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Peripheral Vision Displays: Creating an Unobtrusive LED Notification and Navigation System for Glasses

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22/02/2024

Declaration

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Date: 22/03/2024

Abstract

The goal for this project is to create a peripheral vision display to alert the user about notifications and navigation updates. This was achieved by using a ring of LEDs to shine at the user’s peripheral vision to create an unobtrusive experience of showing notification and navigation alerts from glasses instead of a smartphone. The project aims to make a compact and lightweight display, an application that provides an easy-to-use GUI to send alerts from the smartphone to the glasses and doing this while keeping costs of the product low.

The design of the system focuses on creating an application, designing how the LEDs work to represent different alerts and how the alerts are sent to the peripheral device using Bluetooth. The implementation involves creating a stable connection between the smartphone running the application and the microcontroller which is connected to the peripheral vision display through Bluetooth Low Energy. It also involves how navigation is performed through the handling of the user’s location and Google services.

Findings from participant testing showed the prototype's effectiveness being mediocre as the navigation functionality of the product was not accurate enough to depend on compared to alternatives such as Google maps that doesn’t involve the use of an external display. The main results show that users were able to get to their destination solely using the peripheral display and through changing the design of the LED display, spatial awareness and multitasking could be tested as benefits for using an alternative like this to other navigation systems.

Contents

1. Introduction

Peripheral vision is the 'visual field beyond our current point of gaze that provides information that is essential for a vast range of tasks in everyday life' (Vater et al., 2022). Peripheral vision allows us to see the space around us without the need to focus on it. This helps us to see movement and shapes in our field of vision. Peripheral vision is used in everyday life such as 'walking, reading, driving and sports' (Cleveland Clinic), and so taking advantage of it should be beneficial for most people.

The overall aim of this project is to implement and test the usability of peripheral vision to improve user experience with notifications and navigation, with it being less obtrusive than using a smartphone to check for changes in direction that the user needs to take. This project's objectives include:

The problem with current navigation is the risks of distractions from users focusing on their smartphone instead of their surroundings. This product is a prototype to see if peripheral vision can be used as an alternative to software only navigation systems. This project is worth doing as mitigating risks of pedestrians injuring themselves due to distractions would be very beneficial to help stop. A user that could find this product to be useful is a hand / arm amputees which may only have one hand to hold their smartphone to aid in navigation. With this product, the user doesn't require to have their hand holding a device meaning they would gain the ability to multitask.

1.1. Project Aims and Objectives

1. Creating a functional LED display – A functional LED display is necessary for giving the user the ability to view information from their phone without directly using the phone.
2. Making an unobtrusive LED display – The aim of the project is to make sure that the LEDs are unobtrusive and out of central vision and to make sure they are at a comfortable brightness for users, so they are neither too dim nor bright. The LEDs must not be placed in the focal field of view.
3. Creating a connection between an android phone and an embedded system – The system must communicate between the peripheral device and the smartphone wirelessly with using Bluetooth, being the most ideal way to do this.
4. Develop an application software – The application software is necessary for sending alerts to the peripheral system when the user is given a task during the navigation or for handling other notifications.
5. Making the system compact, lightweight, and easy to use – Presenting the prototype system as a project hobbyists could create, and use is important. The glasses need to be compact and lightweight as it is not desirable for the user to be seen in public wearing large, heavy glasses. To make sure users can run the application for the first time and quickly understand how to use it, the application must be simple to navigate through and use.
6. Evaluate in comparison to existing approaches – With the research taken place, I have gathered information on the limitations of other similar products. I will take advantage of this information and evaluate my prototype based on the existing approaches to see how this product performs in comparison to other competitors.

7. Have cheap and have easily accessible resources – Perform cost and resource checks to make sure that I am not using resources that are hard for hobbyists to access. I also need to make sure that the cost of creating the physical system is cheap as this is a prototype and not a final product ready for consumers.

In the following sections, the results of background research will be provided, the design of product’s induvial sections will be explained, and the implementation of the product will be detailed to provide a to give a brief overview of how different components of the product work together. Information about the user testing procedure will be provided and personal testing of the product will be discussed. The test will be conducted, and user evaluation will be analysed to see areas of improvement that can be considered to improve usability of the product.

2. Background

2.1. Peripheral Vision Display Concepts

The concept of a peripheral vision display, as explored in a paper on ‘Smart glasses with peripheral vision display’ (Nakuo and Kunze), involves a device designed to facilitate ‘implicit and explicit interactions’ by displaying patterns in the user's peripheral vision. Their prototype aimed to control human motion unconsciously and ‘alter walking speeds and motion’ using a grid of LEDs. Figure 1 shows the different notifications that are shown on the glasses to represent actions. The paper mentions a technical problem they faced with limited brightness of the LEDs creating poor visibility. This will affect certain scenarios in my project such as use of the device in daytime or nighttime as brightness can also affect the level of distraction it causes. With this project, the LEDs situated in the user’s peripheral vision are bright enough for daytime use but also dim enough so it doesn’t distract the user away from their focal vision, as this may lead to unwanted risks. An improvement mentioned in the paper was with the idea of attaching 2 LED matrices for each eye which would benefit the amount of information that can be shown to the user but also creates more of a distraction which may be desirable as it makes the alert from the LEDs less likely to be missed by the user.

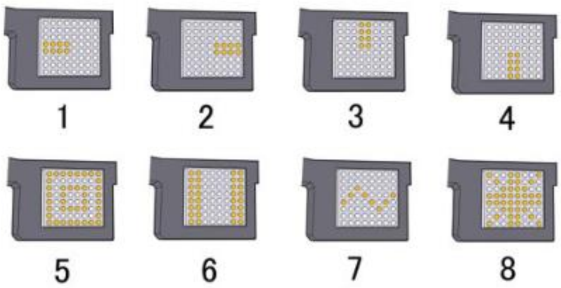

Figure 1: 8 different notification types to be shown on the glasses.

(Nakuo and Kunze)

Another paper which also designs a peripheral vision display is one called ‘Ambiculus’ (Lubos et al.). They created a display extension to the Oculus Rift DK2 by adding RGB LEDs and diffusing foil to extend the visual field. Although the peripheral visual quality was worse than the central field in the head mounted display (HMD), there was still an improvement in the user’s subjective sense of presence which influenced behaviour when participants navigated through a 3D virtual environment. A challenge this project faced was with some participants reporting increased simulator sickness with the additional peripheral light. This is something that will be noted during testing of the peripheral vision display as the addition of the peripheral light being shun in the user’s peripheral vision could increase motion sickness. This project is likely to benefit user’s behavioural changes and safety when displaying notification and navigation alerts as it is implied in the paper that users had increased head movements due to them not needing access to their smartphone while using the display.

In an article that explores and tests “eyeglass peripheral displays for subtle intimate notification” (Costanza et al.), the authors present a new approach to address the challenges posed by disruptive mobile notifications in public spaces. Their design involves integrating a discreet display of red and green LEDs, offering users a means of receiving notifications at a comfortable brightness. The product prioritised customisation, providing users with the flexibility to adjust the brightness and speed of LED patterns. They also found using the Bluetooth device to communicate with the user’s phone, proved to be a more energy efficient than alternatives such as vibrating motors to alert the user. The experiments conducted demonstrate the effectiveness of shining notification alerts at the user’s peripheral vision in various everyday activities such as editing text while walking and reading. From these experiments, it was concluded that the device tended to be less noticeable under high workload conditions which aligned with the goal of minimizing disruption during focused tasks..

One issue with using a peripheral vision display to help users with navigation is adaptability of the product in real life. This isn’t something that can be tested due to time constraints with development and so further testing can be performed to see if the peripheral vision display is a viable option to show notifications and aid with navigation or is using an alternative navigation application the better option. It has already been noted that people with lack of peripheral vision will not be able to use the product, but people with blurred peripheral vision may as there will be no hard to differentiate LED animations for different alerts unlike Figure 1 shows.

Shifting user’s focus from their phone to their surroundings for notifications and navigation alerts has many benefits for user safety as the visual stimuli can shift users’ attention without cluttering their focal vision, decreasing risk of accidents such as from users being distracted from their phone when crossing a road. Although this is a benefit for using this peripheral vision display, distractions are also a negative as the user may be alerted with a very bright LED shining that may distract them from their surroundings such as also when crossing a road. To make sure this doesn’t happen, users will have the ability to change the brightness of the LEDs. An example of this being observed is in a research paper named ‘Guiding Smombies’ (Gruenefeld et al.), which tested augmented peripheral vision to alert the user about critical situations when walking on a treadmill and using a smartphone. The experiment was conducted to evaluate the effectiveness of collision warnings with different light stimuli. There was 100% correctness with light stimuli being easily perceivable and moving stimuli resulting in significantly faster response times than instant and pulsing stimuli. Although true, participants found all stimuli to be alarming and as this project doesn’t require fast response times, the user shouldn’t find a large difference in effectiveness between different stimuli.

2.2. Feedback Methods / Information Channels

A study that explores the sixth sense metaphor which “describes solutions which use multimodal feedback to alert the user about changes in the environment”, and the use of different feedback methods in pedestrian navigation systems (Pielot et al.), discovered that tactical feedback helps reduce distractions whilst using a single actuator for directional cues is effective in aiding navigation. Participants showed a slight decrease in navigation performance with tactical cues, likely due to being more confident with visual systems. Participants found visual feedback led to more frequent map checking when asked to reach their destination under different modes of feedback but also resulted in a significant increase in walking speed. The study mentions using a combination of different feedback methods improved navigation performance by reducing errors, but this product will solely test the usability of LEDs for visual feedback.

The choice of using LEDs instead of other information channels is mainly influenced by the environment which the user would use the system. This project's focus is to alert the user when they have a notification and to aid navigation. As the product is designed to be used outdoor, sounds and vibrations to alert the user would be a poor choice as the user is likely to be in a loud environment, making it hard to check for, resulting in a less intuitive experience.

2.3. Direction / Orientation Detection

'SOMDA (Smartphone Orientation and Movement Direction Alignment)' is an approach to orientation which aims to accurately detect the movement direction and orientation of users carrying their mobile device inside trouser pockets. This is a beneficial concept for this project which would help aid navigation as it considers the movement of the phone when in a pocket to get the users orientation even when moving. A paper dedicated to explaining and testing 'SOMDA' is called 'Direction Detection of Users Independent of Smartphone Orientation' (Kusber et al.). Their results of testing 'SOMDA' achieved an accuracy of 96% with a threshold of 15 degrees using a sampling rate of 50Hz and found accuracy to decrease slightly when using lower sampling rates. 'A-GPS' is an alternative mention in the paper used to detect movement directions using existing servers to get more accurate readings of the user's location, and compared to the previous concept, 'SOMDA' significantly reduces time required to detect changes in user orientation and movement direction with detecting complete turns on average being 3.4 seconds faster than 'A-GPS'. Implementing 'SOMDA' would be time consuming as there is no available implementation of the algorithm meaning it would have to be created and implemented using only reference to the equations of the algorithm. This is too complicated and highly technical for me to understand, so instead the alternative, 'A-GPS' will be used to get device orientation.

3. Design

3.1. Functional and Non-Functional Requirements

3.1.1. Functional Requirements

1. The application must allow connection to a Bluetooth device.
2. The application must provide a map.
3. The application must allow the user to select a destination and handle accordingly.
4. The application must fetch directions data from Google Directions API.
5. The application must parse directions data and display the navigation data on the map.
6. The application must provide real-time location updates.
7. The application must provide real-time navigation instructions based on the user's locations and directions data.
8. The application must listen for notifications from the system and forward a notification alert to a connected Bluetooth device.
9. The application must allow users to customize notification and navigation settings.
10. The application must store user’s settings in shared preferences for future use.
11. The application must run direction checking of the user during navigation in the foreground.
12. The application must run location updates in the foreground.
13. The application must run notification listening in the foreground.
14. The microcontroller must be able to receive data from the application via Bluetooth.
15. The microcontroller must process the data received and display alert using the LED display.
16. The microcontroller must handle disconnection and reconnection with the smartphone.

3.1.2. Non-Functional Requirements

1. The application must use Google Maps and Google Directions API for map and directions data.
2. The application must use Android's Bluetooth API for Bluetooth connectivity.
3. The application must use Android's NotificationListenerService for handling notifications.
4. The application must use Android's SharedPreferences for storing user preferences and LED settings.
5. The application must use Android's Location Services for real-time location updates.
6. The application must handle permissions required for Bluetooth, location, and notifications.
7. The microcontroller should have low latency to make sure alerts are displayed as fast as possible.
8. The alerts shown using the LEDs should each be easily distinguishable from each other.

3.2. System Requirements

The device that was used during development was an ‘OnePlus 7 Pro’ as it supports Android version 12. Aside from the smartphone, the project uses an ‘Adafruit LED Glasses Starter Kit’ (AdaFruit) which included a nRF52840 Bluetooth LE microcontroller and Adafruit EyeLights LED Glasses (Kattni Rembor). The reason for using this bundle was due to it including everything necessary to create the peripheral vision display, being a microcontroller, LED display, Glasses frame and a battery pack. As the hardware was bundled, it was more convenient to get the components and there was no risk for compatibility issues between the components. The design of the kit is to make a wearable device which is easy to construct. The alternative construction of the peripheral vision display was originally planned to be used was a Raspberry Pi Pico W and NeoPixels to create the display from scratch but as this would increase development time, this was the less ideal option to take.

Android is the platform the application is designed on. This platform was chosen as it allows for easy integration with libraries such as Google Maps SDK for Android which is necessary for creating the maps system for the navigation feature of the project. During the beginning stages of development, “OpenStreetMap” (“OSM”) was investigated as an alternative if Google Maps SDK didn’t work for the application. “OSM” is an open-source library which performs the same features needed from Google Maps SDK but also allows for further customisation and better expandability. The reason for not using “OSM” mainly stemmed from the documentation being hard to understand. In comparison, I found Google’s services and libraries to be the opposite as there is very detailed documentation and tutorials which helped me use it. Another reason for choosing Google Maps SDK was due to its seamless integration with Android Studios being the chosen IDE to develop the application. Google’s services are also built to communicate with each other, allowing the use of Directions API and Places API which aid the navigation feature.

3.3. Architecture Structure

The architectural structure of the project’s components includes a battery, android application, microcontroller, and LED glasses. Having a small number of manageable parts to the project allowed for better separation of tasks for the smartphone and microcontroller. For communication between the smartphone and microcontroller, there were two main options being to use Bluetooth or WiFi but, WiFi would’ve likely needed me to create and set up the projects own peer-to-peer network and router configurations which would be a larger learning curve than using Bluetooth Low Energy (BLE). Instead, I opted to use BLE as it was more efficient for battery power which aligns with my requirements. In addition to this, there is better privacy and a cheaper deployment cost, but this comes with a negative with their being lower speed which is said to be “about 2-3 time slower than Bluetooth Classic and 20-30 times slower than Wi-Fi Direct” (Arun AG). Evaluating both options, settling with BLE seemed to be a better option for my use case as the distance between the smartphone and the microcontroller is very small, the costs are cheaper and, lower speeds shouldn’t have much noticeable effect depending on the structure of the messages being sent.

Figure 2 shows the architecture design of the project with what parts of the system do and how they interact with each other.

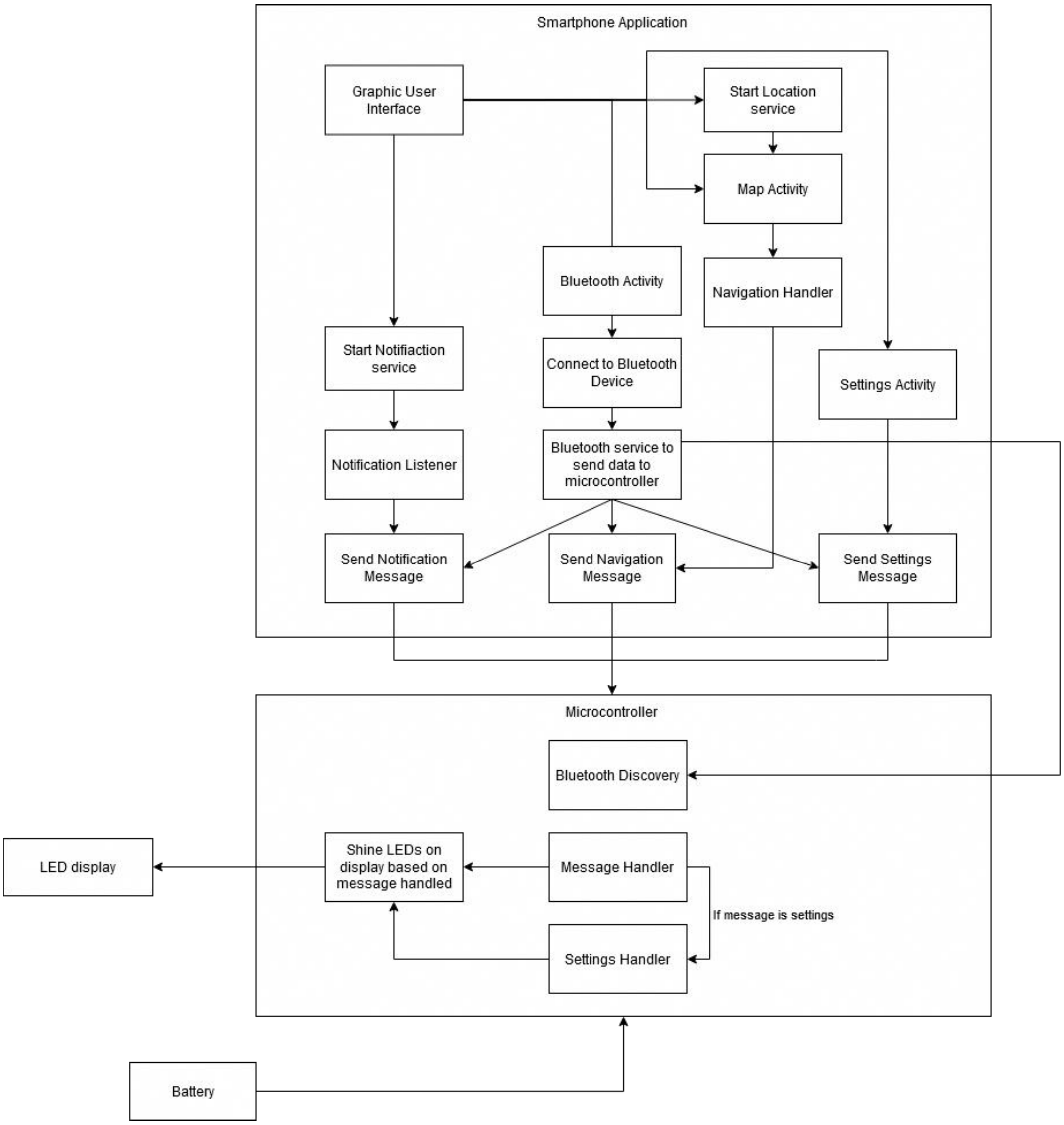

Figure 2: Architecture design diagram

3.4. LED Design

Using Adafruit EyeLights LED Glasses, allow for the ability to individual address LEDs to shine. The display's LEDs that will be used for this project are the two rings around the user's eyes. There are also LEDs on the black bars that go across the user's focal vision which weren't used for the safety of users as it may be harmful to their eyesight and would create extra visual distraction. Designs for the assigned sections of LEDs which represent different alerts were created with each ring allowing for assignment of 25 different LEDs.

The final version that will be used as the default LED states is shown in Figure 3. The reason for this being the final version is due to it uses multiple colours which help differentiate alerts indicate and makes them easier to memorise. The first version of designs primary used the colours red and blue because of them being the most contrasting colours against each other making it easier to see differences even for colour blind individuals. Previous design attempts used too many LEDs which were found to be very distracting to a point where it could be dangerous for users to wear. Having notifications be less distracting than the navigation commands is a good design idea as the navigation alerts must be more distracting to make sure the user views it. To also make sure that the device is not overly distracting or confusing which can cause risks, settings will be created allowing the user to change the brightness, colour, and toggle animation of LEDs. Not included in Figure 3 is the indication that the phone has been paired to the microcontroller. When this occurs, the right and left LED rings are both lit up green.

To indicate when the glasses are still running but are idle during times of no alerts being sent (when the device is connected), I designed the microcontroller itself to constantly shine green on the onboard NeoPixel as it gives an unobtrusive indication of state. Besides showing when the device is connected, I also created 2 more states for the NeoPixel being blue and red which works in tandem with the LED state shown in Figure 3 on the display for pairing mode, and a notification is sent to the device when the user's settings from the application are being processed.

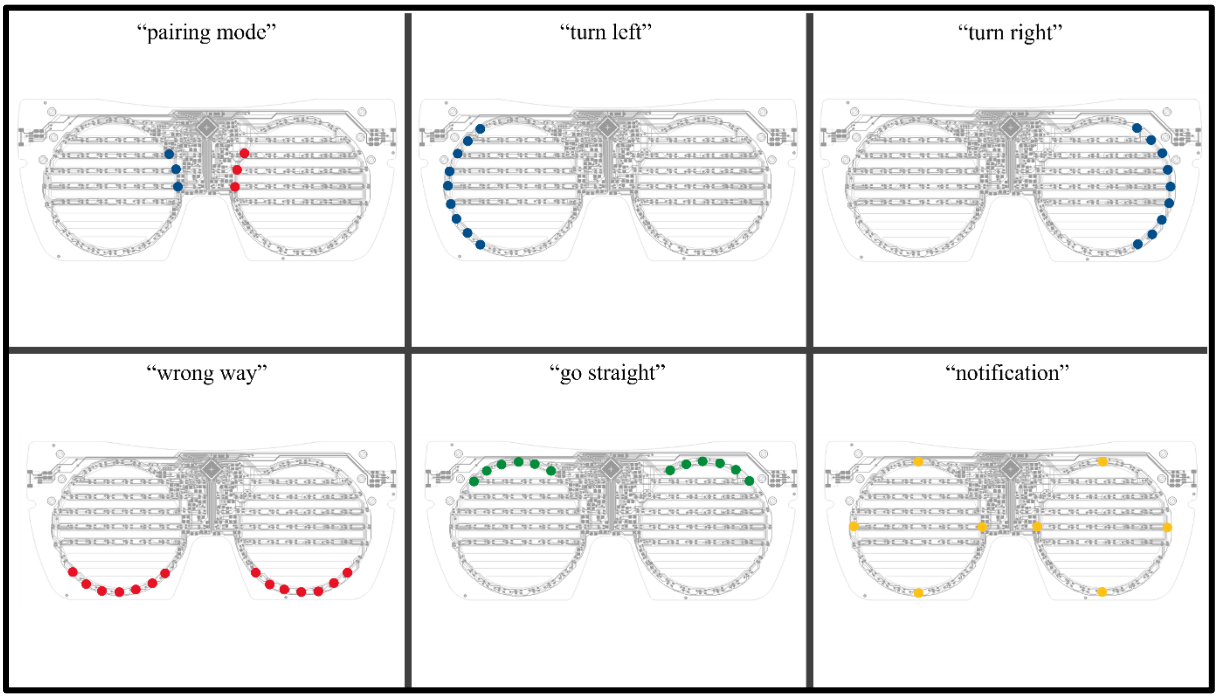

Figure 3: Default LED states

(AdaFruit)

When setting up states for the microcontroller and how it connects to the mobile phone, the view of pairing mode from the microcontroller was altered. Previously, the LEDs were designed to shine red and toggle between on and off. At the current time of development this was a simple way to indicate pairing mode, but when the microcontroller gets an error, by design the LED flashes red in a very similar way which may cause confusing for users. To change this, the NeoPixel embedded into the microcontroller is now toggled between being red and blue. This seems to be a more obvious combination of colours that indicates a pairing mode.

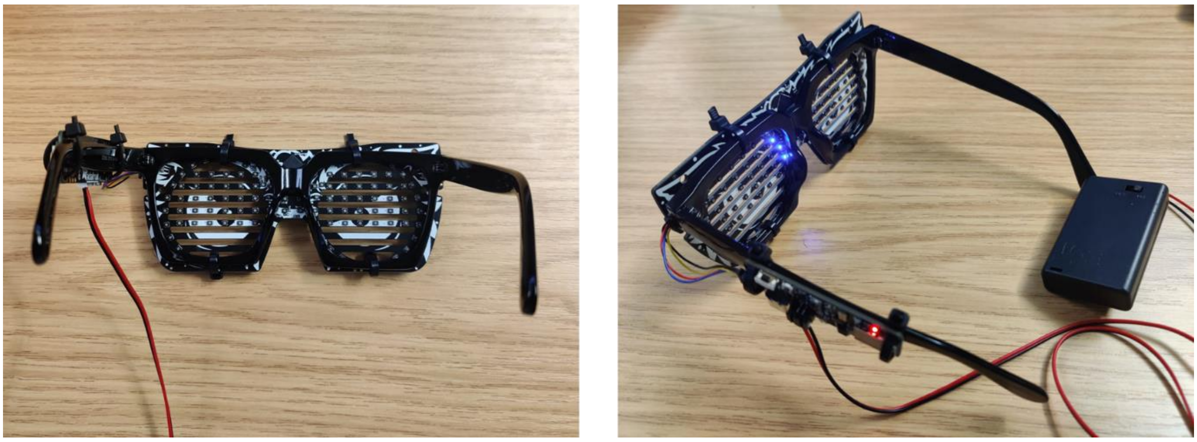

Figure 4: Photographs of the peripheral vision display.

3.5. GUI Design of Application

To present the application in an intuitive format which allows users to access all features of the application, usability was taken into consideration to changes in the design of the application. This was done with the help of Android developers guides (Android), which describes do's and don'ts when designing a GUI. The design of the final GUI was the result of implementing new features and removing redundant ones from the application. Not designing a GUI to base my application on was a poor choice but personally worked better as I didn't predict what new features or alterations needed to be implemented during the development of the application and so, changing the design of the GUI iteratively was more intuitive. An example of the GUI needing a large rehaul is shown in Figure 5 where the map was accessible from a button instead of from a navigation menu and "CALIBRATE PHONE" button on the map screen was used to send the user to another screen. When at this screen, users would have trouble understanding how to go back to the home screen as it requires them to click the back button until they get back there. This is not an intuitive way of navigating the application and so this was updated with the use of a navigation menu.

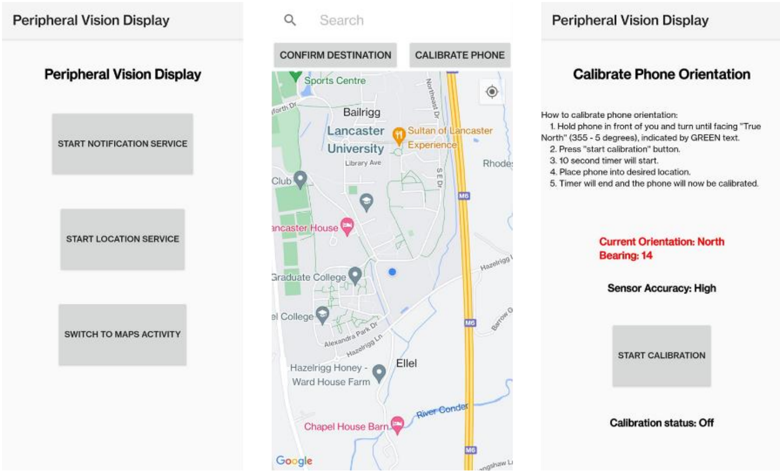

Figure 5: Design of GUI before adding navigation menu

The final design of the GUI shown in Figure 6 uses a bottom navigation menu from Google package classes which allows the user to switch between Home, Map, Bluetooth, and Settings. There are many additions to better the user experience such as the Bluetooth screen highlighting the connectable Bluetooth device so that the user doesn't need to know the exact name of it. Although there aren't any usability issues with not being able to find specific features in the application, the main improvement that could be addressed is with the theme of the application as it is not very aesthetically pleasing. The reason for not doing this is due to time constraints but as this product is a prototype, this was not a very important change for the application.

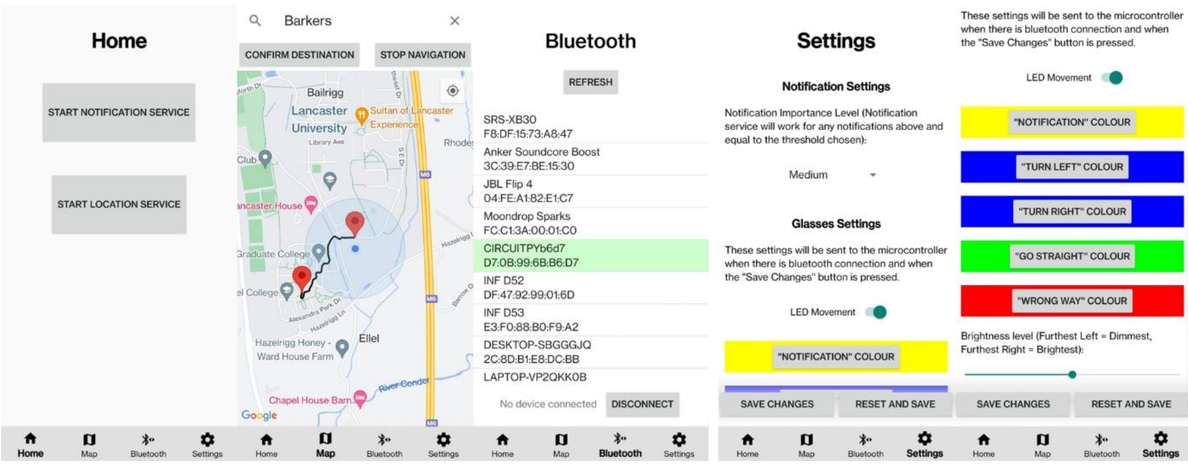

Figure 6: Final application GUI design.

3.6. Bluetooth protocol design

To connect to the Bluetooth device from the smartphone application, there were many designs in place to make sure that the devices can communicate to each other correctly. To initialise the connection, a service UUID and characteristics UUID is used to specify what the peripheral Bluetooth device should do.

The service UUID “6e400001-b5a3-f393-e0a9-e50e24dcca9e” was used to allow the Bluetooth to communicate with CircuitPython which is the language I designed the microcontroller to be written in. (Scott Shawcroft; Melissa LeBlanc-Williams; Dan Halbert)

The characteristics UUID “6e400002-b5a3-f393-e0a9-e50e24dcca9e” was used to allow for NUS compatible RX communication (Scott Shawcroft; Melissa LeBlanc-Williams; Dan Halbert), telling the microcontroller to accept the connection to be a receiver and accept incoming signals. (Ellie B)

Handling of the information to be sent to the microcontroller needed to be designed as well. The design chosen sends messages to the microcontroller about different alerts and to update settings. The issue with this is with the maximum size that the messages being sent only being 20 bytes or less. A delay was also designed to stop notifications from being sent at the same time which could result in messages unwantedly concatenating.

3.7. Notification Listener design

The design of the notification listener was simply to use NotificationListenerService which is an Android service that handles listening to system wide notifications. The designed notification listener will check importance level of incoming notifications against a threshold designed to be changed by the user in settings. If the notification is equal or above the threshold, these notifications are processed. The notification listener will also only process notifications if they contain a ticker text which in general are notifications with higher importance. The design of handling notifications involves checking the current notification being handled is the same as the previous notification. If they are the same, do not process the notification so that the user isn’t bombarded with alerts for the same notification.

4. Implementation

4.1. Mobile Application Implementation

4.1.1. Google Maps SDK for Android

To implement the Map that is used to visualize the user's location and the path they need to take to get to their specific destination, Google Maps SDK for Android was used as it gave a better development experience and very good documentation that made it easy to implement compared to other alternatives such as OpenStreetMap. Another benefit for using Google Maps SDK is that it provides API tools that can be easily introduced, and it is a recognisable GUI that many people have experience with using as Google is a reputable company. OpenStreetMap wasn't used due to having a much harder to understand documentation which would've taken more time to learn and to implement to my application. The benefit of using OSM in the long run is that it is free and open source whereas Google uses billing when reaching a certain number of Requests from APIs and SDKs and for distribution of the application. As I am not distributing the application to the public through the play store and the only request coming through are from me testing or using the application, I did not need to pay for using Google's services.

4.1.2. Places API

To retrieve the users desired destination, I used Googles Places API. This is used in the form of an AutomcompleteSupportFragment which is a search bar that the user can type into. To make the search bar more accurate, there is a location bias set to filter destination suggestions based on the user's current location to prioritise destinations that are in walking distance from the user. The LatLng coordinates of the destination is then processed by Google Directions API.

4.1.1. Google Directions API

To get the directions and the steps that the user needs to take to get to the destination, I used Google's Directions API as it works seamlessly with the Google Maps SDK that was already implemented. After the URL is created using the user selected destination and current location, it is processed and data on maneuverer instructions and step end destinations are extracted from the JSON response. This data is then accessible to classes using SharedPreferences. The API request was performed using DirectionsTask.java which is responsible for fetching directions data from the Directions API, processing the data, drawing the route on the map, and sending the steps data to a background service.

4.1.2. User Direction / Orientation

Handling user direction and making sure the user is walking in the correct orientation to each step destination was a concept that took a large time to incorporate. Many different implementations were used, beginning with creating a calibration system on the smartphone shown in Figure 5 which requires the user to face true north, press the calibration button and during a 10 second timer, placing the smartphone in their pocket. The system will then use the new result of the pockets orientation as the new value for north. The reason why this didn't work was because smartphones use a combination of a magnetometer, gyroscope, and accelerometer to determine orientation which added more variables that the calibration system didn't consider during use making it very inaccurate. It was both inaccurate when placed in the pocket and facing a direction without moving and worse when moving as lifting the leg changed the sensor data to be completely wrong to orientation of the user. To fix this, I decided to try and implement SODMA (Kusber et al.) but the implementation of it wasn't developing quick enough due to its complex nature as it needed me to create an algorithm from complex equations.

Finally, the orientation method that was created didn't directly use any of the orientation sensors but instead took the location of the user during a walking state, and for every step, added the data to an array. After every 8 steps, the steps are put into pairs, average bearing of all location pairs is calculated, and the array is cleared. The result is then compared to the bearing of the first location in the array to the current step destination to check if the user was walking in the correct direction. This implementation showed very accurate results compared to the other versions of calculating user walking direction. The limitation found with this implementation is with there being a 90-degree tolerance to account for inaccuracies in location updates. The number of steps to calculate bearing based was increased from 4 to 8 steps was to make the average bearing was more accurate but also to handle when the user is currently turning as with less steps, the system is more likely to say the user is walking the wrong way when they aren't.

An easy distance checker was created as an alternative to using bearings to find if the user is walking the correct or wrong direction. This calculated the users location with their previous location and checked if the distance from the end location of the step has increased or decreased. If there has been an increase, the user is walking the wrong way and if it decreases, they are walking the correct way. Although this would seem to work, there are issues when it comes to the user being off path and the checker seeming to recognise the data as the user walking the correct way.

4.1.3. User Direction change during user testing.

A last-minute change was added and tested for calculating if the user is walking in the correct bearing to the step destination. There was a large issue with how I calculated bearing of user locations with it previously dividing the total bearing by 1 less than the number of locations the total bearing was calculated with. Another issue was with bearingFromStart previously taking the users first location and finding the bearing from that to the next step end location, but users location never updated meaning it based all bearings on the users first location to different end locations. To fix this, the users first location was taken and added to an array list which then added the step end locations from the Googles Direction API on top of it. Using the index of what the users current step in navigation is now gives the start location and end location of steps when called on the corresponding lists. Additionally, this seemed to fix other crashes that sometimes occurred when testing navigation. During personal testing, I found this to be very accurate and so I removed the distanced based direction calculator as it made the new implementation more inaccurate.

4.1.3. Bluetooth

To implement the use of Bluetooth to connect the smartphone to the microcontroller, I used the Android development website as a reference to create my system (Android, 2023). This was a fairly straightforward guide but there were some stages that were found to be challenging to understand and implement. The final version of the Bluetooth connection system starts with listing available devices in the area. The information of the devices name and address are both shown and used to attempt pairing and connection to the device. The UUIDs for service and characteristics were also used to make sure that the messages from the smartphone were being sent using the correct channel to the microcontroller.

When sending messages across from the smartphone to the microcontroller, there was an issue with the implementation as it seemed multiple messages were either being sent at the same time or processed at the same time when analysing the message from the microcontroller. This resulted in messages concatenating. To fix this, making sure messages are sent individually, a queueing system was implemented to send each message added to the queue, after a 2.5 second delay to the microcontroller. This delay time could potentially be decreased with further testing, but this implementation accurately stops messages from joining unwantedly.

4.2. Peripheral Device Implementation

There were many limitations that stemmed from the circuit python language not supporting threading. This included issues with animated lighting and brightness changing. To overcome the issue with the animated LEDs, I had to find an alternative to threading using CircuitPython. This led me to use yielding as an alternative. Yeilding resulted in the animations working but, in some cases, having a slight delay between LEDs lighting. This shouldn't affect the user experience as the LEDs will be in the user's peripheral vision as there is less visibility. The other issue mentioned being with brightness changing, had an issue where due to the lack of threading and there being multiple time.sleep() function calls which stops the current process until a duration of time. There was no possible way of changing the brightness whenever the user wanted and instead required the user to time when to press the onboard button for it to trigger a function. The usability of this was very poor and so an alternative was made by utilising the previously written code for applying settings from the smartphone to the microcontroller.

On the microcontroller, handling of the messages sent from the application is performed with checking the message and running corresponding code for the alert. It also handles if settings data has been sent and a filter is performed to expand the settings again from needing to be compressed during transmission to the microcontroller as the maximum size to send bytes having to be 20 bytes or less. This was not a concern when sending notification or navigation alerts as they a settings compressor was implemented to alter the settings into 2-byte array representations which fit the 20 bytes or less requirement for sending messages.

5. Testing

5.1. User testing

With improved visual clarity for users focal vision, spatial awareness and multitasking could be tested but as the display has black bars which partially obstruct the users focal vision, the risk of conducting these types of experiments are high and results will not be as accurate.

5.1.1 Risk assessment

A risk assessment was carried out, shown in Appendix 4, for the experiment as there are potential risks from the design of the product. These risks include the user having obscured vision due to the horizontal bars from the LED display and the LEDs themselves being designed to shine in the user's peripheral vision to cause deliberate distractions subconsciously. Although the distractions are designed to be subtle so this doesn't happen, participants may be distracted by the LEDs during hazardous events such as crossing a road. These risks are elevated as the experiment will be taking place in a public space, and so the participants safety will be ensured during the navigation through the experiment conductor warning the participants on any hazards as they may come. Before the participant is asked to undergo the experiment, they are taken through the risks that may happen during navigation and are asked to sign the consent form if they are comfortable with proceeding with the experiment. If the participant is uncomfortable with carrying out the experiment, they can stop at any time.

5.1.2. Testing Procedure

The experiment will start with the user receiving a brief tutorial and explanation of how the system works, which includes the user being shown how to change the brightness of the LEDs and setting it to their level of comfort. After the user feels comfortable with being able to perform the experiment, they will be given the devices and will be observed to see if they are able to perform set instructions. At any stage, if the participant is confused or is having trouble with the system, assistance will be given. Observation of all the features of the application will be directed to if the user doesn't naturally use a feature of the system. This is to make sure that individual participant data can be compared to gain accurate results of their experience. Included in one of the tasks, the user will be asked to enter a location on the device and to navigate to that destination without the aid of seeing the smartphone during the navigation. The smartphone will be placed in the user's pocket and if needed, the user will be allowed to briefly use the device. The reason for performing the navigation task like this is to make sure that the participant is relying on the glasses to navigate themselves to the destination and not the applications map system. This is so that we can compare the usability and effectiveness of using a peripheral vision display for navigation and notification instead of a smartphone application alternative such as google maps.

Following the testing of the product on participants, tweaks were made to the application to try and better the experience based on accuracy of the user being told when they are walking in the correct direction or the wrong way. This involved changing values and the implementation of how user walking direction is calculated using bearing.

5.2. Research Methodology

5.2.1. Qualitative Data

In the form of qualitative data, the participants will talk aloud their thought process throughout the duration of the experiment. This is to understand the users experience when using the system and issues that they may face. These can be used to find improvements for all parts of the system. The notes taken will be selective based on information that is directed to the project and will be shown to the participant after the experiment has been finished to make sure they are comfortable with what has been written.

A survey will take place after the experiment has been conducted to gain better understanding of how the participant found different parts of the system and if there were any changes that they would recommend being made. It will also be used to understand what aspects the user finds good about this system in comparison to smartphone only alternatives such as google maps. These results will help evaluate the usability and the effectiveness of the device in all its individual sections.

5.2.2. Quantitative Data

To test the accuracy of the glasses and the navigation system, I created code to record the user's location during a walking state every 5 seconds through adding markers on the map. This is to help show the deviations in the user's path towards the destination and if they were able to correct themselves when walking in an incorrect path. The results will help evaluate the accuracy and usability of the product. The map with the users' locations will be screenshotted when the participant reaches the end destination. During the observation, the number of times the participant receives messages for "wrong way" and "go straight" will be recorded to also help determine accuracy.

5.3. Battery Life

The nRF52840 microcontroller is capable of being powered from 3x 1.5V-AAA batteries. To test the battery life of the microcontroller, code was created on the smartphone to send notification messages every 30 seconds to the microcontroller. The reason for shining the LEDs every 30 seconds as the user will receive consistent alerts for going the correct or wrong way, making 30 seconds more accurate to real life situations. As the design for the LEDs to shine when receiving a notification only uses 8 individual LEDs, testing the battery life of the device through shining all the LEDs on both eye rings at full brightness without the animated LED settings are the best choices for finding the power consumption and minimal battery life of the device as it is more accurate to real world application of the device. During the test, the peripheral device occasionally disconnected from the smartphone and so the timer had to be stopped and started multiple times meaning I was unable to test the battery life during the night. I also realised as the peripheral vision display runs at low consumption rates and with time restrictions with testing battery life, I couldn't test the full battery life of the device. The result I found from the testing was the batteries last longer than 100 hours.

5.4. Compatibility Testing

The application was tested on multiple smartphones to see if the application would work as intended on different hardware. The application was run and tested briefly on a 'Samsung s21 fe' and 'Samsung Galaxy Note 20' in addition to the smartphone used during development and user testing being an 'OnePlus 7 Pro'.

5.5. Personal Testing of Experiment

Before testing other participants, I tested my product with the tasks that I would ask the participants to perform. This testing occurred when the glasses were finally built, and the software was ready for participants. This test was insightful for finding many issues with my code that couldn't be looked past. These issues included:

1. The glasses saying the user was going the correct direction but when the user walks in the correct direction, it tells the user that they are going the wrong way.
2. Having to look at the smartphone multiple times because it was confusing where the correct path was, if there are multiple turn points in a small area, the device thinks that the user has already hit them and so makes it very confusing where to go.
3. If the map doesn't recognise walking paths, it will place the step end locations to the nearest road location. This means that the distance between the user walking on the pavement and the end location is just over the threshold and so isn't fulfilled.
4. When turning at a bend, because the user is not taking a 90 degree turn but a gradual one, this makes the application think that the user is walking in the wrong direction.
5. The user's location randomly teleports the user to somewhere that the user isn't which messes up the application by saying the user is walking the wrong way when they are.

Many of the errors that stemmed from my location being incorrect may be due to the sensors on the tested smartphone not being accurate enough to support navigations like this.

Point 1 was addressed by calculating user walking direction based on a larger number of locations being changed from 4 to 8. The more locations taken into consideration the more accurate it will be but the downside to this is that the user will be alerted at a slower rate which can be seen as less intuitive as the user may be waiting for feedback to say if they are walking in the correct direction or not.

Point 2 was addressed by decreasing the threshold of the user being at the location of the current step end.

Point 3 was addressed by increasing the threshold of the user being at the location of the current step end to a middle ground between the original threshold and the new decreased threshold. There may be instances where the user will find issues with the step end being placed on the road, but this is not something that would be easily fixable as it is a Google service issue.

Point 4 was somewhat addressed with Point 1 with the increase in locations used to determine what angle the user is walking in. The issue with this is that it may still say the user is going the wrong way depending on the timing that the array of locations gets cleared.

Point 5 was not addressable as it is possibly an issue with the smartphone's GPS sensor being unable to consistently provide accurate updates on location of the device. Testing this with other devices mentioned in compatibility testing seemed to show mixed results.

6. Evaluation / Results

Participant 1:

When testing with the first participant after performing the personal testing of the project, there were a few issues that were found with the application that needed to be fixed before proceeding with further user testing. One of these changes is with handling when the step end destination is on the road instead of pavement. Although already updated through personal testing, the user had an issue with it as it didn't fulfil the step when the user was at the closes point on the pavement. As this issue occurred, the negatives were still considered, and we agreed on restarting the test in another area to test the consistency of the navigation. Although there were very few turns that the user took, I was still able to test other parts of the navigation and application. The experiment was performed during nighttime.

The participant's navigation route is shown in Figure 7.

The notes taken during the talk aloud observation of the experiment include:

Positives	Negatives
Was able to switch device on and connect to it.	Not enough feedback for going the wrong way.
Was able to turn on location service to allow access to the map.	Wanted the user to go on the road instead of pavement because they couldn't hit the step destination from the pavement.
Was able to enter a destination and start the navigation without any complications.	Wanted feedback to go straight when there are potential turnings to show that they don't need to turn.
Green feedback is consistent.	
Immediate confirmation of turn.	
Default colours are intuitive.	
Preferred brightness level during test being 2-3 as anything higher was too bright during nighttime.	
Movement in LEDs caught more attention that static ones.	
Disconnected from the device easily.	

Figure 7: Screenshots of Participant 1's navigation.

Participant 2:

When testing participant 2, there were a few issues seen with the user going the wrong way but the application asking the user to go straight until a certain point where wrong way alerts were consistently shown to the user. There were multiple instances where the application would seem to not alert the user on turns, they needed to take which confused the user and resulted in them using trial and error to see what navigation. The participant altered settings with the glasses being to change left turn alerts from blue to purple to differentiate between left and right by colour and updated the brightness level of 4. The experiment was performed during daytime.

The participant's navigation route is shown in Figure 8.

The notes taken during the talk aloud observation of the experiment include:

Positive	Negative
Connection to the Bluetooth device was easy – assumed the device they needed to connect to be the one highlighted in green.	Not always accurate as it sometimes says they are going the right way when they think they are going the wrong way.
Made a very noticeable led shine which they assumed is them reaching the destination.	Think they missed the step end destination because it got to the end of the path and didn't say if they needed to go left or right so they assumed to go one direction and see if it says its wrong.
They said they would prefer this for the application of using it during driving if the glasses were designed correctly without the black bars in the user's focal vision as it would be much better than looking at a	Green for walking straight works but isn't the most visible as they mentioned that if they were zoned out, they aren't sure they would notice that green would be showing.

screen which shows navigation for safety reasons.	

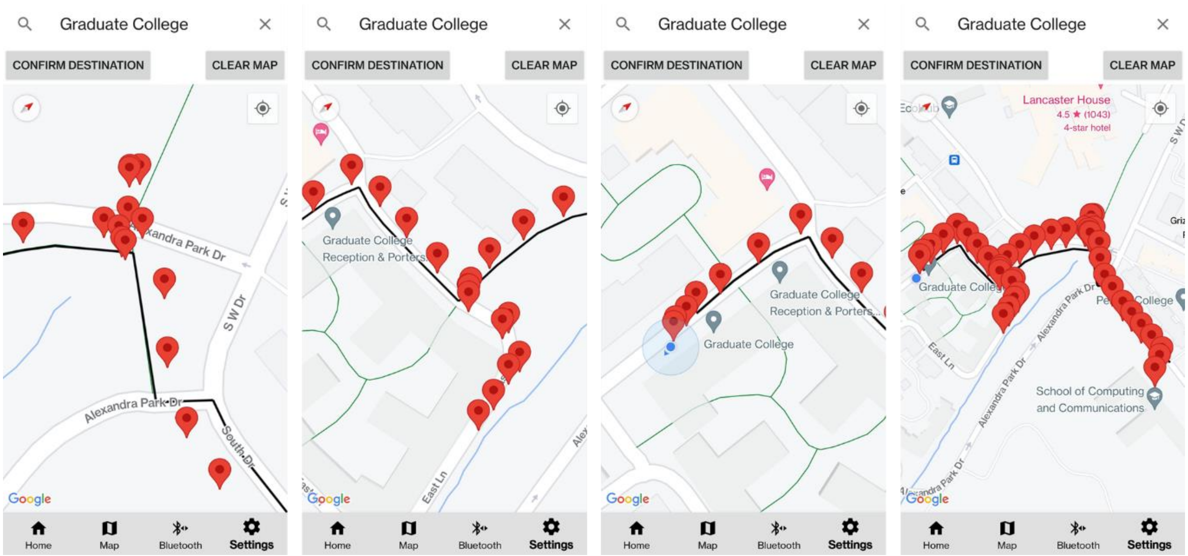

Figure 8: Screenshots of Participant 2's navigation.

Participant 4:

Shown in the 3rd picture from figure 9, the user didn't recognise the step to turn right and so kept on walking forward. This was further emphasised by the users shown by the user being that the user was walking the correct direction until it eventually started saying the user was walking the wrong way and so the user backtracked and ended up walking the correct direction after. From this experiment, it was easily recognisable that the indications for "go straight" and "wrong way", were being sent to the microcontroller too frequently and so the implementation of determining user direction was altered to calculate average bearing based on more location updates. The experiment was performed during sunset.

The notes taken during the talk aloud observation of the experiment include:

Positive	Negative
Overall, signals from the display were consistent but seemed to be delayed sometimes which was confusing for the user as turn signals displayed later than expected.	Alerts were telling the user they were walking the correct way when they were going the wrong way.
Once user was on the correct path, the navigation sent the user the correct alerts.	User waited at turns they already knew they had to take but the peripheral display didn't tell them to turn.

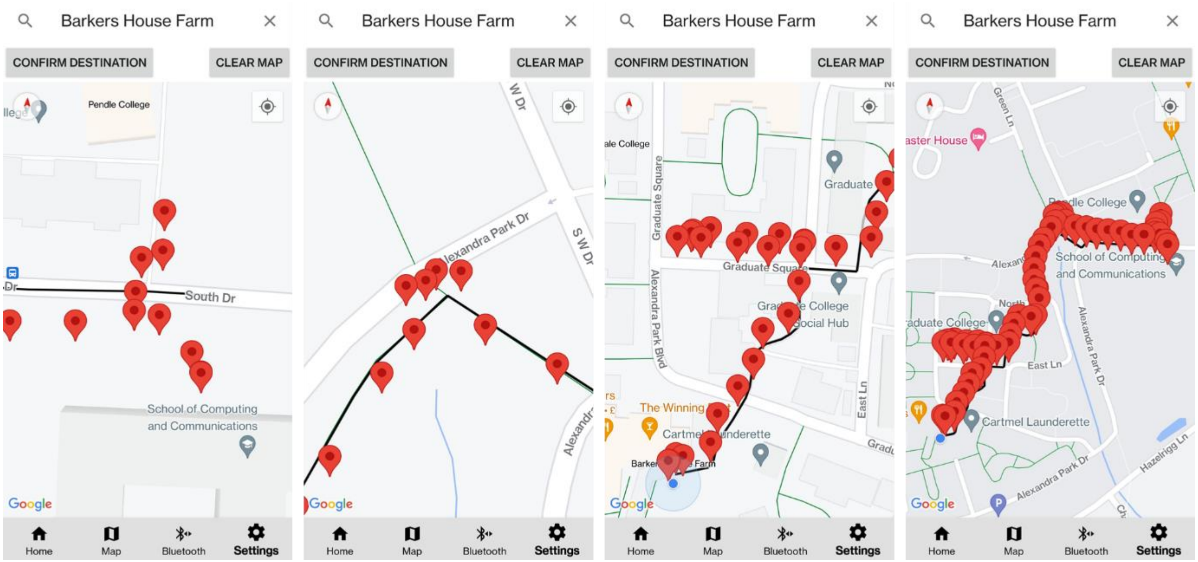

Figure 9: Screenshots of Participant 4's navigation.

Participant 5:

When analysing the screenshots taken of the user's path of navigation, there are a few times where the GPS seems to be inaccurate even when walking in a straight line which is a concern for the accuracy of the product based on the device that the application is being ran on. Overall, there were no issues with this experiment that the user faced but this may have been with the simplicity of the route the participant took. The experiment was performed during daytime.

The participant's navigation route is shown in Figure 10.

The notes taken during the talk aloud observation of the experiment include:

Positive	Negative
Assumed that the Bluetooth device to connect to be the device which had "CIRCUIT" in the name and was also emphasised by it being the only one highlighted in green.	Clicked on the places pin as an instinct instead of needing to write the place at the top of the layout.
Didn't have any issues with the pre given colour settings and managed to traverse the settings very easily.	
The user managed to get to the destination without any deviations in the path.	

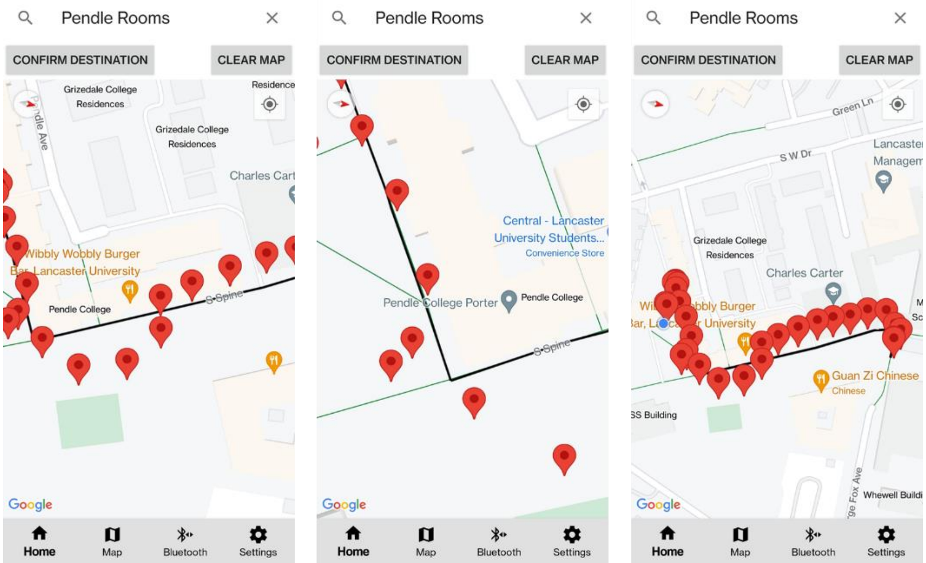

Figure 10: Screenshots of Participant 5’s navigation.

Participant 6:

There was a slight issue with this experiment as the application had a crashing issue due to slight adjustments made throughout the testing process to try and better the experience. When a crash occurred, the glasses automatically went into pairing mode which the participant informed me of. The experiment was still fully carried out, but the application did have to be restarted multiple times. With testing the brightness levels, the user found 5 to be their ideal brightness level. The screenshots that were available showing the participants navigation route are shown in Figure 11. The experiment was performed during nighttime.

The notes taken during the talk aloud observation of the experiment include:

Positive	Negative
Consistent wrong way and go straight feedback which the participant liked.	User took longer than expected to find the location service as they didn’t expect it to be on the home page but got there eventually via trial and error.
The participant was most alerted when their full peripheral vision was lit up to indicate they reached the destination. They automatically assumed that this meant they reached the destination.	With the way that red shines, the participant found red to shine slightly on the top due to high brightness which is not ideal.
	Sometimes inaccurate with the number of times it shows go straight when the user was walking in the wrong way.

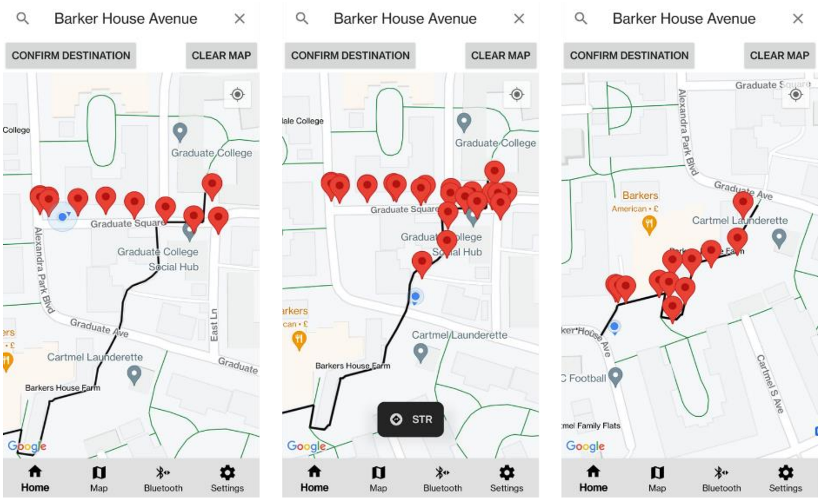

Figure 11: Screenshots of Participant 6's navigation.

Participant 3:

During this experiment, the user was able to get to the destination without any deviations in the navigation. Although true, they mentioned there was many inaccuracies with alerts saying that they were going the wrong way when there wasn't an alert for the user to turn. This mainly happened during the path going south in the first picture from Figure 12. Although they noticed multiple 'wrong way' alerts, they decided to ignore them thereafter if they thought they were walking in the correct direction. The experiment was performed during nighttime.

The notes taken during the talk aloud observation of the experiment include:

Positive	Negative
Turn indications were very accurate and were shown at very convenient times.	False 'wrong way' alerts were shown when it shouldn't be.
'Wrong way' alerts were more visible than 'go straight'.	

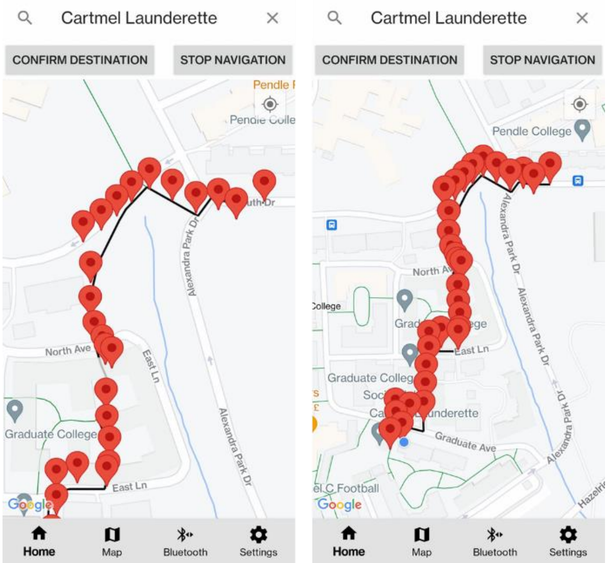

Figure 12: Screenshots of Participant 3's navigation.

6.2. User evaluation and testing analysis.

The questionnaire and the results from participants are shown in Appendix 2. From the results, it can be analysed that most users found the application and overall product easy to use, the alerts to be easy to differentiate by both position and colour. There were mixed results when asking the participants how effective the product was in taking them to the destination. This is due to me altering the application between user testing with participant 1 finding it ineffective but most participants finding it somewhat effective.

When it came to stimulus testing to see if users found animated LED alerts to be more obvious than the other ones, 4/6 people agreed that animation was more obvious.

Testing of the experiment was conducted during daytime, sunset and nighttime to see what brightness level users preferred during different outdoor scenarios. Participants that ran the experiment during the daytime found higher LED brightness 5-4, more comfortable and participants which ran the experiment during subset and nighttime, found brightness levels of 2-3 more comfortable. The range of data was only from 2-5. As there were restrictions with the weather to test the experiment, participants may find higher brightnesses better for viewing the LEDs. Overall, participants said they would be more likely to use alternatives than this product due to its inconsistencies making the product feel more restrictive than using a smartphone application alternative. Most users found the LEDs not distracting.

The main restriction that was apparent when performing the experiment involved the weather. As the device is a prototype, there was no waterproofing that was added to the microcontroller or the LEDs meaning they were exposed to the elements. This meant that the experiment with participants had to be halted until the weather was at an appropriate level which slowed down the rate at which I could perform experiments and made it harder to find participants. Testing the brightness of LEDs on participants during clear skies would be beneficial to see if the higher brightness levels for the LEDs would be the more comfortable and visible for users.

As I was able to reach a total of 6 participants to carry out the experiment for the peripheral vision display, this gave me a good basis of how different users would find the product which helps evaluate the usability of the product and the effectiveness of it getting the user to their specified destination. Although I was able to reach the number of participants that was previously planned for, I made the range from 6-12, with a higher number of participants possibly giving a more desirable and accurate representation of user experience.

Evaluating the design of the LED's based on participant feedback, it can be said that the black bars which obscure the user's focal vision didn't seem to have a significant issue as previously speculated. This being said, it would've benefitted user experience for it to not be there, but the current prototype was viable to get appropriate feedback on the product to see areas of improvement that could be made.

Fixes that could be made:

Application fixes:

Throughout participant testing and personal testing, it became apparent that a large issue was with calculating bearing. Although the concept does work for some cases, if the user is required to navigate through a curved path instead of a straight line, there its higher likelihood of them experience false negatives during navigation. One way to fix this is with not calculating the average bearing of multiple locations but take the singular pair from the user's 1st and 8th location, disregarding the rest and base bearing off that. Another fix is to use another implementation such as checking if the user is following the polyline shown on the map during navigation.

LED fixes:

The main fix for the LED board is with its design by removing the LED bars which go across the user's focal vision. This would better the user experience as during the experiments, participants mentioned that they didn't like how they couldn't see parts of their vision accurately. Another change that should be made to the LEDs or the frame of the glasses, is with making sure that the LEDs aren't obstructed by the frame. This wasn't easy to test with participants, but a few users did seem to miss turn indications which from personal testing of the prototype, can be evaluated from LEDs being harder to see for certain lighting configurations.

7. Conclusion

7.1. Review of Project Aims and Objectives

The usability of the peripheral vison improving user experience with notifications and navigation was poor as there are issues with the way user walking direction is calculated that sometimes gives users false information about their navigation which creates confusion, resulting in a less intuitive experience. The display was somewhat less obtrusive than using a smartphone as the device can work without the need for the phone to be in hand. The issue with the display, however, is black bars that obstruct the user's focal vision slightly.

1. I was able to create a functional display which gave users information from their smartphone.
2. I was somewhat able to create an unobtrusive LED display, the only issue with the display used having black bars which go across the user's focal vision.
3. I was able to create a connection between the smartphone and peripheral display using Bluetooth Low Energy.
4. I was able to create an application software which performed notification and navigation handling.
5. I was able to make system compact, lightweight, and easy to use as the hardware for the peripheral display came in a kit.
6. Evaluating the product in comparison to other alternatives for navigation, this product has issues with consistency of performing navigation and so other map applications such as Google Maps is better.
7. As all the hardware to use the project other than the smartphone, the cost of the product is £59.70 which is expensive for a product which cannot perfectly aid in navigation.

7.2. Cost Analysis

Hardware costs: The hardware that was used for this project included an 'Adafruit LED Glasses Starter Kit' (AdaFruit) which was £59.70 from https://thepihut.com/products/adafruit-led-glasses-starter-kit. There was no hardware cost of the android phone that the application was tested on as I used my personal smartphone. This is the price that hobbyists would have to pay to create this prototype. = **£59.70**

Software costs: Although using Google services, as the API was only used for personal development, there wasn't any costs for using it. If the application was to be made public on the 'Google Play Store', there would be costs to run the API based on the number of requests being sent. The cost of the IDE was also free. = **£0**

Development costs: Based on PayScale's average salary for software developers in the UK from 10th March 2024 (PayScale), the average base salary is £14.78, hourly. This equates to £44.34 daily income based on 15 hours of work per week for 20 weeks, is a total of £886.80. = **£886.80**

Testing costs: Participants were informed that they will not be paid for participating in the testing of the product, meaning there was not cost for testing. = **£0**

Maintenance, Marketing and Other costs: As there are projected costs that will be accumulated after the project is completed for running servers, marketing of the product or any other costs, this is also free. **= £0**

Total costs = £946.50.

7.3. Future Work

I decided to make my project open source to allow for future work on the application and so Javadoc and pydoc was added to help understand how the project is coded. During the development of the project, I have learned how to create an application and perform Bluetooth LE connectivity with a microcontroller. I have also learned how to access specific LEDs from the glasses display using the microcontroller which was difficult for me to implement but will make it easier for the next person to work with.

7.3.1. Future work on application.

Features that would improve the application include creating a different version of the bottom navigation bar as it is uses Android's BottomNavigationView which is designed to work with fragments instead of how it is currently implemented with Activities. To improve the user experience, allowing for the user to click on a place and allow them to navigate based on that instead of having the user type the destination in manually would be more intuitive. Another feature that would be important to add is a way to stop specified applications from triggering the notification alert to the glasses.

7.3.2. Future work on glasses.

Other than the application, there are a few improvements that would be important to make for the glasses, the most being to remove the black bars on the LED display which obscure user's focal vision. Another improvement includes creating a custom 3D printed frame for the glasses so that all the LEDs around the left and right rings can be visible in the user's peripheral vision which is an issue found in this prototype. For the code on the microcontroller, as I am not as experienced with CircuitPython, there are likely to be a few issues with how I run the animations for the LEDs as CircuitPython doesn't support threading.

These are features that I and discovered during and after development of the project. The reason I didn't add these features myself was due to poor time management and so compromises were made but for the future development, I know what I would've liked to add to the project to improve the experience and usability of it.

7.4. Revisions of Design and Implementation

During the start of the project lifecycle, I didn't have a vision for the design of the application or exactly how the project would be implemented and so there were many iterations of changes made to the project to improve it. The main change in the design of the project was with the look of the application. This wasn't a priority at the beginning of development as I didn't know exactly what I needed the application to do but as I started implementing more, I realised that the basic application I started with needed improvements in navigation. There were many changes to the implementation of the system which resulted in classes being created and deleted to make sure features work as intended. The main implementation which took multiple iterations to find accurate results is with DirectionForegroundService to calculate whether the user is walking in the correct direction or not. Initially, bearing calculations were used to get the phones orientation to see if the user is facing towards the step destination, but with more development, distance calculations were added and removed, changes were made to how bearing was calculated, and now, bearing is calculated based on multiple user locations to see if they are moving to the step destination.

7.5. Personal reflection

During the making of the peripheral vision display, I learned many skills which I found to be useful and areas of work that I haven't previously experimented with. The main one being with learning how to work with embedded systems and how to use Bluetooth LE to connect a smartphone application to a peripheral device. I also believe that my skills in java development have improved with me also learning how to use java to create smartphone applications. Although the application works, there are many areas of improvement that could've been revised with more time being available to develop the system, such as making sure that the application is written in a way that can be further developed by another person. An example of this includes using fragments instead of activities for the different pages accessible from the bottom navigation bar. Another improvement to take into consideration when developing similar projects is time management as I had a slow start to the project. This was because this type of project is something I have never previously worked on and so starting to develop the program was confusing and time consuming for me. I also didn't realise or plan out the amount of work I would need to do and so there were stages of development where much more work was completed than others. This meant that there was increased stress to reach deadlines which could've been stopped by working at a consistent pace.

Throughout the development process, I naturally found it better to work the project following a waterfall methodology than an agile one as I ended up getting to areas of the project that required certain things to be done and only then can I work on more. The biggest example of this was with adding the Bluetooth implementation to the application in its entirety so I would be able to access the microcontroller to help code how the LEDs would work based on what messages are sent from the smartphone. The whole process of development did not solely rely on using the waterfall model as there would be small fixes or additions from lack of expertise which meant phases of development weren't finished before moving on.

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Appendices

Appendix 1 - Project Proposal

Peripheral Vision Displays: Creating an Unobtrusive LED Notification and Navigation System for Glasses

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Abstract

This project aims to develop an unobtrusive notification and navigation system using a ring of dim LEDs around the frame of glasses to shine at the user's peripheral vision when designed. The project also aims to provide an easy and cost-effective prototype solution for hobbyists while not looking strange to wear. The prototype will be tested with a range of participants to see if an effective solution compared to other existing notification and navigation approaches.

Introduction

The proposed project is to examine, implement and evaluate the benefits of using peripheral vision to help users get to a desired destination. Peripheral vision is the 'visual field beyond our current point of gaze that provides information that is essential for a vast range of tasks in everyday life' [1]. Peripheral vision allows us to see the space around us without the need to focus on it. This helps us to see movement and shapes in our field of vision. Peripheral vision is used in everyday life such as 'walking, reading, driving and sports' [2] and so taking advantage of it should be beneficial for most people.

As physical maps become more and more outdated, there is an increase in the number of people who use electronic devices to navigate around unfamiliar areas. Using GPS has become much more convenient as it comes built into most smart phones and electronic devices. In the recent years, the size of the global GPS tracking device market has had a 27.6% increase from 1.2 billion US dollars in 2020 to 1.66 billion US dollars in 2022, and a projected increase to 2.38 billion US dollars in 2025 [3].

With an increase of pedestrians using GPS navigation apps, there is a subsequent increase in the likelihood of accidents to happen because there is a lack of spatial awareness of roadside events. This is because the posture when using a mobile phone while walking decreases the view of your surroundings which can lead to accidents but also creates distractions as your focus is on the screen. This is why making a peripheral vision display where the user can still use navigation without the need to physically hold a device. It also allows for multitasking using different devices as the user can navigate to a destination with the glasses but also text on their phone at the same time without the need to pay direct attention to where they are going [4].

Background

A peripheral vision display as described in the a paper written by Nakuo Takuro and Kuzune kai, is a 'device that enables implicit and explicit interactions utilizing peripheral vision' and a their demonstration of this was to 'display patterns in the peripheral vision of the user' [5]. Their paper is an example of a very similar concept to the idea that I will be expanding on as they made a prototype to control human motion without consciousness and to alter walking speeds and motion. While their design using a grid of LEDs, I will use a single array as the user will not be asked to move at angles and at specific speeds.

Appendix 2 – Questionnaire with results

Please provide your anonymous ID which was sent before the experiment:

3

6

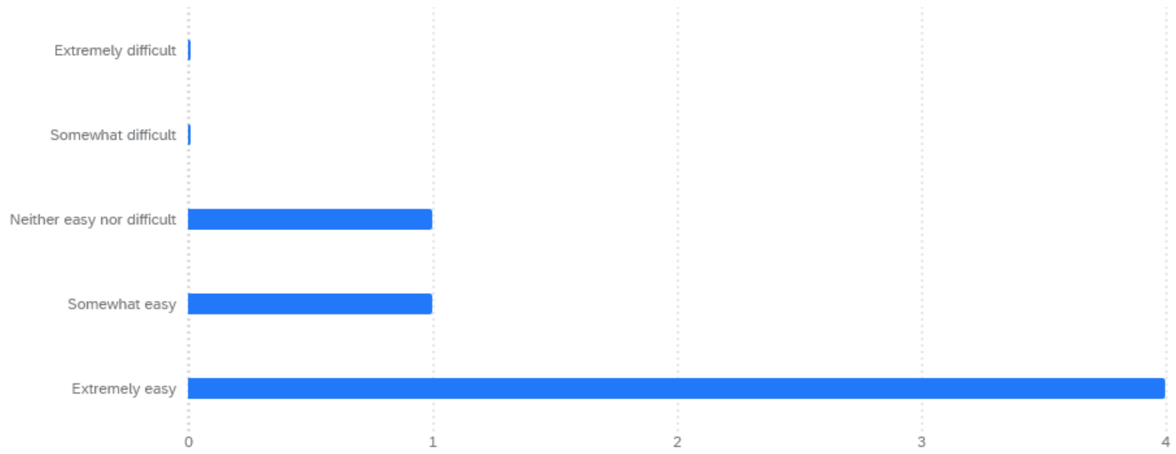
5

4

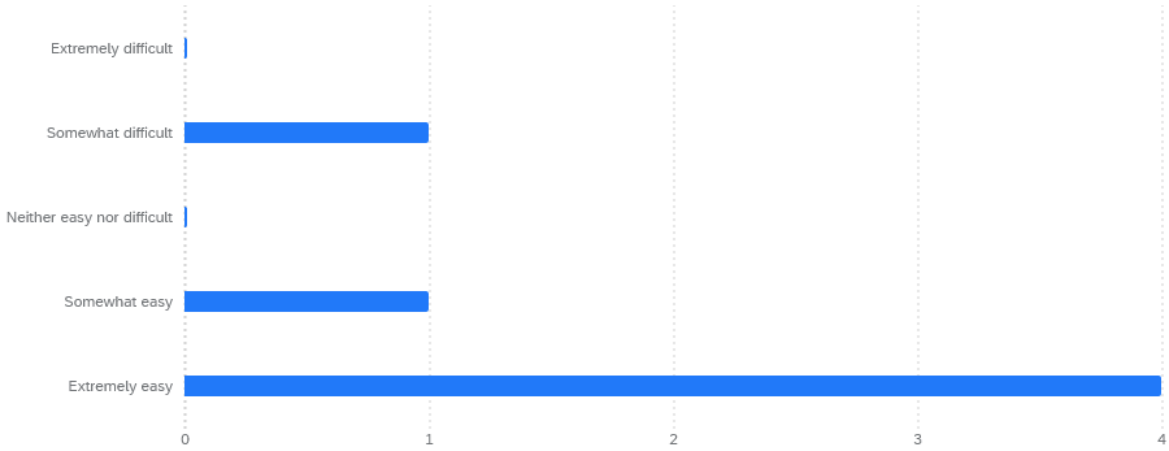
2

1

How easy was it to connect to the bluetooth? 6

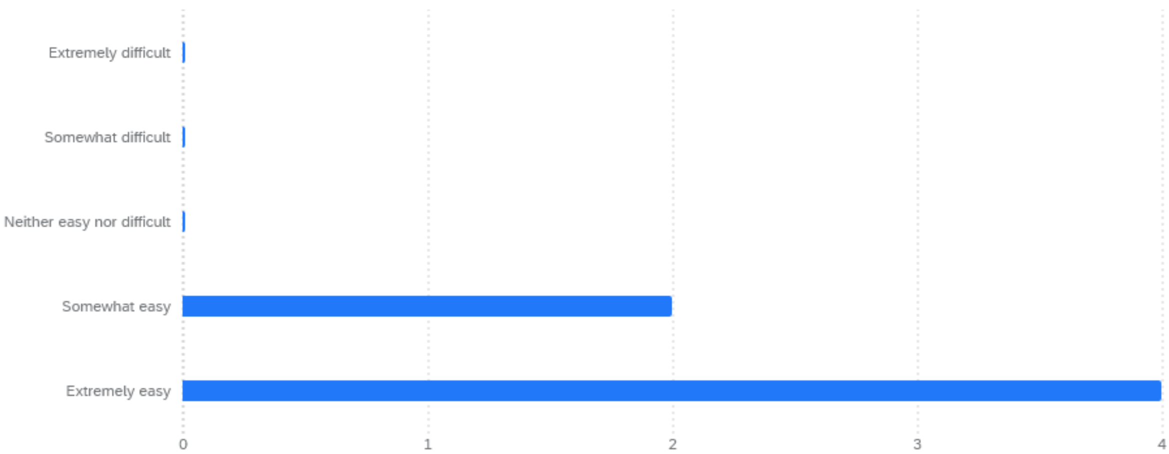


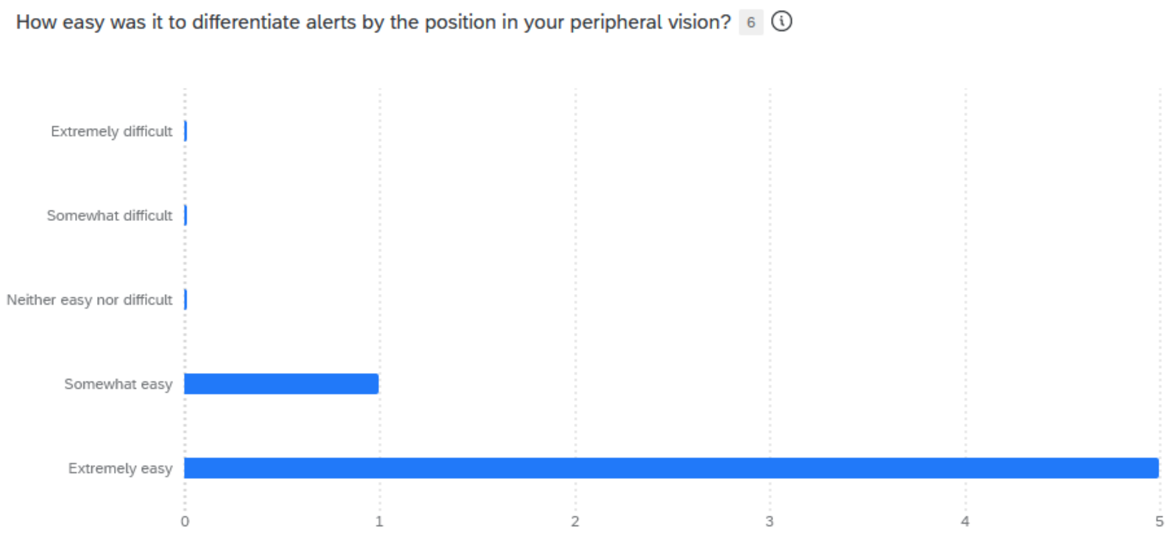
How easy was it to start up the notification and location services? 6

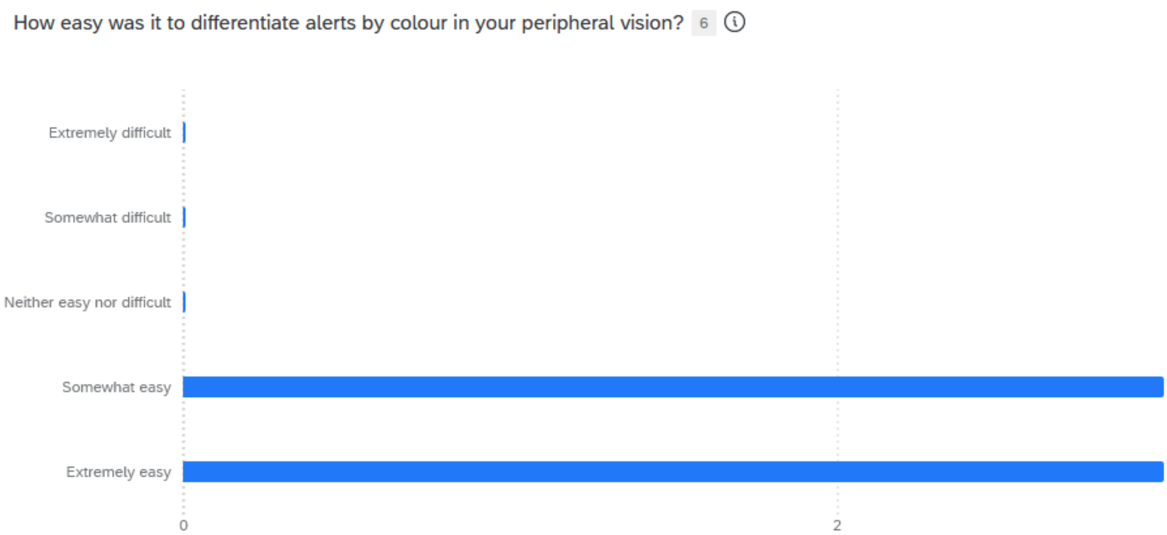


How easy was it to set a location? 6

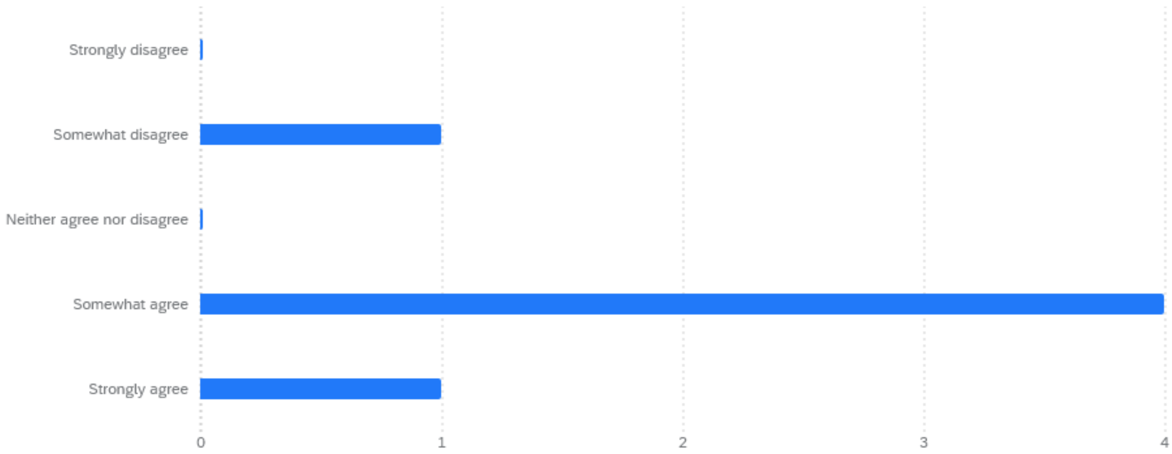
How easy was it to change and update settings? 6




How easy was it to differentiate alerts by the position in your peripheral vision? 6
Extremely difficult
Somewhat difficult
Neither easy nor difficult
Somewhat easy
Extremely easy
0
1
2
3
4
5


How easy was it to differentiate alerts by colour in your peripheral vision? 6
Extremely difficult
Somewhat difficult
Neither easy nor difficult
Somewhat easy
Extremely easy
0
2

Was the product effective in being able to take you to the destination? 6



If disagree, please briefly explain why, and if possible recommend changes.

The leds kept on shining to tell me I was walking the wrong way when i was on a path that didnt have any turns. I was still able to get to the desitination based on signals saying i was going the right way and turn signals.

lots of times it just didn't give directions. it also often said keep going straight when i was supposed to turn. So because i know the directions i would turn then it said correct direction. soemetimes it would tell me to turn when it was impossible like into a wall.

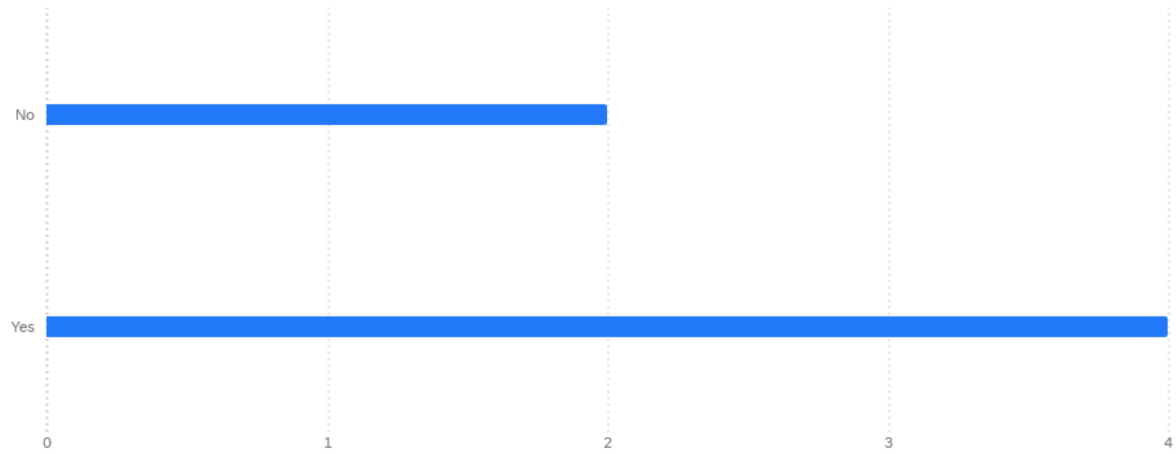
No more results to show

Was the overall product easy to understand and use? 6

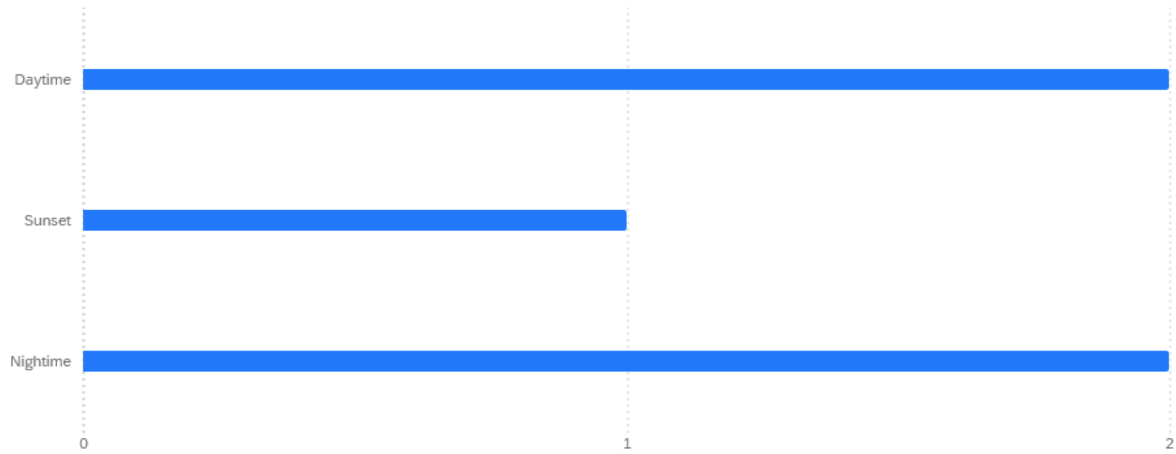
If disagree, please briefly explain why, and if possible recommend changes.

No data found – your filters may be too exclusive!

Were the animated LED alerts more obvious than the pulsating / static alerts? 6

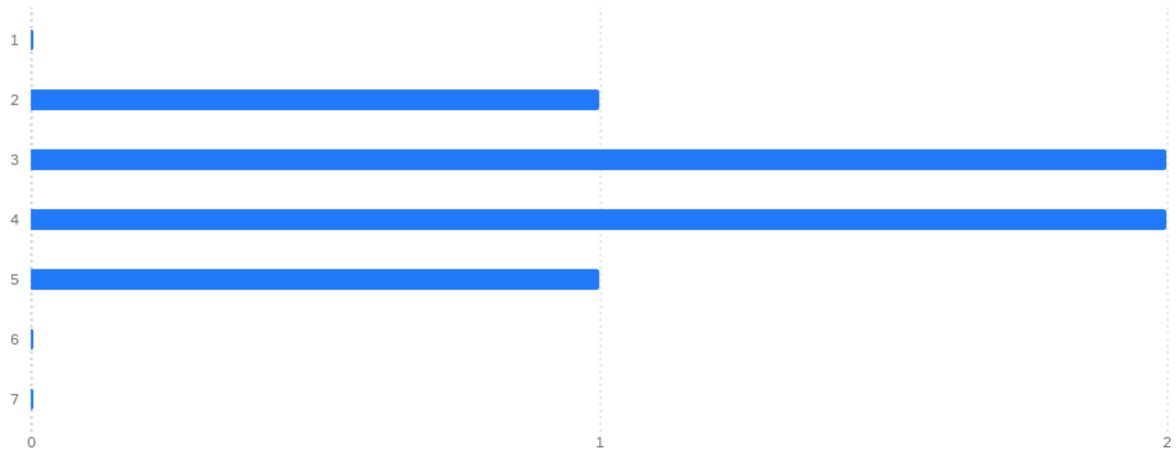


Did you perform the test during daytime, sunset or nighttime 5

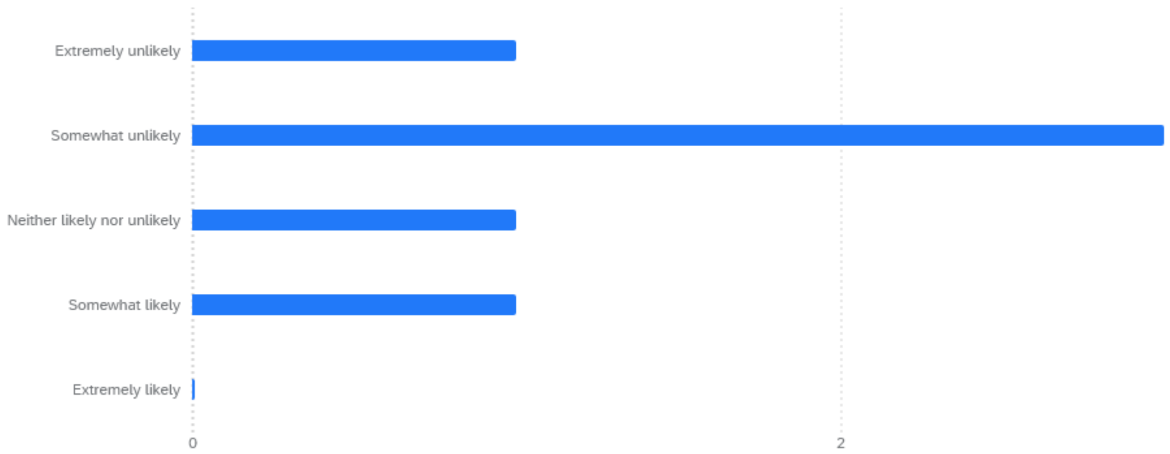


Participant 1s response wasn't shown but their experiment was conducted during nighttime.

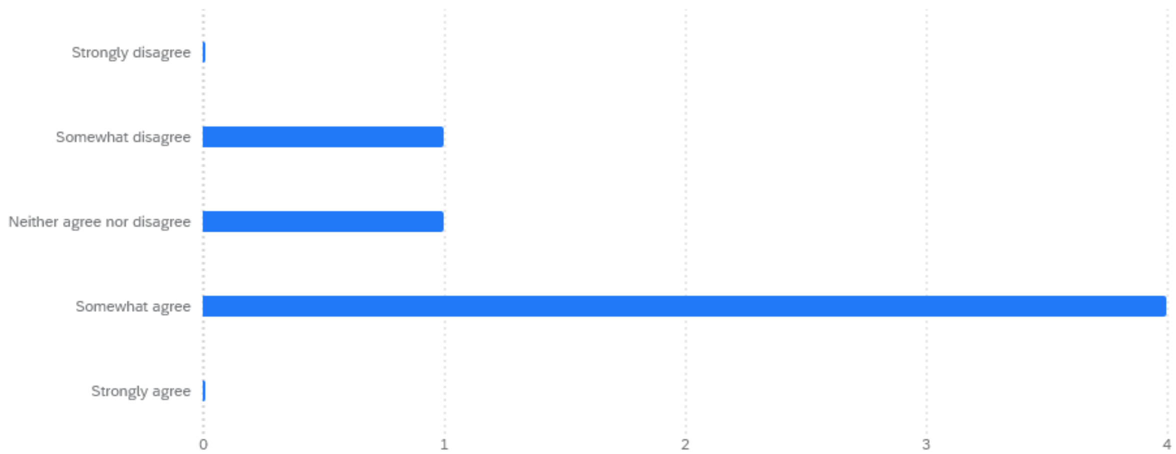
What was your preferred brightness setting? 6



How likely would you use this product instead of using a smartphone application such as google maps? 6



Did you feel less restricted using the product than if you were to navigate using a smartphone? 6



How distracting did you find the LEDs? 6

Q10 - How distracting did you find the LEDs?	Percentage	Count
Very distracting	0%	0
15	17%	1
16	0%	0
17	33%	2
Not distracting	50%	3

Are there any other comments you would like to briefly mention that weren't covered by the previous questions?

The glasses were confident with right turns but not very confident with left turns. The app also seemed to crash a lot during our walk.

The only issue encountered was the slight inaccuracy in the GPS positioning, which meant sometimes a turn was indicated after the turn was passed.

The led commands were a bit delayed which made navigating a little difficult when I went the wrong way but got told later rather than immediately

go straight was sometimes hard to see

No more results to show

Appendix 3 – Ethics form

SCC Undergraduate Ethics Form

1. Basic information

Name of Student: Nikhil Patel **Student ID:** 38539144

Course: SCC.300: Third Year Project

Name of Supervisor: Paul Dempster

Project Title: Peripheral Vision Displays: Creating an Unobtrusive LED Notification and Navigation System for Glasses

Aim(s) of the research project.

The aim of the research project is to evaluate whether users find the Peripheral Vision Display created to be sufficient for directing them to a specified destination while being unobtrusive to their vision. The research will also help to find usability features that would improve user experience which were overlooked in the making of the product. The effectiveness and the benefits / negatives users find when using this product will also be researched to evaluate the overall usability of the glasses in real world situations. In line with GDPR, the lawful purpose of this research is a task in the public interest.

https://www.lancaster.ac.uk/research/participate-in-research/data-protection-for-research-participants/

2. Proposed research methods and analysis

The research design methods that will be used include a questionnaire and a talk aloud observation and data logging of the users location during the experiment every 5 seconds to show their navigation path.
The participants will be provided with the LED glasses and an android smartphone. They are required to start the peripheral vision display, connect to it, set a location, travel to the set location around the Lancaster University area without the smartphone in their hand, and test the range of application settings to identify what visual stimuli are the most effective. Participants will be guided through the procedure if necessary and will be alerted of any potential safety hazards during the test. They will be asked to voice their actions and thoughts aloud whilst completing this. I will conduct the observation and write down issues that the participants came across. The data collected from the observation and the questionnaire will be used to evaluate the overall usability and effectiveness of the device and the users experience with it. The data will also be used to improve features in the program from inference based on the comments given. The location data logging will be saved to a file for every

Appendix 4 - Risk analysis

Record of a risk assessment

Task: **User evaluation of SCC.300 project system, a peripheral-vision wearable device**

Department	SCC	Assessment ID	SCC.300.PD.2324.1
Assessor	Paul Dempster	Date of assessment	29/02/2024
Authorised by	Paul Dempster	Review date	14/03/2024

Step 1 **List significant hazards**	**Step 2** **who might be harmed**	**Step 3** **determine appropriate controls**	**Step 4** **make it happen**
Guidance: *List here the significant hazards associated with the task.* Study participants will be asked to walk around campus while	*Guidance:* *Include all people who may be affected including those not directly involved in the task* - Participants of the study. - Bystanders on campus that encounter the	*Guidance:* *Use the hazard-specific worksheet if one exists or use the generic hierarchy (ERICPD) to determine your controls* - Participants will be informed of what the equipment is like and have	*Guidance:* *A risk assessment will not protect people; it is the adoption of control measures into a 'safe system of work' which will keep you and your colleagues safe. This will include one or more of the following:* • ***Procedures*** • ***Training*** • ***Supervision***

Appendix 5 - Participant information sheet

LANCASTER UNIVERSITY DEPARTMENT OF COMPUTING

RESEARCH INFORMATION SHEET

TITLE OF RESEARCH:

Peripheral Vision Displays: Creating an Unobtrusive LED Notification and Navigation System for Glasses

PRINCIPAL INVESTIGATOR:

Nikhil Patel, n.patel10@lancaster.ac.uk

Address: Computing Department, Infolab21, Lancaster University, Lancaster LA1 4WA

INTRODUCTION

You will be taking part in a research study concerned with evaluating the effectiveness of using a peripheral vision display to aid navigation while being non-obtrusive to the user.

We invite you to participate in a study that will involve the collection of qualitative data.

It is important that you read and understand several principles that apply to all who take part in our studies;

a) taking part in the study is entirely voluntary.
b) personal benefit may not result from taking part in the study, but knowledge may be gained that will benefit others.
c) any significant findings will be discussed with you if you desire.
d) you may withdraw from the study at any time.
e) you are provided with all the equipment for the experiment.

The nature of the study, the risks, inconveniences, discomforts, and other pertinent information about the study are discussed below. You are urged to discuss any questions you have about this study with the investigator before you sign this consent.

In accord with all of our research protocols, privacy will be fully protected and confidentiality maintained at all times.

BACKGROUND & PURPOSE:

This research study is concerned with assessing how using a peripheral vision display may benefit or negatively affect user navigation without the assistance of using a smartphone to visually show directions during navigation. Key interests include observing how much more attention users will have on their surroundings, the ease of understanding the system and using it, the effectiveness of it guiding the user to a specified destination and analysing settings to evaluate what stimuli (static or motion LEDs) are best for average users.

STUDY PROCEDURE:
You are being asked to participate in a study that will require your cooperation in one or more of the following:

- Survey / questionnaire.
- Verbal feedback.
- Observation.
- Location logging only during the experiment.

Appendix 6 – Participant concent form

Research Participant Consent Form

PROJECT TITLES: Peripheral Vision Displays: Creating an Unobtrusive LED Notification and Navigati for Glasses

INVESTIGATORS: Nikhil Patel

PARTICIPANT NAME: ________________________________

TITLE: ________________________________

I agree to participate in the project named above, the particulars of which have been explained to me. I have read the Research Project Description a written copy of which has been given to me to keep.

I understand that any information I provide is confidential, and that, subject to the limitations of the law, no information that could lead to the identification of any individual will be directly disclosed in any reports on the project, or to any other party.

I agree to: (tick as appropriate):

- ☐ Take part in an observation;
- ☐ Take part in a survey;
- ☐ Have location information logged during the experiment;
- ☐ Take part in an experiment which involves using provided peripheral vision glasses and smartphone to get to specified destination;
- ☐ Have no impaired vision;
- ☐ Have no mobility issues;

I agree to the following data being collected:

- ☐ field notes;
- ☐ questionnaire results;
- ☐ location results;

I also agree to the data above being used for later analysis by the researchers above only. To preserve anonymity, I understand that all written work referring to this data will use pseudonyms for me unless written permission is later obtained. I also understand that direct access to the identity of participants is restricted to named researchers above only.