNA, 2022). On the other hand, the epidemic poses a massive threat to lives worldwide, with more than 6.5 million people affected and close to 400,000 dying worldwide in the early stages of the outbreak, according to WHO. Greater evidence suggests that visually impaired people are more susceptible to COVID-19 (Armitage, 2020) because, firstly, most of the emergency notifications issued by their governments are aimed at the general population, which leads to difficulties for visually impaired people in accessing relevant information; secondly, they are not sufficiently aware of the disinfection of tools; and thirdly, they still rely on direct contact with the environment to access environmental information, which increases their probability of becoming ill (Senjam, 2020). In such a situation, visually impaired people cannot quickly seek help from others, increasing the risk (Cochran, 2020). They may face transportation problems and increased dependency on seeking help from others. In conclusion, research related to navigation devices needs to be iterated in the epidemic era to improve their environmental adaptability and be ready for future environmental challenges.

Figure 4: The epidemic has changed the social order.

In research on navigation devices for the VI, many scholars have pointed out that wearable devices can be more conducive to transmitting information to the visually impaired. The importance of wearable devices is reflected in their ability to facilitate daily, social, and inclusive activities for individuals (Caporusso,2017). Velázquez (2018) investigated a wearable pedestrian navigation system for the blind, which is used for information presentation through tactile foot stimulation. The study illustrates how research on wearable systems for navigation for the blind remains unwieldy and inconvenient. For example, The shape and location of smartphones are not convenient for finding directions, and their vibrating signals are challenging to detect by the user. For example, traditional non-technical aids such as guide dogs and white canes often take up the user's hands and prevent them from interacting with the device (van der Bie, 2019). Some scholars have also shown through simulations that the ear, wrist, hand, or foot are the appropriate locations for tangible feedback when a VI person is walking (Machida,2016). Tapu (2020) presented several advantages and disadvantages by analyzing wearable devices for the VI over the last decade and created a data comparison table that summarises in detail the future trends of wearable devices and the issues that should be noted in the research. He indicated that wearable devices had been commonly considered assistive devices for the VI. Overall, wearable devices may be better suited as a place where tangible feedback can occur, significantly increasing navigation devices' interactivity, comfort, and accuracy.

Figure 5: Some of the travel aids that are being researched (Behance, 2023).

Bai (2019) presents an innovative wearable device that can be used in indoor and outdoor scenarios, accurately and efficiently sensing its surroundings through a unique system. While the study demonstrates environmental resilience, it lacks human-computer experience design in terms of haptic feedback and uses only a single repetitive vibration signal. Ramadhan's (2018) study describes a wearable system that integrates auditory and haptic navigation and incorporates real-time mobile phone tracking, which allows the system to send a distress signal to family members in an emergency. The study demonstrates a solution incorporating haptic feedback to alert the user when auditory feedback is interfered with in a practical situation. Freeman (2017) proposes a wearable device for visually impaired young children that help them access information about their environment by combining the sound of the wearable device with sounds from the environment, thus encouraging them to participate more in group activities. The study demonstrates an innovative solution to integrate environmental feedback into the overall system, allowing the device to respond to changing environments as it does not require the device to react. Todd (2018) and his team designed a system that includes an eye with bone conduction audio and a glove with a vibrating motor and uses ultrasonic sensors to detect obstacles, in addition to a good human-computer interaction experience, due to the user-friendly interface and the leather material chosen for its use. However, the study does not explain why the eyes and gloves were chosen as the main vehicles for the system, and the feedback signals are not clearly articulated. In energy sustainability, Ramadhan (2018) provides a sustainable intelligent wearable device for the visually impaired, using solar panels to recharge the product.

Figure 6: Wearable devices that can be used for different body parts (Dias & Paulo Silva Cunha 2018)

While many scholars and designers have also experimented with the use of multisensory compensation to provide a rich variety of navigation support for the VI, for example, Lock (2019) has built an assistive device that allows VI people to access spatialized signals using bone conduction audio input as a non-visual signal, which allows VI people to hear the voice feedback from the device when navigating, as well as receiving the sounds of their surroundings. Based on sensory compensation, Barontini (2020) has designed an indoor wearable navigation system that uses cameras primarily for environmental detection. The entire system was developed with feedback from visually impaired people, which informed the overall system's effectiveness. However, the study firstly lacks human-machine experience considerations. It does not consider whether the appearance of the device is socially acceptable, and secondly, the camera's performance can vary under different lighting conditions. Thirdly, the technology is costly. Jicol (2020) also discusses how multisensory integration can bring greater accuracy to navigation aids and considers this key in helping VI's in their work. Moreover, Cho (2021) also conveys that opportunities for perceiving the world through multiple senses are expanding, even as he conveys the advantages of multisensory perception, which is more informative than information obtained by sight alone. On the other hand, the multiplicity of sensory sources can lead to an increased learning burden for the user, who must adapt to different product usage guidelines. Overall, while multisensory compensation can facilitate access to information for the VI population, attempts should be made to reduce sensory learning costs in the long run. For example, a standardized tactile learning system or a uniform sensory feedback signal. The comfort of the wearable device also needs to be considered, as this is in direct contact with the human skin.

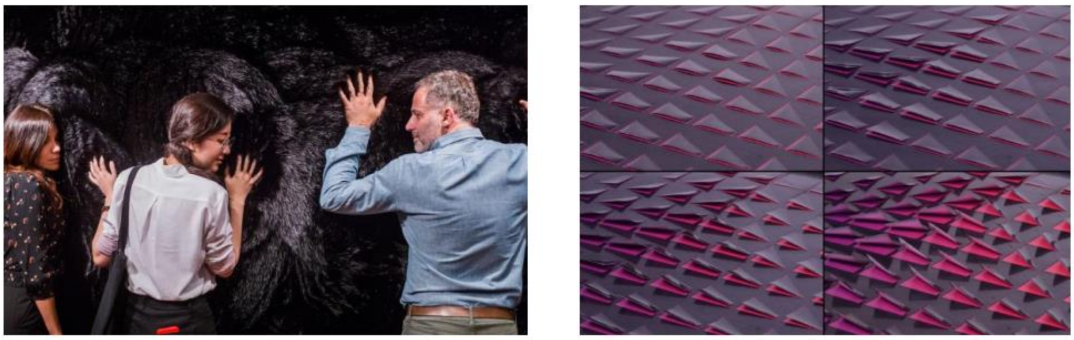

Figure 7: The sense of touch can bring a variety of sensations (Heller,2018).

However, about making information more accessible to the VI, some scholars have investigated how tangible symbol systems can help significantly in reducing the burden of information access for VI. Caporusso (2017) proposes a new approach to the design and development of assistive technologies, classifying haptic language into three types according to different dimensions. This categorization significantly reduces the learning burden and diminishes the cognitive stress of people with multisensory impairments. The study, although contributing to the establishment of norms, did not provide benefits to users due to the lack of actual output devices. Tangible symbols are objects or parts of objects that can be physically manipulated and share a perceptual relationship with the thing they represent (Trief, 2010), which also means they have a lower need for memory and expressive skills. In Velázquez's (2018) study, he verified that the efficiency of transmitting information to users could be improved with systematic tactile specifications, which demonstrate that tangible symbol systems are intuitive and easy to understand. Field studies have also applied standardized tangible symbols to the classroom and everyday communication and point to findings that facilitate independent walking for VI users (Trief, 2013). Therefore, we can try to co-design a reasonable tangible symbol system that allows VIs to reduce their learning burden when they try to use new navigation aids.

This literature review describes some of the difficulties faced by VIs in the epidemic era, as well as some examples of unsuitable navigation aids. The uniqueness of wearable products for the development of navigation aids is described. The advantages and disadvantages of multisensory compensation techniques are described, as well as the development of tangible symbol systems in VIs, and implications regarding the reduction of VI learning costs. It is suggested that in the research for this paper, firstly, there should be research into wearable devices, for example, the reasons for choosing gloves and glasses as system carriers. Secondly, the principles of sensory compensation should be appropriately integrated to help VIs access information, and a unified haptic specification or system should be designed in parallel. Thirdly, the design of the human-machine experience should not be neglected, including the choice of materials, the design of the form and structure, and the design of the tactile feedback mechanism. Fourthly, it should incorporate sustainable design concepts and use sustainable energy sources such as solar energy. Fifthly, it can be combined with mobile phone software to fulfill additional scenario requirements.

Methodology

Introduction

This chapter will outline the design research methodology for tangible symbol systems and wearable navigation devices. This paper will divide the entire research into four phases based on the Two Diamond Design Process model: discovery, definition, development, and delivery (Design Council, 2007). An appropriate method for collecting data will be selected in each phase. The methods include brainstorming, interviewing, role-playing, scenario testing, and design probing. Finally, the authors will discuss some important ethical issues.

The Double Diamond Design Process

The Double Diamond design process is a popular design research method. The double diamond method was created as "a simple graphical way to describe the design process" (Design Council, 2007). The model is a scientific design research tool that moves from identifying generalized and vague problems to giving detailed solutions and design solutions. The model evolves from a linear process to one that includes iterative loops and backtracking steps as the value of the design increases and time passes (Gustafsson,2019). This is also more applicable to real-world design projects, helping designers to complete projects more quickly. In the course of this paper, the fact that the primary users of the study were visually impaired complicated the pre-research and post-testing, making it even more important to have a flexible, visionary approach that responds quickly and appropriately to create change.

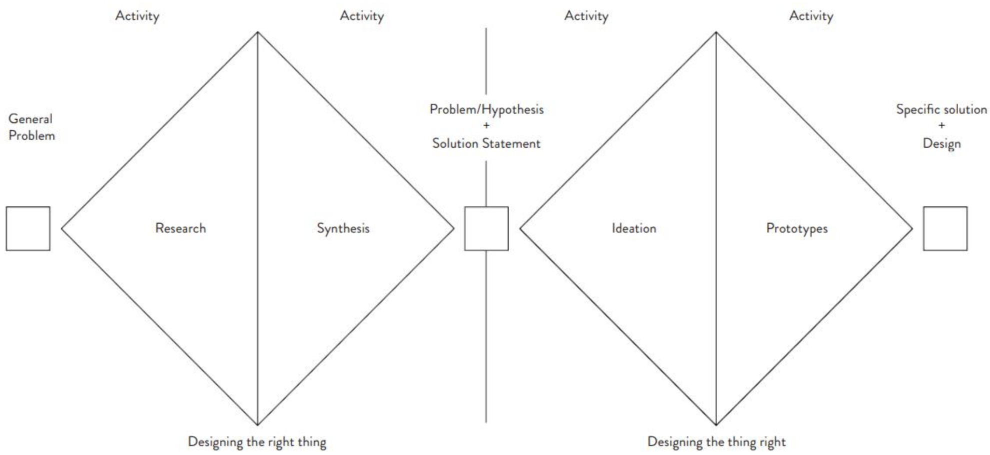

Figure 8: The double diamond approach (Rutiezer, N. 2017).

Participants

The participants in this study were divided into two parts, one of which belonged to the visually impaired population, including students attending schools for the visually impaired and visually impaired massage therapists. The other is the normal population, which includes my undergraduate students and my mother. The reason is that I want to make my design adaptable to the visually impaired and the general public, which has the advantage of increasing the practicality and inclusiveness of the product.

The student at the school for the visually impaired is a 12-year-old boy with four years of experience at a school for the blind. The visually impaired masseuse is currently working in a massage parlor and has ten years of experience. They were interviewed by telephone and offline, respectively, after I obtained the contact method through the internet. The overall criteria for selecting the participants were: (a) high visual impairment, (b) high need for going out, (c) expectation of navigation aids.

The undergraduate students selected were all around 23 years old, all studied industrial design, and all had a high sensitivity to problem identification. My mother, on the other hand, is a 45-year-old intellectual working woman with some aesthetic and insightful skills, and she can provide a uniquely female perspective. The overall criteria for selecting the participants were: (a) a complete lack of knowledge about research related to the visually impaired, (b) a sense of social responsibility (c) an interest in wearable devices or jewelry.

Brainstorming

"Brainstorming" is not complicated at the end of the day. It's a way to generate ideas around a certain topic and list everything in your head that is related to that topic (Design kit, 2021).

In this study, the participants could use "brainstorming" to imagine boldly from different angles, levels, and directions and to come up with original ideas that are as different and original as possible, which is a very concrete manifestation of the wisdom of brainstorming and teamwork. In addition, "brainstorming" can open up someone's mind to a greater extent and generate much inspiration within a certain period.

Before the "brainstorming" process begins, the members generally consist of six people, and one person is selected as the leader, responsible for the overall direction of the discussion and timing. During the "brainstorming" process, each person writes down the ideas that come to mind on sticky notes, and at the end of the process, all the sticky notes are put together and summarized by the leader.

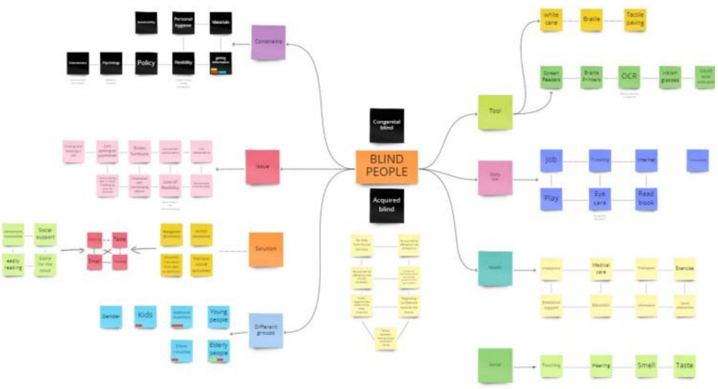

Figure 9: Brainstorming map about Visually impaired.

Interview

Qualitative research methods are considered appropriate when a researcher or investigator investigates a new area of research or intends to identify and theorize salient issues. Interviews are the most common mode of data collection in qualitative research. (Jamshed, 2014) Interviewing is a research method in which the researcher collects information about each other's psychological characteristics and behavioral data through verbal conversation with the research subject (Design kit, 2021).

Since the interviewees in this paper all belong to the visually impaired group, a group of people we rarely know in our ordinary lives. The interview method allows us to understand their heart, daily behavior, and lifestyle more efficiently to analyze their user needs.

No more than two research team members (interviewer, recorder) should be guaranteed during the interview process. Moreover, prepare questions in advance, from broad questions to more specific questions, those directly related to the challenges studied in this paper. Also, it is worth noting that it is essential to record exactly what the interviewee says and avoid subjectivity.

Figure 10: The interviewees included blind students and blind masseurs.

Observation

Observation became a scientific tool and a method for researchers to collect data.

When the observation method is used to perform research, it will be performed systematically, containing planning and recording (Cr, 2020).

In this study, the participants were ordinary people who were blindfolded and were chosen because, firstly, they had a keen fashion insight, and secondly, they had zero experience in pathfinding in a visually impaired situation.

However, there is a certain amount of subjective misinformation about this because the participants had their eyesight. The advantages of the observation method, on the other hand, are that objective information is obtained, that this information can be more effectively developed into valid demand points, and that the information obtained is directly related to the purpose of the study and is not complicated by external factors, and that the personal demands on the participants are low, especially for those who are unable to verbalize their feelings accurately (Cr, 2020).

In the preparation phase, participants were blindfolded and rotated to eliminate their sense of orientation to the known environment. After being blindfolded, participants were asked to complete a series of tasks, including reaching the bedroom, going from the first floor to the second floor, and going to the living room to get a glass of water. In addition, they were also asked to complete a set of comparison experiments in which they completed the same tasks with voice guidance to demonstrate the importance of voice feedback for the visually impaired.

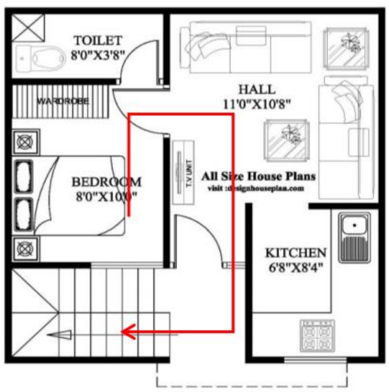

Figure 11: Blinded to play the role of a visually impaired person.

Design probes

The Design Probe is based on the method "HOW MIGHT WE" proposed by IDEO and combines it with the "Culture Probe" method. Design probes are executed by asking indirect users one or several futuristic and experimental questions. This approach solves a common dilemma when developing projects for unfamiliar groups (Gaver, 1999). Moreover, by weakening the focus of the target users on known needs, it increases the freedom and innovation of the design and facilitates the researcher to think outside the box.

Participants were asked to answer the question, "There is a high-tech device that needs you to wear for 12 hours. Which part of the body do you want it to be placed in?" and a human form was drawn to record their preferences for wearable products. The red dots represent the parts they can accept, and the slashes represent the parts they cannot accept at all while recording the reasons. Finally, the parts with the highest overlap were recorded.

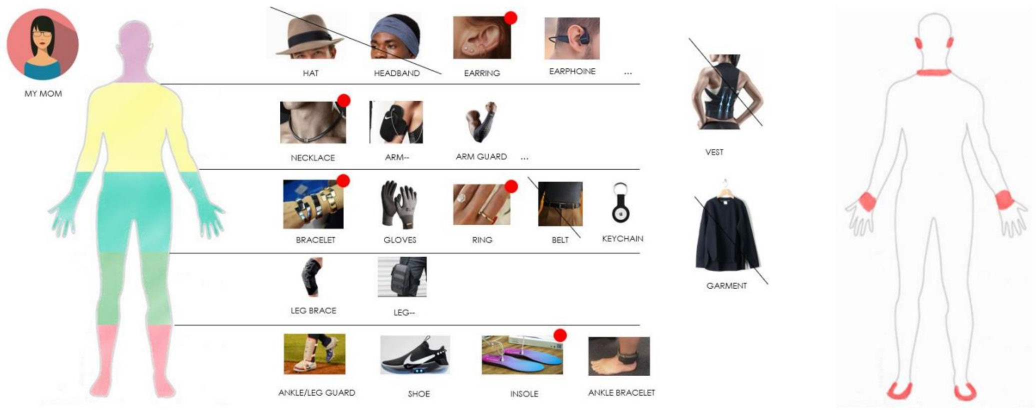

Figure 12: Gathering information on the preference of different people for wearable devices.

Sketching & Rapid Prototyping

In the development phase, designers typically visualize their concepts by hand and use them to determine what to create prototypes of. This is followed by a rapid prototyping approach to create a more expressive and complex model, as elaborated by Rodgers (2013), which uses some simple materials to create a full-size or scale model designed to capture early concepts.

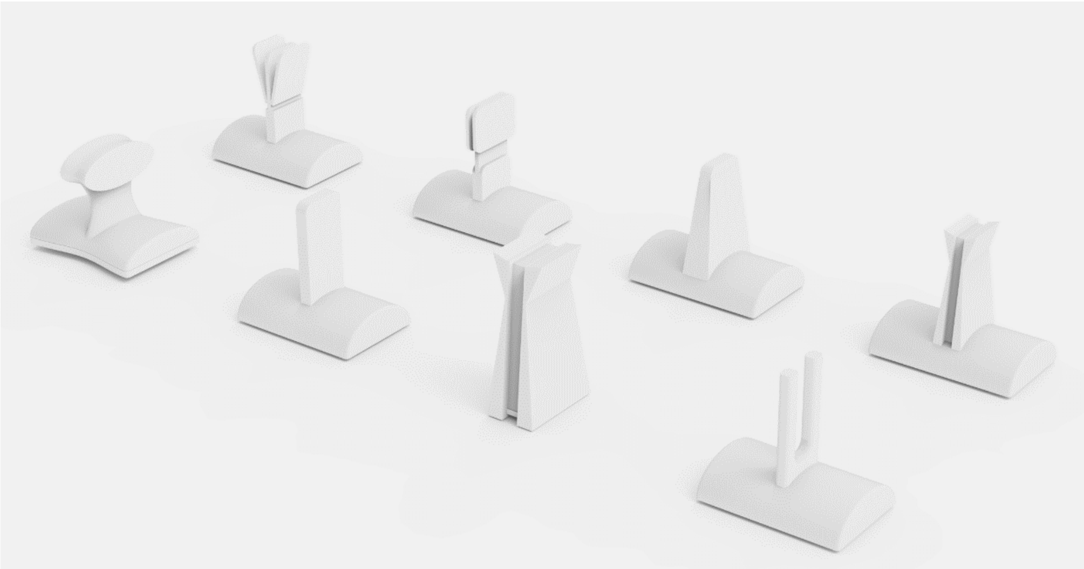

Figure 13: Iterative model of a group of charging stations.

In this study, prototyping allowed the researcher's numerous ideas to become tangible. It enabled users to experiment with the product to give some key feedback, which could help the researcher identify concepts with potential impact (Design kit, 2021). For example, the feedback given by users after wearing the prototype regarding the wearable product can increase the efficiency of product iterations in terms of human-computer experience or material selection. Ultimately, with continuous feedback and iteration, research goals will become more straightforward and precise.

After the initial sketching of the concept, the researcher will complete the prototype with an engineering layout by 3d printer and get feedback from users in the following steps to ensure the direction of the research.

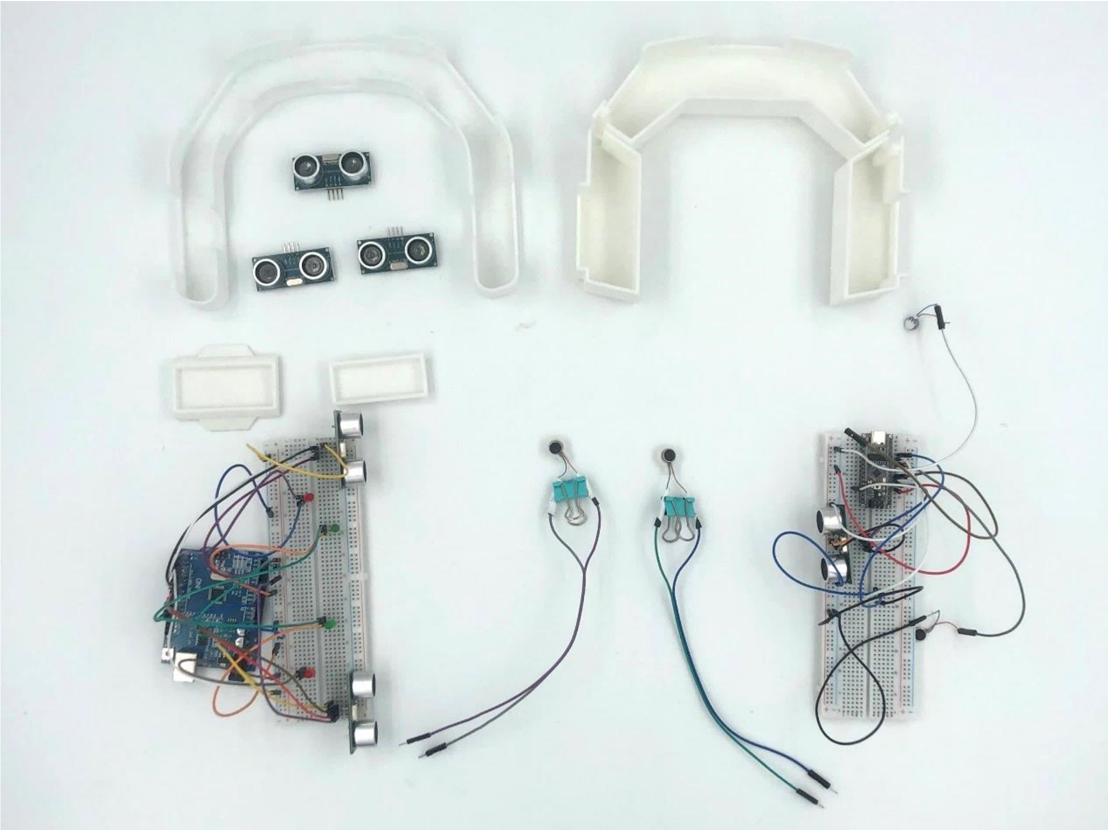

Figure 14: Some functional prototypes were tested, including ultrasonic distance measurement and vibrating motors.

Live Prototyping

Live prototyping is the process of putting your solution to the test for a few weeks or months. (Design kit, 2021). This approach allows us to see holistically how our system works together, which is significant for the wearable device designed in this study, as it is necessary to test the entire system's operational experience and troubleshoot any possible faults to optimize it further.

Before the methodology can be implemented, the researcher needs to identify the problems that need to be solved and validated. Furthermore, we need to determine the data required for the entire test, including the location, duration, and scope of the test. Afterward, researchers need to fast-track progress and iterate on existing solutions. In this study, we will select users for blindfolded testing, wear the equipment designed for this study, and run the entire system in its entirety - conducting walking experiments in the field, recording the user's complete use of the product, and collecting user perceptions. This feedback will then be collected and analysed and optimized.

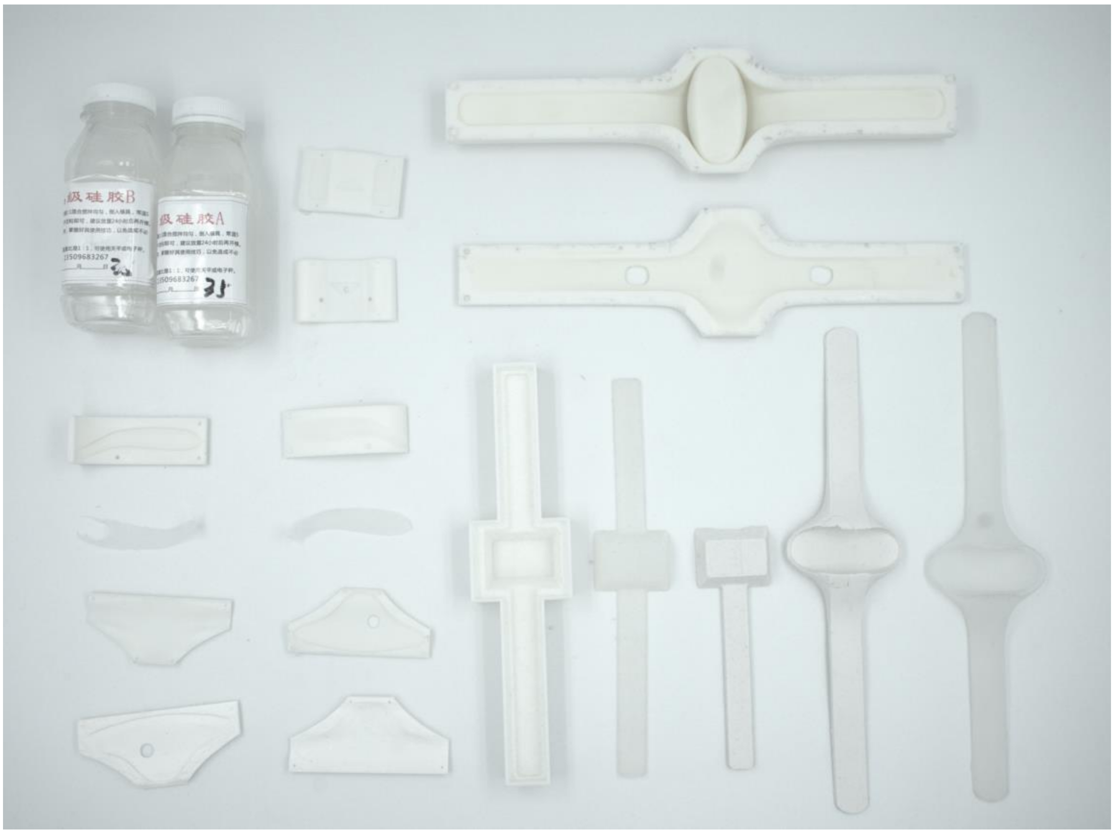

Figure 15: Silicone abrasives and silicone prototypes.

Design process

After the previous analysis, we move on to the design process phase. This stage will show how the development process goes from concept to the final high-quality prototype.

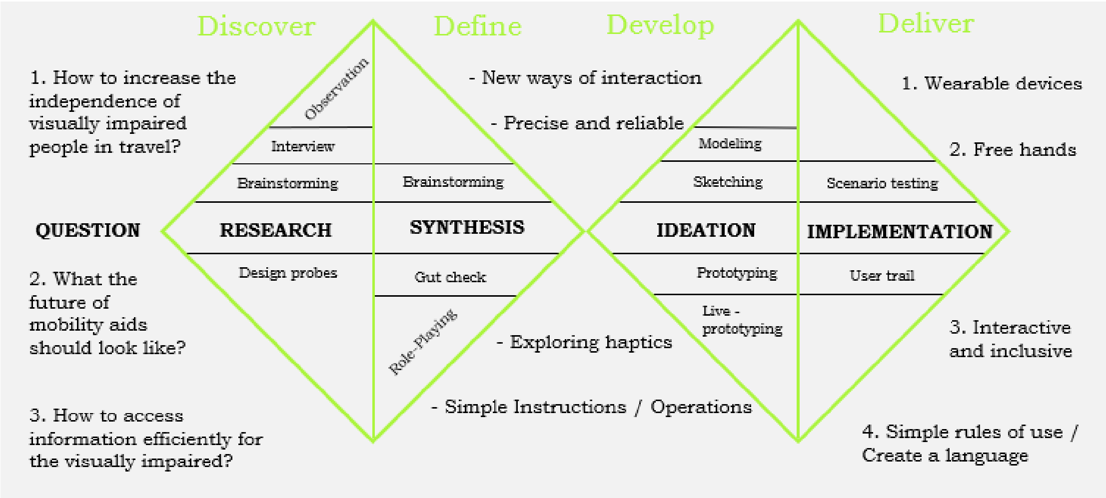

Figure 16: Research framework.

Design task

Our task was to design a navigation system with four components: a haptic feedback device, an obstacle detector, a charging port, and an instruction manual. After the previous analysis, we decided to use the neck and wrist parts to design the components. In addition, we wanted to start designing the charging pile and the instruction manual after we had designed the wrist and neck parts to set the tone for the whole project.

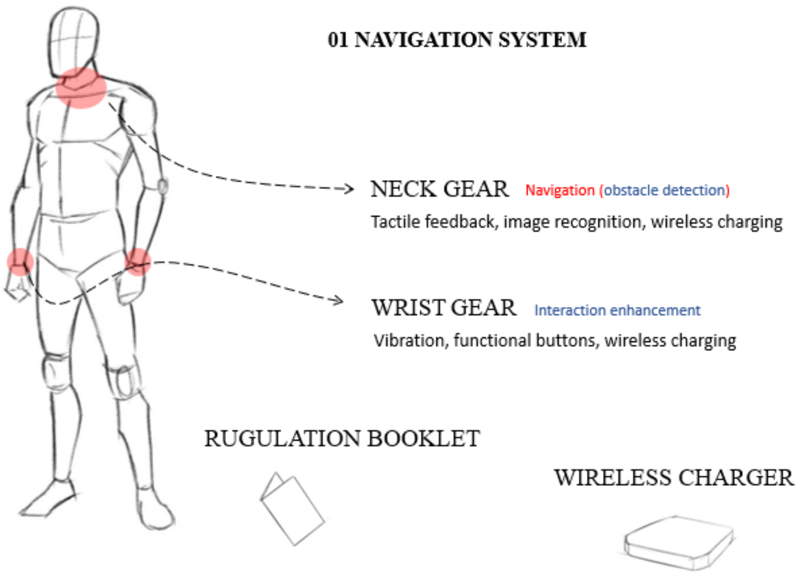

Figure 17: Overview of the design task.

Initial sketch

The initial sketches were based on the moods we selected, and we tried to find a futuristic, streamlined, and stylish style in the initial sketches. We also tried to draw some interactive gestures, such as how to turn the phone on and off and switch modes, to increase the product's interactivity.

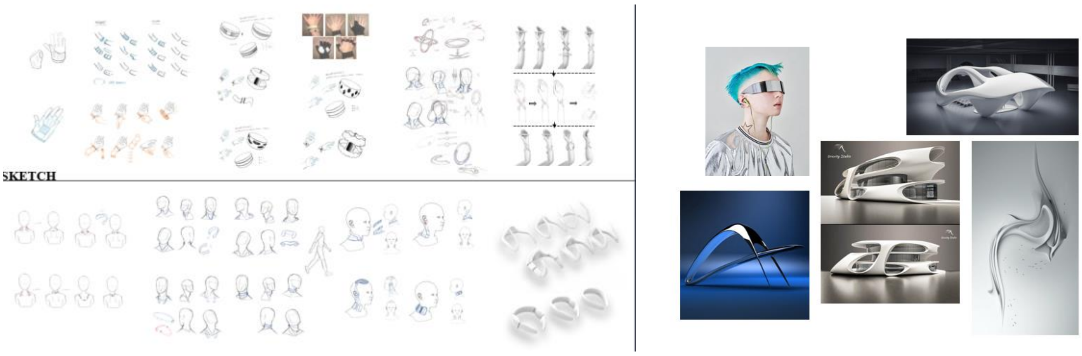

Figure 18: Sketches & Moodboard.

Tec analysis

The technological analysis analyzed the strengths and weaknesses of similar products on the market, taking the best and discarding the worst. At the same time, we also analyzed the structure and layout of the components of similar products in order to obtain the necessary layout design for our product.

Figure 19: Tec analysis & Layout design.

Engineering experimentation

After the technological analysis, we carried out simple functional tests using rough 3D-printed models and the Arduino platform. This not only helped us to determine the approximate dimensions of the product but also gave us an idea of what type of electronic components and sensors we needed to match to avoid any disconnect with reality when designing.

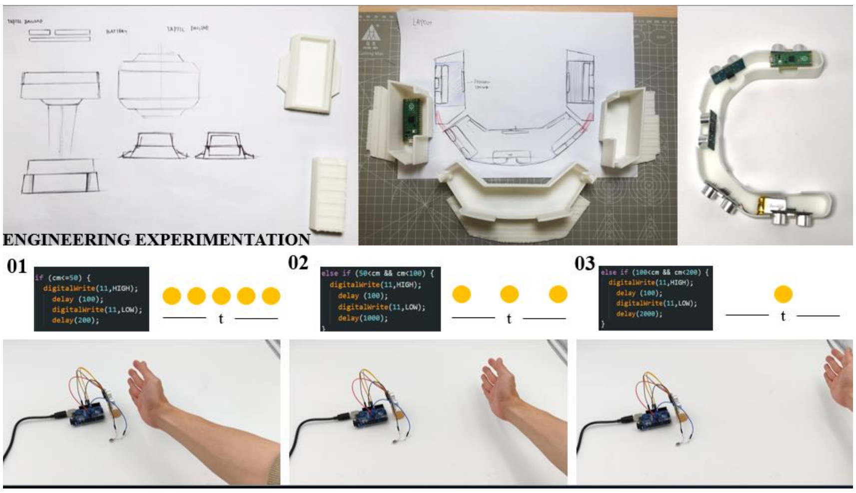

Figure 20: 3D prototypes & Arduino test.

Advanced sketching

The advanced sketches should be carefully considered to give a uniform stylistic shape between the different components, which can also be described as having the same design language. In addition, the spatial proportions of the product also need to be sketched to complete the design. Rather than being limited to sketches, we can also use 3d modeling software to construct rough models to simulate the actual spatial proportions.

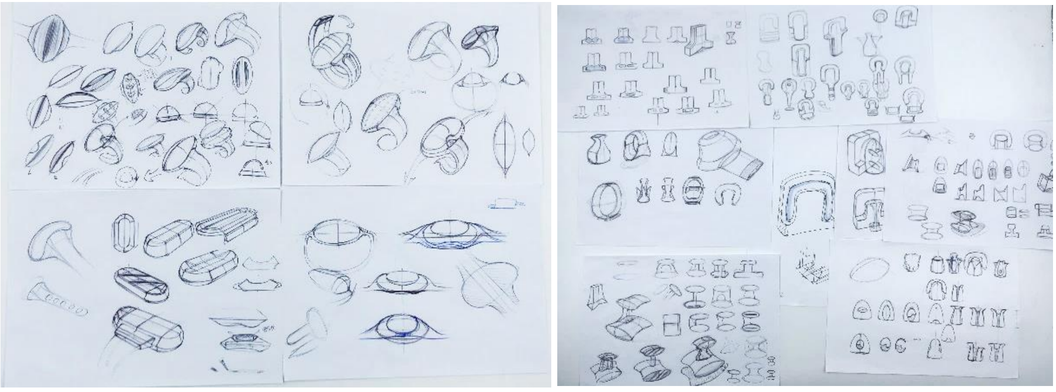

Figure 21: Detailed sketches.

Wearable test & Details iteration

There are two parts to the wearable test, and the first part is to give the rough 3d model to the participants to use for testing and deriving direct feedback on wearability. The second part is to iterate on the previously obtained feedback and create a high-quality prototype for the participants to test. For example, the charging stake was too high, so we used black tape on the bottom to quickly represent the abated parts; the wrist parts were drawn with black lines to test how much the wristband flexed; and the marks were made on the 3d models to simulate the details that would be added and they would change the curvature of the curved surface.

Figure 22: Wearable test of the wrist gear.

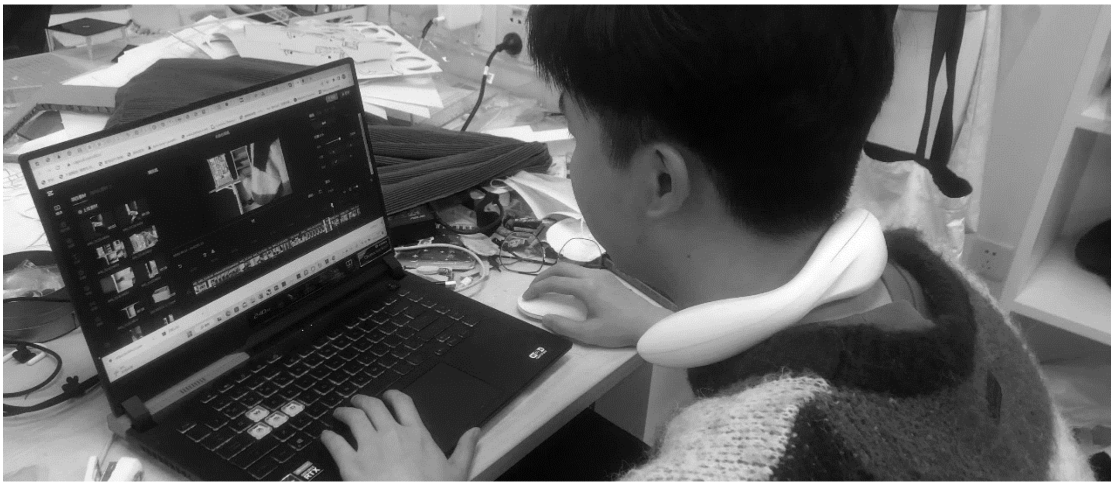

Figure 23: Wearable test of the neck gear.

Figure 24: Wearable test of materials.

3D visuals

Through rendering, we can give the product different materials and colors to simulate the final high-quality prototype, which allows us to define the visual scheme and provides a guiding scheme for painting the physical model later.

Figure 25: 3D visual of the charging station.

Figure 26: Haptic experience when placing neck parts.

Paint spraying

The renderings are used to paint the high-quality 3d model and assemble the appropriate technological components to complete the final high-quality prototype.

 

Figure 27: Painting the prototype in the paint room.

Findings

Sensory help navigation

In order to confirm whether the senses are helpful to the visually impaired in navigating, first-hand research methods such as role-playing, observation and interviews were used to obtain immediate and realistic data from the subjects and to get an unambiguous picture of what the visually impaired need and want during walking. In addition, we also surveyed existing technologies in the market and compared several reliable haptic feedback technologies. As a result, visually impaired people rely on five basic directions when walking to ensure they can walk safely, and it is known from existing technology that many suitable tactile feedback devices provide navigation information.

Figure 28: Analysis of the pros and cons of the products already on the market.

Interaction based on wearable devices

To confirm the suitability of wearable devices as navigation vehicles for the visually impaired, low-tech prototype testing, high-tech prototype testing, and comparative user testing were used to obtain the preference of visually impaired and ordinary people for different navigation devices. Comparing different ways of accessing information, such as physical contact with different parts of the body, verbal cues, and non-wearable devices such as white canes and simple guide dogs, it was concluded that wearable devices have direct contact with the human skin, which means that mechanical signals can be transmitted well through the sense of touch and that wearable devices can be concealed in a person's daily wear and are easy to carry.

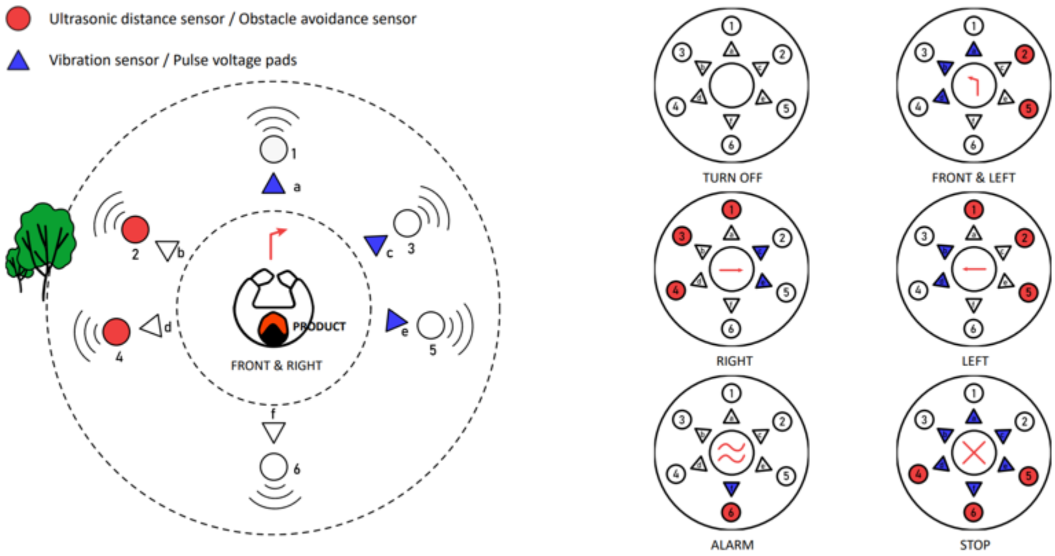

Figure 29: System design and demonstration of the haptic feedback principle.

Improving the environmental resilience of products

To confirm the importance of improving the adaptability of the product at the links, numerous prototype iterations, sketches, and extensive brainstorming sessions were carried out to simulate various usage scenarios, identifying that the design requirements would change for different scenarios from both a user experience and product design perspective. In this paper, we argue that in addition to the need for signal indication at junctions, there should also be an alarm signal in the event of an unexpected situation. In the absence of danger, the device should also have a signal to provide a sense of safety for visually impaired people walking. The user is equipped with a certain level of adaptability when encountering different environments. In terms of the product itself, the main focus is to improve the product's detection and obstacle avoidance performance by placing five detectors to ensure coverage in all walking directions, which facilitates the detection of dangerous obstacles in complex environments.

Tangible symbols help learn to use the product

To see if the tangible symbol system would help visually impaired people to learn new tools, we tried analogies to Braille, blind alleys, and similar products to try to find patterns in them. In addition, we also resorted to some printing designs, an intaglio printing process to ensure tactile dots on the paper. Also, we tried different colors to make it easy for visually impaired people to use, but also for ordinary people. Overall, the tangible symbol system does reduce the learning burden of the visually impaired to a great extent and allows them to turn to the content they want to see at any time.

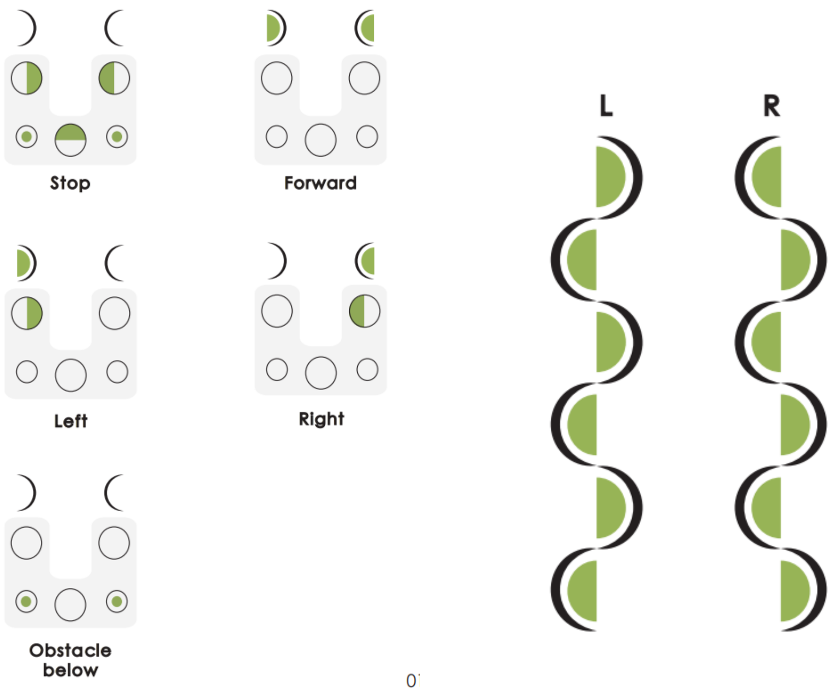

Figure 30: Design of tangible symbol systems.

Discussion

To review a few of the research questions we have asked, how can sensory and tangible feedback be used to better navigate for the visually impaired? Are wearable devices suitable to be designed as navigation devices? How can the environmental resilience of accessible navigation products be improved? How can tangible symbol systems create inclusivity and accessibility when visually impaired people are exposed to new tools? The research methodology results in this paper are that the design of a wearable navigation device with haptic feedback and the use of a navigation system in conjunction with a tangible symbol system is innovative and of research value. This is because the wearable device demonstrates inclusiveness by ensuring functionality while being somewhat discreet, comfortable, and aesthetically pleasing. At the same time, having a scientific haptic feedback system provides an excellent interactive experience and frees the hands of the visually impaired when walking. In addition, a simple and familiar system of tangible symbols eases the burden of learning new tools for the visually impaired.

System design & equipment design

The results of this piece show a future, beautiful and complete product and system design. Industrial design differs from existing research in that the design is innovative in terms of appearance and functionality, increasing the user's comfort throughout the entire product experience and optimizing the tactile feedback in many ways. On the one hand, the appearance is mainly organic and curved, with various materials and colors, to make it safe and comfortable for the visually impaired to use and to be able to choose the product according to their preferences. The functional components are equipped with haptic feedback, which means that the user can wear the product with tangible feedback when turning, when charging and when finishing using the product, and with a high precision ultrasonic distance measuring device, which makes the work of detecting obstacles sensitive and accurate. The wrist part is designed with a silicone strap and a plastic pod with a metallic feel. Both the strap and the pod can be chosen according to personal preference, including color and material, and the whole shape tends to be streamlined, making it easy for the user to touch, put on and take off; the neck part is designed with a soft plastic shell, and silicone is placed in direct contact with the skin. The addition of a fading surface on the back side of the part is to increase. In addition to detecting obstacles horizontally, the front two probes can detect obstacles on the ground, which ensures that there are no dead ends in the detection area. The shape is based on the outline of the neck part, and the height is based on the length of the wrist strap on one side of the wrist part. The overall shape is based on a minimalist style because the part is worn for only a short period, is generally placed more on a wall or table, and should be considered furniture. In addition, the head and lower body ellipses are wirelessly rechargeable. They can charge the neck and wrist parts, respectively, and the platform on the head informs the user via haptic feedback when the neck part is placed at the end of use.

Figure 31: The entire system is designed in a unique style.

Some of the limitations of this study include the fact that the results focus on the designer's subjective design and the lack of usability testing on the target user, which means that some of the study data may be inaccurate and unreasonable, such as how easy it is for the visually impaired to put on and take off the wrist piece, and how easy it is to switch the product on and off when out and about. In addition, the design lacks material research, which means that different materials should be considered for the areas of the product that come into direct contact with the human body. This is because materials play an essential role in the experience of using the product. For example, soft and delicate fabrics give a feeling of thoughtfulness and warmth, while materials with rough and hard surfaces give a feeling of reliability and sensitivity. It is essential to look for ways to contact target users across multiple platforms and actively collect usability testing results from target users to help iterate on the product. In addition, more attention should be paid to material research manufacturers to obtain different new materials and use them in research.

In future research, it is essential to first look more deeply into the target user's product usage behavior, increase the target user's engagement and involve them in the whole design process, and secondly, look at ways to incorporate material design into wearable device design, which will significantly increase the haptic feedback experience of the product.

Interaction

The results of this piece demonstrate a subtle and novel way of interaction that not only increases the adaptability of the product to the environment but also offers the visually impaired the possibility of freeing their hands when walking. First of all, while traditional navigation systems can only tell the user the approximate direction, e.g., turn right 600 meters ahead, traffic lights ahead, turn left in 100 meters, etc., the difference in this study is the inclusion of detection and obstacle avoidance for unexpected situations, which means that the user can avoid obstacles in the pavement, such as rubbish bins, illegally parked cars, small potholes in the road, etc. while walking. In addition, the user is informed of the exact steering angle, which is achieved through a collaboration between the person and the device, with the device's haptic feedback transmitting a tactile signal to the user that they can walk when they turn in a direction free of obstacles. This dramatically increases the device's adaptability, as instead of general route navigation, the user's position is used to detect and navigate around obstacles, which means that when faced with complex scenarios, the system can always tell the user instantly and accurately whether there are obstacles ahead. In addition, this eliminates the need for the user to hold a tool to detect obstacles, which can help visually impaired people move away from traditional tools such as guide dogs, white canes, etc. The innovative combination of a wearable device and haptic feedback forms a unique interaction for this study and demonstrates the difference between this study and existing research in the interaction that is familiar and advantageous to the visually impaired.

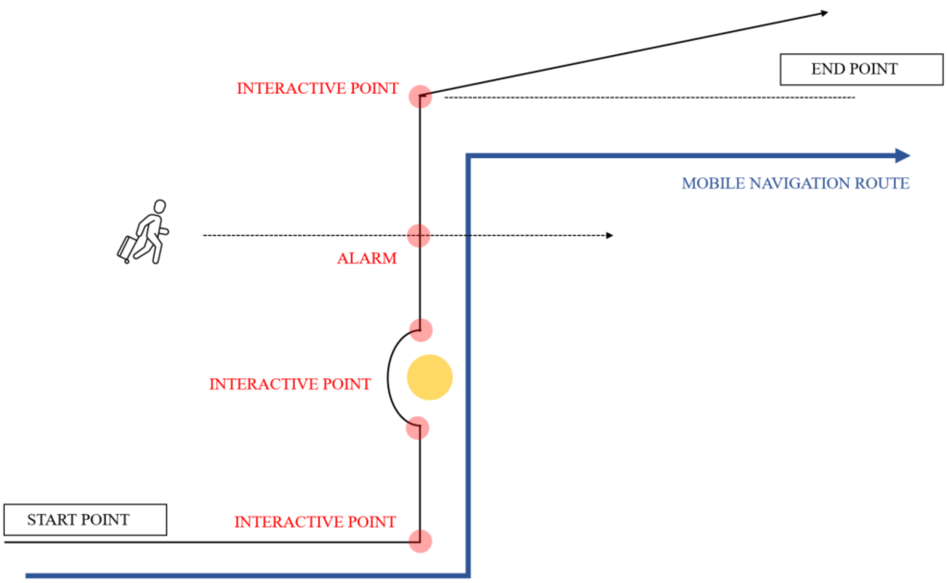

Figure 32: Differences compared to traditional navigation and individual interaction points.

In this section of the results, we did not bother to test the product's comfort. During our research, we only used the Arduino-based haptic feedback prototype to test it. Although it ensured that the system could function fundamentally, we should have tested the feedback intensity; for example, we divided the haptic feedback into ten levels, with level seven intensity applying to the signal of a detected obstacle, level two intensity applying to regular tactile signals generated when walking safely, level four signals apply to steering, etc. In addition, when designing the interaction, there needs to be more testing when the user is wearing different clothing, as different types of clothing can affect the efficiency of the haptic signals, such as whether the product is in direct contact with the user's skin. Finally, tests on whether the parts are connected to IoT need to be included in the results; we only used the Bluetooth module as the technical principle for IoT.

Future research should complement the haptic feedback and IoT components of this study with the help of specialist technicians, and tests on haptic feedback should also be carried out, including the efficiency of haptic feedback when wearing different clothing and the effect of different haptic feedback intensities on the user experience. The findings of this panel are significant for developing haptic possibilities in designing products for the visually impaired, extending the benefits of haptics in the field of visual impairment, and offering new human-computer interaction possibilities for wearable devices.

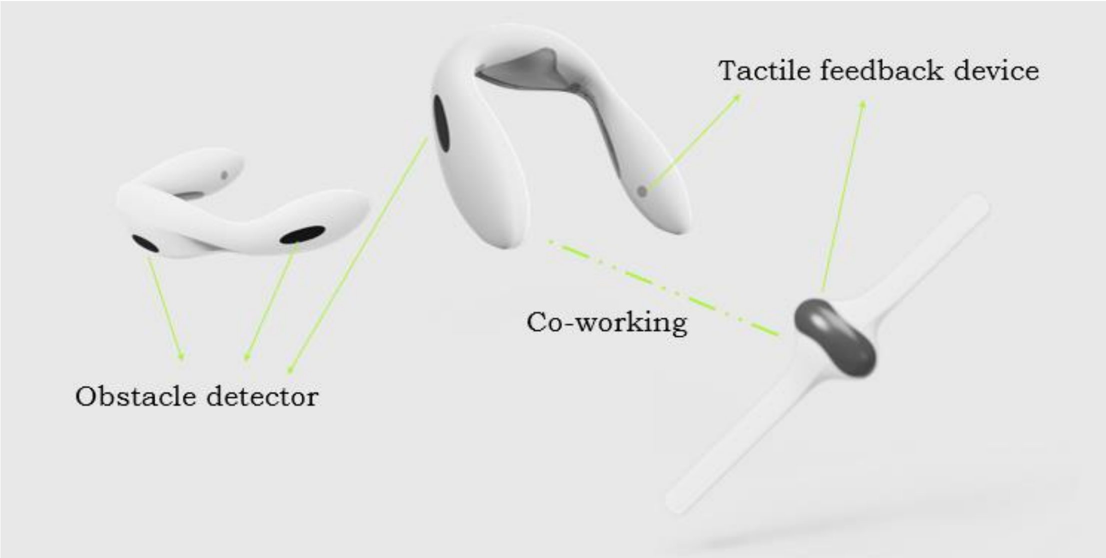

Figure 33: The principle of operation of the system and the sensors.

Language & language

Surprisingly, the tactile language in this system is designed to ease the burden of learning to use new tools for the visually impaired. Firstly, we have designed special tangible symbols based on the shape of the product in order to allow the user to connect these symbols and the product quickly. For example, the main body of the tangible symbol is a "U" shape, derived from the shape of the neck part. The steering symbol is derived from the particular curve of the wrist part. In addition, to represent the different directions on a two-dimensional level, we have used embossing to convey different tactile sensations on the watercolor paper, in the same way, that Braille and blind alleys work, which is a familiar way of learning for the visually impaired. The advantage of this is that the user can learn how to use the new tool using a familiar learning style and can quickly access the desired content in everyday life because the entire study guide is presented in the form of a booklet and, more importantly, the guide is also printed in color, the reason for this being to make it easier for other people with visual impairments to use the product as well. Finally, in this tangible symbol system, there is an attempt to use regular tangible symbols to convey a sequence of actions. For example, a typical response from a tactile feedback device means walking is safe. Unlike current research, for example, where the learning guide in Google Glass is in the form of a voice packet in the software for the user to learn, most other products released on the market do not even have an associated learning manual or instruction manual.

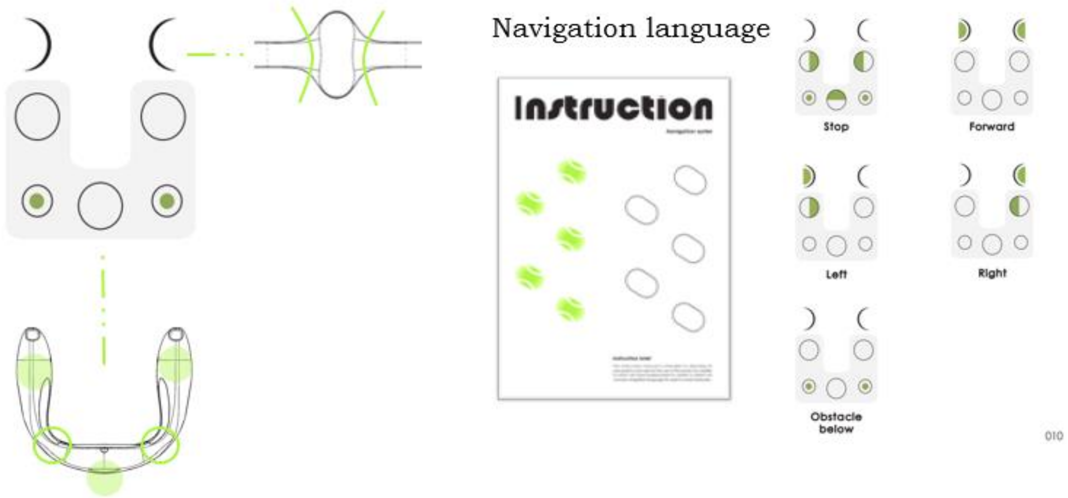

Figure 34: The development process of the tangible symbol system.

The results here showcase highly stylized products, which demonstrate the trend towards inclusivity in the future. We have created a pyramid of needs that shows that to increase the social identity of visually impaired people, they should be empowered in the same way as ordinary people. This means that inclusivity should be seen as ordinary, rather than specific, among the visually impaired, for example, by designing products for the visually impaired that can also be used by ordinary people rather than specifically designing a product that can only be used by the visually impaired. Unlike traditional research, the products in this study are equipped with bright colors and stylized shapes, which provides autonomy for the visually impaired as they can choose their preferred style and wear the device. For example, they can choose a furry wrist and a yellow neck. At the same time, using different tactile feedback methods to convey information also means that we can consider not only the comfort of the product through the sense of touch but also the different sensations of the different materials when designing products for the visually impaired. Moreover, in the future, we can discuss dressing, fashion, and style among the visually impaired, another expression of inclusiveness.

Figure 35: Different styles of wrist gears.

Figure 36: Different styles of neck gears.

However, the lack of usability testing in this study means that the design of the tangible symbol system in this system may only be helpful for some visually impaired people. In addition, the functional panels in this system are limited by the need for specialist machines to implement the tactile manual fully, and the choice of paper is limited to thicker sketch paper.

Despite its limitations, the tangible symbol system proposed in this study is forward-looking and sustainable because it can be developed into a uniform and standardized transport language for the visually impaired, which provides a basis for safe travel for the visually impaired community and also reduces their learning burden when they choose different tools. Future research will need to spend much time on usability testing, actively iterating on the product during the design process, and exploring more tactile materials.

Conclusion

This study is a system for navigation for the visually impaired, where unpredictable natural disasters and social circumstances lead to challenges for the social inclusion of the visually impaired. The project optimizes the travel experience of visually impaired people, thereby enhancing their social identity.

Based on the analysis of haptic feedback and wearable devices, excellent human-computer interaction experiences, wearable device design, and tangible symbolic system design are essential factors that must be considered when designing products for visually impaired people. The results show that using haptics as a medium of communication between humans and devices as a unique and standardized language is a familiar form of communication for visually impaired people. In addition to being more conducive to conveying haptic information, the wearable navigation device as the core of the whole system is also more likely to improve comfort and interaction for visually impaired people when walking independently, optimizing the experience of using the product and more importantly, It is also easier to improve comfort and interaction when walking independently, optimizing the experience of using the product and, more importantly, creating a set of highly stylized wearable navigation devices, increasing the fashionability of the product while significantly increasing the inclusiveness of the system. Finally, this thesis proposes a new approach to designing travel assistance systems. While limited user testing, material testing, and technical support limit the generalisability of the results, the proposed system offers new insights into the inclusivity of the visually impaired. It broadens the design thinking of designers and academics.

Recommendation

Looking back at this project, the issue of safe and reliable travel for the massive number of visually impaired people does need to be considered. However, due to the unpredictable environmental crisis and the rapidly evolving human society, relevant research should have a specific forward-looking and sustainable solution.

Through this project, I have gained a better understanding of the importance of including designers' design projects in addition to objective data collection, which is the key to innovation. Although we have done much preliminary first-hand research, such as interviews, observations, and user testing, much of the data still needs to be generalizable.

For future research, collecting data from long-term user testing and representative scenario analysis will make the project more generalizable. Also, I would advocate more experimentation with wearable materials, providing many possibilities for haptic feedback in the project.

Considering how the project could be shown to be inclusive, it is possible to switch between different target groups. For example, we switch the target group identity of visually impaired people with that of ordinary people. In that case, we could consider the research equally applicable to ordinary people, such as navigating older people, providing obstacle avoidance services to people who work in dangerous jobs, etc.

This project is worthy of long-term research and is not only providing solutions for the future of mobility for the visually impaired, but is also opening up new forms of expression for the future of inclusion.

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Appendix