A RESPONSIVE AUDIO AND TACTILE WAYFINDING METHOD FOR THE VISION IMPAIRED

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Abstract.

The number of people in Australia with vision impairment is projected to grow to over 500,000 in the next decade, according to Vision Australia. Currently, much of the technology provided for people who are vision impaired is static and non-responsive. This research aimed to develop an interactive method of providing wayfinding information through audio and tactile feedback. An iterative method of testing resulted in the development of a 3D printed model of a building which included sensors to detect the position of a vision impaired person's hands. These sensors activated specific audio feedback relating to a space in the building model. Furthermore, vibrations were used to guide the user along a path to reach their desired destination. This was found to be an effective method of providing wayfinding information to people who have vision impairments and provided an improved spatial awareness and navigation experience.

Keywords. Vision Impairment; wayfinding; audio; tactile; interactive.

1. Introduction: Research Aims and Motivations

The number of people in Australia with a vision impairment was 384,000 in 2016 (Vision Australia, 2016). This is projected to grow to over 500,000 in the next decade; this is a substantial number of people who will have issues accessing the built environment. Giudice & Legge (2008, p479) state that "to facilitate safe and efficient navigation, vision impaired individuals must acquire travel skills and use sources of non visual environmental information that are rarely considered by their sighted peers". Currently, much of the technology provided to the vision impaired is static and non-specific, such as tactile dots on the ground. This means that people with vision impairments must adapt to their environment. How might the environment adapt to the specific needs of the user? People who are vision impaired typically rely on other senses to navigate through new places, including hearing and touch. This research investigates how audio and tactile feedback can be included in technology in order to appeal to vision impaired user's sense of hearing and touch respectively. Research was undertaken to understand how verbal instructions and tactile information can help vision impaired users with wayfinding. Based on this, a design solution was created, using an interactive 3D printed building model with audio and vibration feedback.

2. Research Observations and Objectives

The objectives of this research were to determine an efficient and user friendly method of assisting people with vision impairment by providing audio and tactile information to help wayfinding in an unfamiliar public building. The design would respond to user inputs by providing information specific to the needs of the user. The information provided would be updated when required, through a wireless internet connection. It would be located in public spaces and require minimal prerequisite knowledge and equipment from users. In order to better understand the needs of people with a vision impairment, research was undertaken. This took the form of analysing case studies, to define common obstacles that people with vision impairments experience during interactions with current technologies as well as existing solutions. This research defines requirements for vision impaired people to be able to find the device and how they can efficiently interact with it. This resulted in an effective design solution that can be deployed and installed in many public buildings.

3. Research Questions

This research aims to explore ways in which tactile and audio information can assist wayfinding for individuals with a vision impairment in an unfamiliar building. Through a comparative analysis of existing research, the benefits and advantages of using responsive audio and tactile information for assisting individuals with vision impairments with the task of wayfinding, will be put forward. As the advantages are made clear, a user based test scenario will be created. This will take the form of a tactile model of a building, intended to be placed in entry areas of public buildings. As a user moves their hand over the model, audio feedback will be provided to correspond with their inputs. This will give specific and up to date information to assist users in navigating the building. The model will be tested by the authors and the outcomes analysed against the initial research.

4. Methodology

The objective of this study was to explore how audio and tactile information can assist people who are vision impaired in the task of wayfinding and to produce a prototype based on the research findings. Research was undertaken into the features required to assist vision impaired people and useful methods to aid wayfinding. Following this, a 3D printed tactile model, based on the Square House building at the University of New South Wales (UNSW), was created. The authors of this research tested this model, as well as colleagues who were unfamiliar with the form of the building model. The testing procedure involved wearing blindfolds to simulate the effects of being vision impaired and the users not having any prior knowledge of the building.

An action research methodology was adopted during this research, whereby "...a cycle of posing questions, gathering data, reflection, and deciding on a course of action" (Ferrance 2000, p2). This cyclical approach allowed research to inform the design solution and meant that it could be tested, analysed and improved throughout the entire process.

Iterations were modelled, tested by the authors and modifications made. 3D printing materials were tested, including finding a suitable size for the tactile elements, such as walls and steps, as well as the testing of the performance of two types of 3D printed plastic. Three methods for path identification were tested, to determine an effective method of conveying a path on the tactile model. These were heat lines, controlled air jets and vibrating discs. These methods were deemed suitable for conveying tactile information as they provide an obvious output. Research was undertaken into the which of these methods would be effectively controlled by the Arduino board. Vibrating discs was the method chosen and it was tested on the model. Adjustments were made to the model to accommodate the discs, including creating plastic pieces that are separate to the overall model, and using dampening materials to isolate the vibrations.

The authors of the research tested the model, aiming to see if the model can recognise user inputs and provide the correct output. Blindfolds were used to simulate a vision impairment in the user and the people testing approached the model with the intention of finding a path to a specific location. Following this, the users were asked about their experience and the level of spatial awareness they had attained through their interaction with the model. These findings were used to improve the model at each stage of the prototyping process.

5. Background Research

There have been many efforts over time to use new technologies to assist people with vision impairments, with much success. Traditionally, the white cane has been the major piece of technology for assisting the vision impaired. More recently, technological advancements include the Walking Assistant Robotic System, developed by Ni et al. It was a type of walking frame that contained sensors to detect obstacles, which send a signal to a vibro-tactile belt worn by the user. While the system was effective in allowing users to walk confidently, it was cumbersome and not suitable to environments where there are steps or uneven terrain. Ross Atkin Associates' Responsive Street Furniture provides individuals with "brighter street lighting, audio information, extra places to sit and more time to cross the road" (Ross Atkin Associates 2015). The furniture responds when a user's smartphone enters a radius and adapts according to their individual needs. This is a great example of how environments can adapt to suit the specific needs of those with vision impairments, however it relies on users to anticipate and register their needs in advance on a website.

Verbal instructions are a major resource that individuals with vision impairments use in wayfinding in unfamiliar places. However, the quality of verbal instructions can vary greatly and they must contain specific features if they are to be successful. Bradley & Dunlop performed a series of experiments on people with a range of different vision impairments. These people were given verbal directions containing various features and the most useful features were determined. These features include "directions consisting of a reduced amount of textual-structural and textual area/street information, and incorporated sensory, motion, and social contact information" (Bradley & Dunlop 2005, p402). Similarly, the Wayfindr app provides specific verbal instructions to a user's smartphone in order to assist wayfinding. Their developer guide outlines vital components of audio instructions, including "Verbs, which communicate the action required … orientation information, environmental features, … and phrases that communicate direction" (Wayfindr 2017, p26). According to these texts, vision impaired users who receive instructions with these features need less mental effort to travel and are more comfortable in the environment.

Tactile models are an effective method of conveying spatial information to people with vision impairments. Vermeersch et al. tested this during design meetings, where architects communicated building designs through the use of scale models. The findings of these tests were that "processes of action, perception and cognition turn out to occur in a haptic exploration of a design proposal similar to sighted practice" (Vermeersch et al 2011, p732). This finding means that tactile models can greatly enhance the spatial awareness of people with vision impairments and can assist them in wayfinding.

Merging audio and tactile features on a map is a way of taking advantage of sight and touch senses for the benefit of wayfinding. Wang et al. created a system that provided an interactive tactile-audio map using embossed paper and a touch screen. They found that "interactive exploration on the tactile map image with audio feedback allows better access to map information than pure textural descriptions or traditional static tactile maps" (Wang et al. 2009, p50). Similarly, Brock & Jouffrais created an interactive map with microcapsule paper and a touch screen. They also found "that interactive audio-tactile maps are more usable than regular tactile maps with braille text for blind users" (Brock & Jouffrais 2015, p8). These findings prove the viability of using audio and tactile features for the purpose of wayfinding for people with vision impairments.

6. Case Study

Currently, people who are vision impaired rely on a variety of methods for wayfinding in an unfamiliar place. These include forward planning, seeking assistance, using canes and guide dogs. Based on the research gathered, regarding the requirements for conveying information for vision impaired users, it was found that audio information and tactile models were effective methods in conveying spatial and path finding information. It was anticipated that the users of the 3D model design solution would develop an understanding of the building to a level that is sufficient to follow a path. This would be achieved by interacting with this 3D tactile model and interpreting the audio information.

In order to further investigate the findings outlined in the literature, a case study was developed. This involved creating a tactile model of a public building, in this case, the Square House at UNSW. This model provided audio and vibration feedback, depending on user inputs.

Firstly, 3D printing techniques were tested. The first test aimed to determine the size of elements that could be effectively felt and distinguished by users. The printed elements included walls ranging from 5mm to 50mm in height and small bumps ranging from 0.5mm to 5mm were printed. The authors tested the effectiveness of the size of the printed elements on their sense of touch. Two different 3D printing materials were tested; Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA). These materials were also tested with the author's sense of touch, to see how appealing they felt to touch. The model was created using the findings of these tests and placed on an MDF board.

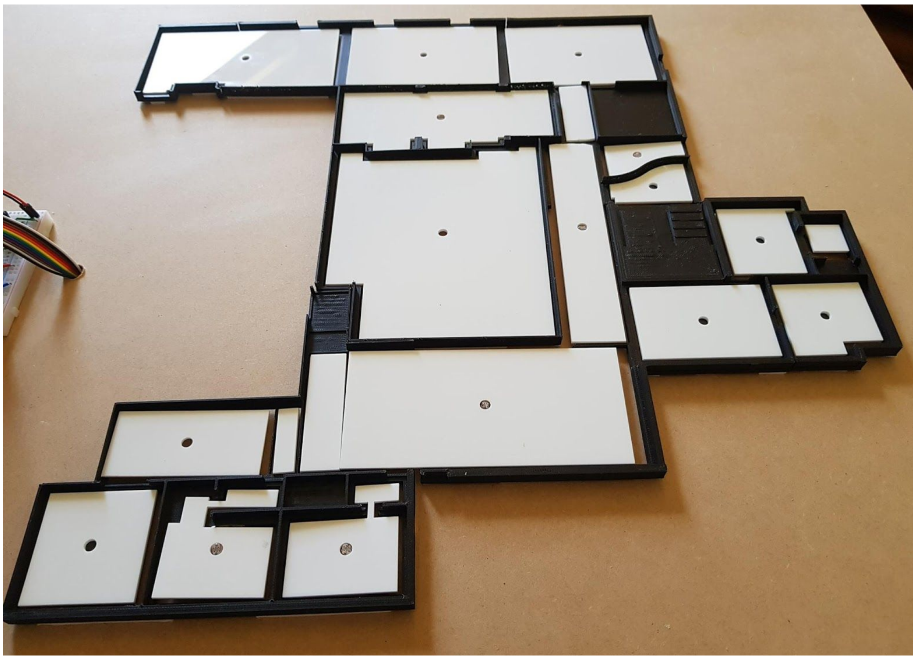

Figure 1: Tactile, responsive 3D printed model

Path discovery methods were another area of the modelling process that required testing. Three methods were tested: heat lines, air jets and vibration. The heat lines method involved a heated element to be embedded in the model to indicate the location of a path. Once a user triggers an input, the element heats up and the user can follow this using touch. The second method of path discovery was air jets. This involved using a 12-volt blower fan controlled by an Arduino board and powered by an external source, such as a large battery. Pipes would connect to the fan and feed the air to specific areas of the model in order to produce tactile feedback. The final method involved mini vibrating discs. These discs, similar to those found in mobile phones, were placed at locations under the model to demonstrate a path. They were controlled and powered by an Arduino board.

Vibrating discs were found to be the most suitable method for path discovery. This lead to the testing of a suitable input to trigger the disc vibration. Firstly, simple buttons were used to refine the code required to trigger the vibration. Once the code was working, a prototype was developed using the Particle Photon. This has the same functionality as an Arduino board, but can be controlled via the internet. The internet capabilities allows a user to trigger a vibration on the model using a smartphone app, meaning they can customise their experience.

Another three methods were tested to trigger the audio input, namely photoresistors, capacitive touch sensors and proximity sensors. All of these sensors used an Arduino board to control and record inputs. Photoresistors are small sensors that detect lighting conditions. If a user has their hand above the sensor, it would block the light, triggering a response. Capacitive touch is a method of sensing human touch, through the electrical capacitance of a body part. This means that if a user touches a part of the capacitive sensor, an Arduino would be able to recognise this and trigger a response. The final method to test was proximity sensors, which use ultrasonic sound to detect the proximity of an object to the sensor, typically within 800mm. If the hand of a user is within a specific range, this would trigger a response.

Figure 2: Photoresistors embedded in the model

The output method for audio consisted of a series of pre-recorded messages that corresponded to specific rooms and information that would help a person who is vision impaired to navigate to this area. An Arduino was used for this task, which stored the audio files on an SD card. The audio message would be triggered by the photoresistor and played through a speaker.

An issue that arose during the testing process for the vibration was that it was difficult to determine a specific point of the source of the vibration, making path identification difficult. A solution that was tested was to create laser cut acrylic pieces that were separate to the model to provide vibration isolation. These pieces needed to be raised to allow space for the vibrating disc as well as the photoresistor. Two methods were tested for this: a light foam material to be adhered to the underside of the acrylic, and a harder, silicone based material, also to be adhered to the acrylic.

Once testing was undertaken on the final iteration of the model, the issue of finding the entry of the model arose. The solution to this was to take inspiration from the tactile ground surface indicators which are used by people who are vision impaired to indicate an area for their attention, such as at the top or bottom of stairs. For this model, a row of small dots were placed from the edge of the MDF board and lead to the entrance of the model. Once the photoresistor at the entrance of the model was triggered, information about the model, the building and how to interact with it was given.

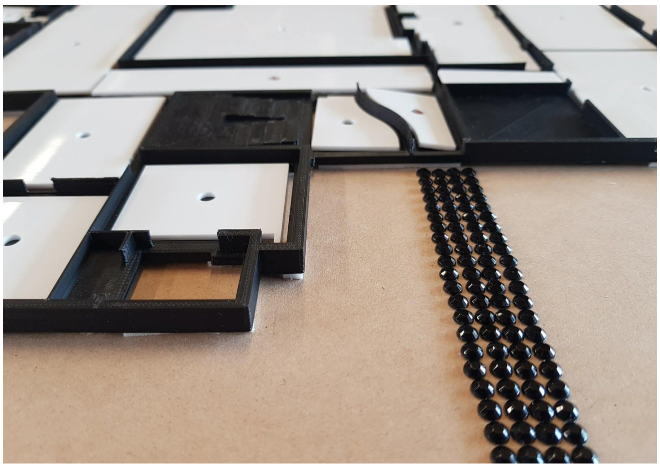

Figure 3: Tactile path indicators

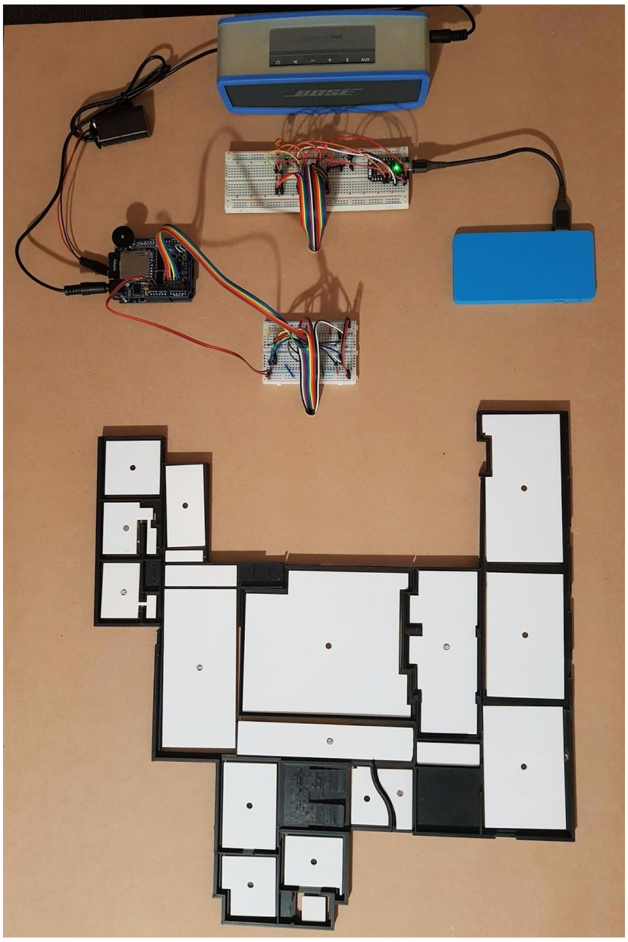

Figure 4: Final model arrangement

7. Significance of Research

The significance of this research is that it provides a method of wayfinding for people who are vision impaired, many of whom rely on static technologies such as white canes, braille, memory or depending on other people. This can result in feelings of uncertainty, frustration or a lack of confidence. This research and the solution based upon its findings will give independence to people who are vision impaired and make navigating unfamiliar places a less demanding and less stressful task.

8. Evaluation of research project

Wayfinding is a major issue faced daily by people who are vision impaired. Much of the technology available to aid wayfinding is based on providing visual cues, and there is little available to provide audio and tactile information. By creating a tactile model with audio feedback, the authors of this research have endeavoured to improve wayfinding accessibility for people with vision impairments. As mentioned by Vermeersch et al. (2011, p732) “processes of action, perception and cognition turn out to occur in a haptic exploration of a design proposal similar to sighted practice”. This demonstrates that tactile models are an effective method of providing spatial information. When used in conjunction with other innovations, such as the Wayfindr app, the audio tactile model can provide a comprehensive wayfinding solution for people with vision impairments and make buildings more accessible.

Material tests were undertaken in the design process, testing different aspects of the model. These included size of printed elements, such as walls and steps, as well as the material used. From these tests, it was found that people could distinguish between printed elements as small as 0.5mm. The tests also found that walls higher than 5mm were too tall, resulting in difficulty in moving the user’s hand between rooms on the model. Therefore, walls on the model were designed to be 5mm high and steps were designed to be 1mm high. Two types of plastic were printed, to test how different materials felt. ABS was smoother to touch, whereas PLA is more abrasive, making it unpleasant to touch. For this reason, ABS was chosen for the final model.

Path identification was another area of the model that was researched and tested. Three solutions were researched: heat lines, air jets and vibration. Heat lines, a hot wire embedded in the model, would potentially provide a tactile method of determining a path to follow on the model. However, this method was deemed inappropriate for this solution for a number of reasons. These included the fact that they would retain heat after they have been used, meaning users cannot use the model in quick succession. Furthermore, managing the heat emitted by wires is difficult to control using Arduino, resulting in safety issues. Air jets were also researched for the purposes of path identification. A fan blew the air through pipes to be fed through specific holes in the model. The user could then follow these jets of air and find a path. This was a safe option, that could be easily turned on and off. However, controlling the air via Arduino would also be a difficult process, requiring voltage conversion. Moreover, the pumping of air through the model would create unwanted noise, which would potentially disrupt the audio components of the design solution. Finally, vibration was tested for the path identification. Vibrating discs were placed under the model and pulsed to indicate the location of the path. These discs were simple to control with Arduino and required only a small amount of power. However, they caused the entire model to vibrate, making it difficult to find the source of the vibration specifically. The solution to this problem was to create a separation in the model, whereby laser cut acrylic pieces were placed in holes in the model, removing the mechanical connection with the 3D printed elements. This proved to be a successful solution and resulted in a clear and consistent representation of a path for users to follow, using their sense of touch.

Upon testing of the final model, it was found that the tactile elements were effective in conveying the spatial values of the building. Walls were of a suitable height to stop users from moving to other rooms. Furthermore, elements such as doors and stairs were able to be felt and understood. As the users moved their hands over the model, the audio information provided was clear and concise. Users initially used two hands to comprehend the model, however this resulted in too many inputs and the audio output kept being interrupted. Vibration was effective in identifying a path for the user to follow, however some parts were vibration worked less effectively than others, meaning users were occasionally lost. This was due to the fact that all rooms had one vibrating disc, however, they were not all the same size, meaning the vibrations were weaker in the larger rooms.

Limitations to this research include the model not being testing on vision impaired users and limited testing of electronics. Due to time constraints and not having the required ethics approval, the model was not able to be tested on people who are vision impaired. While the authors (who are fully sighted) endeavoured to understand the issues experiences and needs of people who are vision impaired, they cannot entirely understand what it is like to live with a vision impairment. Attempts were made to simulate the effects of a vision impairment by using blindfolds, however having people who are vision impaired test the model would provide multiple useful results and recommendations. Finally, the technology used was predominantly selected based on their availability to the author. With more time, a range of fabrication solutions would be tested, as well as a range of electronics and sensors. Furthermore, the code that was created to run the sensors only allowed for one input at a time. This meant that when a user used two hands to interact with the model, there were too many inputs and the audio feedback was inaccurate.

With further research, full voice interaction and artificial intelligence would be included with the model. This would improve the user experience of the model and provide customised and specific information to the user. Adding real-time data, gathered from sensors in the environment, would also improve the model by making the information conveyed more specific and current. Finally, testing the model with people who are vision impaired would have a significant impact on the usability of the model.

This research demonstrates a method of wayfinding in an unfamiliar building, for people who are vision impaired. Audio and tactile feedback are used, in order to appeal to the non visual senses of users. This increases accessibility in the built environment which, in turn, increases the levels of independence experienced by people who are vision impaired.

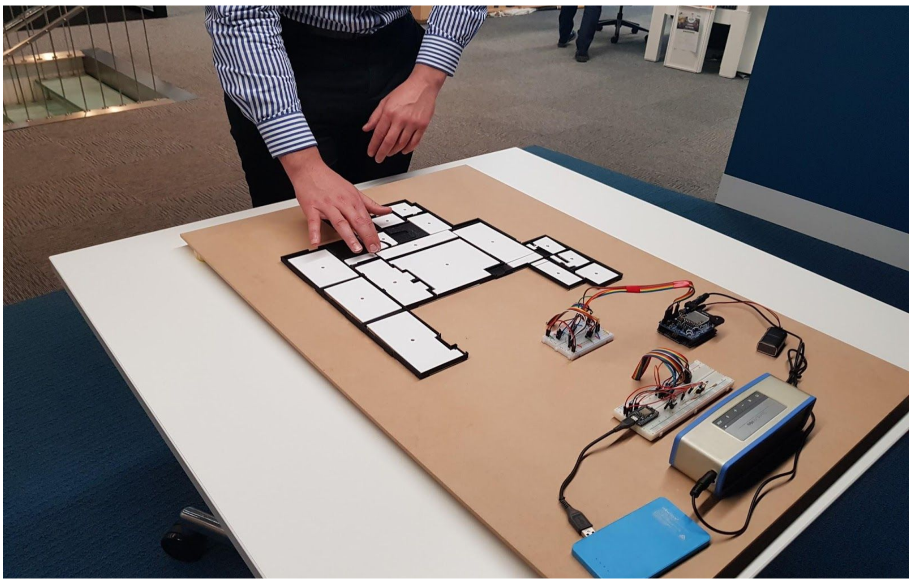

Figure 5: Final model being used.

9. Conclusion

This research demonstrates that audio and tactile information are suitable and effective wayfinding methods for assisting people with vision impairments. Based on these findings, a design solution, featuring an interactive 3D printed building mode, which provides audio and tactile feedback, was outlined and created. If this solution is to become prolific and common place, people who are vision impaired will have improved wayfinding capabilities in unfamiliar spaces. Due to the number of people with vision impairments increasing, wayfinding solutions are an important factor to consider in the built environment. Non-visual technologies must be considered and implemented, to provide real-time, audio and tactile information to assist the vision impaired and to make buildings more accessible to all.

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