Daylight Personalised Interface

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April 27, 2025

Gitlab link:
https://gitlab.com/final-year-project7250539/daylight-personalised-tracker

Testflight Invite: https://testflight.apple.com/join/c6wWBr3G

Contents

Abstract

Problem:Modern technologies such as shelter, electricity, heating and computer devices have removed people from daylight exposure that they would otherwise have received living in outdoor-oriented cultures, this has led to negative impacts on sleep. Sunlight exposure is crucial for physical and mental health, as it supports vitamin D production and regulates circadian rhythms, influencing sleep, mood, and alertness. However, a large amount of people in the world often do not receive enough daylight.

Why is this project needed?:While there are tools to measure daylight exposure (e.g., Apple Watch, which only recently started providing sunlight exposure data), they don't guide users on how much light they should get, when they should get it, or why it is important. This project's hypothesis is that individual awareness is a key limiting factor in people getting sufficient light exposure. Providing actionable feedback helps people make easy changes, like sitting by a window or walking outside during phone calls, to get more daylight and improve their well-being.

Solution vision: This project aims to raise awareness of the importance of light exposure and provide personalised feedback to help individuals improve their health. Unlike extreme measures, like banning heating, it offers practical, low-effort changes that have a direct impact on well-being. The solution should be cost-effective, scalable and go beyond what previous solutions have offered by delivering actionable insights at a low cost. It will focus on addressing the following questions:

- How much light exposure did they get that day or previous day?
  - Reviewing past exposure encourages mindful habits
- Did they get the recommended amount of light exposure per day?
  - Minimum 30 - 120 mins per day
- Am I getting more or less light exposure compared to last week, this time last year etc.?

Why a personal tracker? A personal tracker might help users link light exposure to physical and mental health, targeting those who understand the benefits of sunlight but need help boosting awareness. An app is chosen due to its convenience, accessibility, and low cost. Displaying the information with both text and graphs allows users to quickly spot patterns, directly compare data, and understand insights more clearly, with text adding context and detail that enhances the clarity and impact of the visual information.

Characteristics of the solution and how they address the problem?

1. The app utilizes the phone's GPS to track the user's outdoor activity and measure the amount of time spent outside.
2. Use weather api to ensures that outdoor time is aligned with daylight hours
3. The app presents collected data in an intuitive graph format, allowing users to compare their outdoor activity with past experiences and personal goals.

Measures to assess if the solution is successful?

Functional: The app integrates GPS and weather API to track sunlight exposure and displays the data visually through graphs as measured by end-to-end pipeline demonstrating visualisations are working.

Efficacy of display / increase of awareness: Measure effectiveness of the visual display for helping people answer questions as measured by the results of a quiz done by participants after the study

Validity: The app's accuracy is validated by comparing its data with personal experience and manual tracking as measured by manual tracking of light exposure and whatever the ground truth data is (e.g., wearable device)[19]

Usability: the information display is easy for people to use and understand as measured by the System Usability Scale and self-reported responses.

1 Project Specifications

The primary goal of this project is to track and display users' daylight exposure through a personalised daylight tracker, with the aim of encouraging healthier lifestyle habits. By making users more aware of how much natural light they are receiving each day, the app motivates them to spend more time outdoors, supporting improvements in sleep quality, mood, mental health, and overall physical well-being. This project aims to track the users daily exposure to daylight using GPS accuracy and weather data. By offering regular feedback on their daylight exposure, the project hopes to establish a clear correlation between outdoor time and improvements in sleep patterns, mental clarity, and physical health. Additionally, the app will motivate users to increase their time spent outdoors, encourage them to make informed decisions about their daily routines.this tool is designed to encourage a lifestyle change that embraces the health benefits of natural light, fostering better sleep hygiene, mental resilience, and overall well-being.

Core Goals:

- Create a working app that can track a persons hours in daylight using GPS
- Develop a method of storing the gathered data
- Create an interface for the user to interact with that will display the data among other things
- With the gathered data assess how the app has improved users hours in daylight

Advanced Goals:

- Add awards for users who meet certain goals eg. getting the recommended amount of daylight x days in a row
- Notify the user about the hours available for the following day
- Warn the user about harsh weather conditions

2 Introduction

2.1 The importance of Daylight

Daylight plays a major role in our everyday lives, it effects us in many ways that a lot of us take for granted. One of the main ways that daylight effects us is our Circadian Rhythm. The Circadian Rhythm is the body's internal clock, governing sleep-wake cycles.[2, 21] Daylight plays a crucial role in synchronising this rhythm, ensuring that our sleep patterns align with the day-night cycle of the environment.[21, 2] This alignment promotes better sleep, mood, focus, and overall health. When this rhythm is disrupted, such as from not getting enough daylight, it can lead to sleep issues, mood swings, and difficulty concentrating.

Vitamin D is another key benefit of sunlight exposure. When the skin is exposed to sunlight, it triggers the body's production of Vitamin D, a nutrient that plays a vital role in maintaining bone health. Beyond its role in bone strength, Vitamin D is also crucial for supporting the immune system, helping the body defend against illnesses and infections. Without enough sunlight, many people may struggle to produce sufficient Vitamin D, which can lead to deficiencies and related health issues. Insufficient Vitamin D has been linked to conditions such as osteoporosis, rickets, and a weakened immune response. Low levels of Vitamin D may increase the risk of chronic diseases like cardiovascular disease, diabetes, and even certain types of cancer.[10]

Exposure to natural light has been linked to improved mood, reduced symptoms of depression, and better overall mental health.[4] Natural light boosts mood by increasing serotonin, which helps regulate emotions. It also helps synchronise the body's sleep cycle, reducing stress and improving focus. Additionally, sunlight triggers the release of endorphins, which promote a sense of well-being. Overall, regular exposure to natural light is essential for maintaining good mental health and emotional balance.

Daylight has a positive impact on both cognitive and physical health. Exposure to natural light helps regulate the circadian rhythm, improving sleep quality and boosting energy levels. On a physical level, sunlight encourages the production of vitamin D, which is essential for bone health and immune function. Regular exposure to daylight enhances both mental sharpness and physical well-being, supporting a healthier and more active lifestyle.

Insufficient daylight exposure can lead to several long-term health risks. Disrupting the circadian rhythm, this causes sleep disturbances, which can result in fatigue, weakened immunity, and increased risks of obesity, diabetes, and depression.[4] Lack of sunlight also raises the risk of cardiovascular issues by increasing blood pressure and stress, which contribute to heart disease. Additionally, inadequate sunlight can lead to vitamin D deficiencies, affecting bone health and immune function. Over time, this can result in conditions like osteoporosis and a weakened immune system. Reduced daylight exposure is also linked to mental health problems like depression and anxiety, highlighting the need for sufficient sunlight to maintain overall health. This is a particular concern here in Ireland, where natural light levels are very low during winter. Conversely, for conditions like bipolar disorder, too much light can also be harmful, highlighting the need for careful light management.

2.2 Lack of Awareness and Actionable Insights

Many people are unaware of the optimal amount of daylight they should receive daily or its direct impact on their health. Even when researching this it was difficult to find a clear answer on the optimal amount of daylight due to different parts of the world having varying latitudes, seasonal differences, and climate conditions. These factors significantly influence the amount of sunlight available and the duration of exposure a person can safely receive. Therefore, the amount of sunlight a person needs to maintain optimal health can vary widely depending on geographic location and environmental factors. This projects focus is on optimal daylight for the northern Hemisphere.

Another reason why people may lack awareness is the confusion between sunlight and daylight. The recommended amount of sunlight refers to direct exposure where the recommended amount of daylight is both direct and indirect. In terms of daylight exposure, studies often suggest that the optimal amount for health benefits is typically around 30 minutes to 2 hours of daylight exposure per day, depending on factors like location, skin type, and the time of year. Direct sunlight is recommended for 15-30 minutes, it is often recommended for Vitamin D production, but daylight is broader and also contributes to regulating circadian rhythms, improving mood, and promoting overall well-being.

While some devices track light exposure, they do not provide actionable insights on how to optimize daylight exposure for better health.[16] These devices might record the duration and intensity of light exposure, but they rarely offer personalised recommendations on when, where, or how much daylight is needed to maintain and improve a healthy lifestyle. Without this guidance, users may struggle to interpret their data meaningfully or make changes that could genuinely improve their well-being through better daylight exposure.

Additionally, people often lack practical tips on how to incorporate sunlight into their busy schedules or understand why prioritising daylight is so important. Without this awareness, they miss simple opportunities to reap the benefits of sunlight which could significantly enhance their health over time. One of the main focuses of this project is to change this by informing people on these opportunities and potentially increase their hours in daylight.

2.3 Optimising Daylight Exposure

Studies show that getting 45 minutes of daylight each day offers important health benefits. This includes 30 minutes of morning light to help regulate your body's natural sleep-wake cycle, plus 15 minutes around midday to boost vitamin D production. Research confirms this amount is enough to make a difference for both physical and mental health, while still being realistic for most people's daily routines. The morning light helps reset your internal clock and improves mood, while the midday sun exposure ensures enough vitamin D for strong bones and immune function. This simple daily target helps counteract the effects of spending too much time indoors and can easily fit into normal activities like walking to school/work or eating lunch outside.

2.4 Objective of the Project

The overall objective of this project is to encourage healthy outdoor habits by integrating daylight awareness into users daily routines. By highlighting the physical and mental health benefits of natural light exposure, I aim to motivate users to make small but impactful changes, such as taking phone calls outside, incorporating outdoor breaks into their workday, or going for short walks in the sunlight. Through personalised feedback and reminders, the project will help users recognize opportunities to get outdoors, fostering habits that can improve mood, increase productivity, enhance sleep quality, and boost overall well-being. By making daylight exposure an achievable and conscious part of everyday life, we hope to create lasting behavioural changes that support healthier, more balanced lifestyles.

To achieve this the aim of the project is to develop a user interface that not only tracks when users are outside but also correlates this with real-time sunlight exposure. This interface gives users actionable insights about their outdoor activities. Additionally, the system provide personalised recommendations for optimal times to go outside, considering when the sun rises and sets.

To gather the necessary data from users, the interface is developed as an app that tracks when they are indoors or outside, as well as when sunlight is available. The app estimates indoor or outdoor status based on the user's phone GPS accuracy with a lower value (in meters) meaning the user is outside and a higher value meaning the user is probably inside. To ensure that outdoor activity coincides with daylight, the app will use a weather API to obtain accurate sunrise and sunset times, this defines when the window of daylight is available. This combination of location tracking and daylight data aims to provide reliable insights into when the user is exposed to natural light.

Finally the thing that will help users the most is how the interface is displayed. The interface needs to be user friendly and reliable. Users need to be able to easily understand the data displayed before them and be able to navigate the app easily. The plan was to have at least two sections one that displays a graph showing the number of hours the user got today and one that displays a graph showing previous hours in daylight.

3 Literature Review

This section examines research on the benefits of daylight and its effects on our health and well-being. It will explore studies on how natural light influences sleep, mood, circadian rhythms, and physical healths. By highlighting the importance of adequate sunlight exposure, this review provides the scientific basis for developing a personalised daylight tracker.

3.1 Health Benefits

3.1.1 Vitamin D

When talking about the benefits of daylight the first thing that is associated with it is Vitamin D. Exposure to sunlight gives our bodies Vitamin D. Vitamin D is essential for maintaining skeletal health, calcium-phosphorus balance, and immune system function.[10, 8] Deficiency in vitamin D is associated with a spectrum of health issues, including rickets, osteomalacia, cardiovascular diseases, and even disturbances in sleep [12]. While consuming food contributes to our vitamin D intake our primary source of vitamin D is through our skin, which absorbs ultraviolet B (UVB) radiation from sunlight [8]. This process is influenced by factors such as latitude, season, and atmospheric conditions, making populations in northern mid-latitudes particularly vulnerable to deficiency during winter months when UVB levels are insufficient. [8].

Limited exposure to natural light, whether due to modern indoor lifestyles, urban environments, or geographic location, exacerbates the risk of Vitamin D deficiency. This can lead to significant health problems, particularly bone-related conditions like rickets and osteomalacia, as well as cardiovascular diseases. [12].

3.1.2 Circadian Rhythms

The circadian rhythm is a biological cycle regulated by a "master clock" in the brain, influencing alertness, productivity, and sleep patterns over a 24-hour period. Genetic and environmental factors create individual differences known as chronotypes. Exposure to sunlight is a primary driver of this rhythm, as light entering the eyes helps synchronise the body's internal clock with the external environment. However, everyday factors can disturb this rhythm. Persistent disruption of biological rhythms due to "social jet lag" (e.g., early work hours misaligned with natural sleep patterns) is linked to health problems like cardiovascular disease, obesity, and mental health disorders.[17] Circadian misalignment is especially prevalent in approximately 80% of the population[1]. Recent studies demonstrate that bright daytime light reduces risk of depression, PTSD, and psychosis, while nighttime light exacerbates these conditions. These effects are independent of sleep quality, suggesting direct circadian modulation.[4]

Late chronotypes—those naturally inclined to sleep and wake later—are especially vulnerable, experiencing greater misalignment and compensating with behaviors like extended sleep on free days.[17]. Reduced exposure to daylight due to indoor lifestyles or reliance on artificial light can de-synchronise the circadian clock. This leads to a delay in sleep onset and other circadian disruptions, especially among late chronotypes[17].

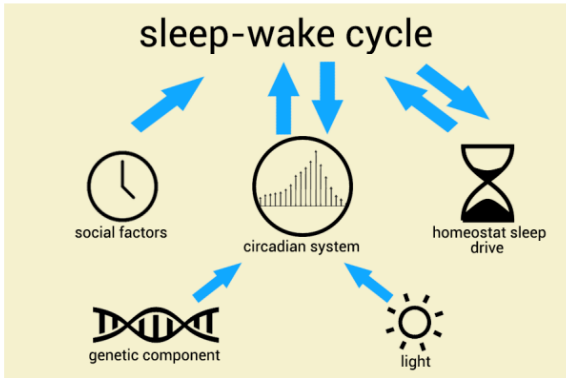


Figure 1: Sleep-Wake cycle

Recent advancements in circadian computing emphasize the potential of personalised interventions tailored to individual chronotypes, such as early birds and night owls. These systems leverage data from mobile devices to passively track sleep patterns and circadian misalignment, providing actionable insights into how daily routines can be adjusted to minimize disruptions. For example, studies have shown that incorporating smartphone usage patterns to identify sleep phases and social jet lag can help synchronise internal clocks to external schedules. This underscores the value of adapting interventions to the biological rhythms of individuals, such as morning light exposure to advance sleep phases for those with delayed rhythms[1].

One of the most significant disruptors of the circadian rhythm today is blue light emitted by electronic devices. Devices emit blue light, which is particularly disruptive to the circadian system. Blue wavelengths are more effective at suppressing melatonin and delaying the sleep phase compared to other light types[6]. The blue light from devices significantly suppresses melatonin secretion. In the study, participants using light-emitting devices had their melatonin levels reduced by over half compared to those reading printed materials. According to the same study, evening use of light-emitting devices led to a 48-minute delay in the circadian rhythm's dim-light melatonin onset , disrupting the body's natural timing of sleep. The study also noted increased morning sleepiness following evenings of device use, with participants being less alert upon waking due to reduced sleep quality and circadian misalignment[6]. To mitigate these disruptions, exposure to natural daylight, particularly during the morning, is crucial. Regular daylight exposure helps synchronise the circadian rhythm, improving sleep quality, daytime alertness, and overall well being[17]. Modern environments, which emphasize artificial lighting, fail to provide the same benefits as natural daylight, underscoring the importance of integrating more daylight into daily routines.

3.2 Methods for Tracking Outdoor Activity

Advancements in technology have enabled researchers to use smartphones and wearable devices for light exposure tracking. A critical component of these systems, especially for this project, is the ability to determine whether a user is outdoors. Outdoor environments provide the primary source of natural light, essential for regulating circadian rhythms, supporting mental health, and synthesising vitamin D. Tracking outdoor activity is therefore not only a technical challenge but also a health-focused endeavour.[19] Several tracking methods have been explored in recent research, offering diverse solutions for environment classification and activity monitoring. These methods vary in accuracy, energy efficiency, and practical implementation, with a focus on mobile and wearable technologies. Researchers have greatly enhanced the reliability of environment classification by combining multiple sensor systems or utilizing advanced computational methods such as machine learning.[14]

3.2.1 GPS (Global Positioning System)

GPS tracking is one of the most widely used methods for determining outdoor activity, due to its ability to provide precise geolocation data.[20] This technology relies on signals from orbiting satellites to calculate a user's position, which makes it particularly effective in open outdoor environments. However, GPS performance degrades significantly in environments with obstructions, such as urban canyons, dense forests, or indoors, where satellite signals are either blocked or scattered.[14]To address these limitations, fused GPS systems have been developed. These systems integrate data from additional sensors such as accelerometers, barometers, magnetometers, and Wi-Fi networks. This fusion improves accuracy in environments where satellite signals are weak or unavailable. For example, barometric data can help identify elevation changes, while Wi-Fi signals can provide supplementary location information in urban areas. Despite these enhancements, the continuous operation of GPS imposes a significant drain on battery life, limiting its practicality for long-term sunlight exposure monitoring. As a result, GPS is often supplemented with other low-energy methods for improved performance and efficiency[20].

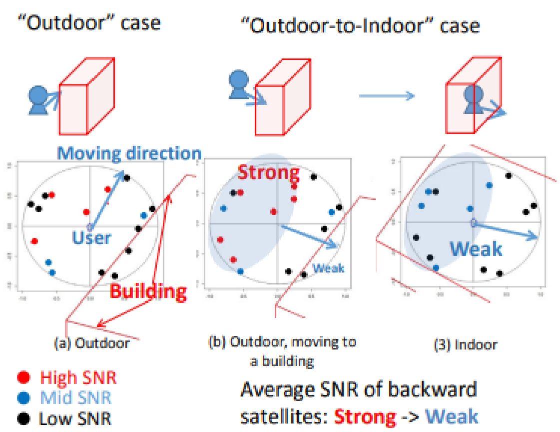


Figure 2: GPS diagram

3.2.2 Signal strength-based detection

Signal strength-based detection, especially utilizing GSM (Global System for Mobile Communication), offers a highly energy-efficient alternative to GPS for determining whether a user is outdoors.[19] This method analyses variations in the signal strength from nearby cellular base stations to classify environments into categories such as open outdoors, semi-outdoors, light indoors, and deep indoors[20]. Wang et al. demonstrated the effectiveness of this approach by applying machine learning algorithms, such as K-Nearest Neighbors (KNN) and Random Forest, to GSM signal patterns. Their study achieved classification accuracies exceeding 97%, highlighting the reliability of GSM-based detection for environmental classification[20]. Unlike GPS, GSM signal analysis consumes minimal additional energy, as it leverages existing smartphone infrastructure, making it an ideal solution for prolonged tracking. This method also shows great potential for urban applications, where GPS signal quality is compromised by buildings and other obstructions. By focusing on signal patterns and fluctuations, GSM-based detection can maintain high accuracy without relying on resource-intensive location tracking systems[20].

3.2.3 Ambient light sensors

Ambient light sensors, integrated into most modern smartphones, provide a practical method for tracking outdoor activity by measuring light intensity. These sensors serve as proxies for sunlight exposure, which is a critical factor in assessing both circadian rhythm regulation and vitamin D synthesis.

High light levels detected by these sensors often correspond to outdoor environments, making them a straightforward method for identifying periods of sunlight exposure[20]. However, ambient light sensors alone cannot reliably distinguish between indoor and outdoor settings due to the potential influence of artificial lighting. For instance, bright artificial lights can mimic outdoor sunlight levels, leading to false classifications.

The challenge of distinguishing between artificial and natural light in ambient light sensor data could be addressed by incorporating predictive computational models. These models can simulate the specific impact of different light spectra, such as the blue wavelengths that are most disruptive to melatonin suppression. By integrating these insights, light sensors can refine their classifications and better assess the role of light exposure in regulating circadian rhythms.[7]

To improve accuracy, ambient light sensor data is often combined with other methods, such as GPS or GSM-based detection[19]. Anagnostopoulos et al. emphasized the importance of combining ambient light sensors with location data to enhance context-awareness and avoid mis-classifications This integration enables a more holistic approach to environment detection, ensuring that users' exposure to natural light is accurately assessed[19].

By leveraging advancements in GSM signal strength analysis, researchers have developed highly energy-efficient and accurate methods for tracking outdoor activity. Unlike GPS, which offers high precision but is resource-intensive, GSM-based detection consumes minimal energy and reliably classifies environments such as open outdoors, semi-outdoors, and deep indoors. This makes it an ideal choice for applications requiring prolonged monitoring, such as tracking light exposure. Although ambient light sensors can measure light intensity directly, they are not being used in this project due to practical constraints of smartphone implementation and their susceptibility to inconsistent readings based on device positioning. Instead, GSM signal strength-based detection ensures efficient and reliable tracking of outdoor activity, serving as a proxy for light exposure. This decision balances practicality and accuracy, providing users with meaningful insights into their natural light exposure.

3.3 State of the art for data visualisation of light exposure

3.3.1 Visualisation Techniques and Personalised Data

The ability to effectively visualise light exposure data has seen significant advancements, ranging from static graphs to dynamic heat-maps. Studies have emphasized the importance of personalisation in these visualisations to cater to individual differences in circadian rhythms and lifestyle preferences. For instance, time-series visualisations have proven effective in tracking circadian patterns, while newer tools incorporate user-friendly design principles to enhance accessibility and engagement[18]. Personalised dashboards let users combine environmental light data with their own metrics, like sleep and activity logs, giving them a complete view of their light exposure. These systems can help users make changes to improve their light exposure for better health[13, 18].

3.3.2 Predictive and Actionable Insights

Modern light exposure trackers are leveraging predictive analytics to translate historical data into actionable recommendations.[13] These tools utilize algorithms to predict future exposure patterns, advising users on optimal light settings or schedules. For example, machine learning models trained on user-specific data can forecast light needs to enhance alertness during the day or avoid circadian misalignment in the evening[16]. These insights depend heavily on accurate and continuous data collection, which poses challenges in ensuring reliability across diverse user environments. Despite these challenges, early evidence suggests that such systems can significantly impact user behaviour, promoting better sleep quality and daytime performance.

3.3.3 Challenges and Emerging Innovations

Despite the progress in light exposure visualisation, challenges persist in scalability, data privacy, and user engagement. Many systems struggle to balance the complexity of visualised data with user comprehension, particularly for non-expert audiences[18]. Additionally, ensuring data privacy while providing personalised insights remains a critical concern. Innovations like augmented reality and wearable technologies are addressing these challenges by offering real-time, immersive visualisations that integrate seamlessly into daily life. Emerging trends in data visualisation design also emphasize accessibility, such as the use of colour-blind-friendly palettes and multi-device compatibility.These advancements pave the way for more effective tools that cater to diverse user needs[13].

Summary of Literature Review Overall, the literature review explores the health impacts of daylight exposure, methods for tracking outdoor activity, and approaches for visualising light exposure data. The findings highlight the strong link between daylight and both physical and mental health, while also identifying the technical and usability challenges of tracking and presenting this information. For this project, the key takeaway is the importance of developing a solution that is accessible, protects user privacy, and presents data in a way that is simple and actionable. Building on previous research, the app aims to deliver a practical tool that encourages healthier daylight habits through clear, user-friendly feedback.

4 Project Approach

This section outlines the practical steps taken to design and implement the Daylight Personalisation Tracker. It covers the tools and technologies used, why they were chosen, and how everything fits together. It also discusses key architectural decisions, data considerations and strategies for visualisation and behavioural change, setting the foundation for how the project goals were translated into a working app.

4.1 Tools / Architecture

4.1.1 React Native

For the development of the daylight personalisation interface, I opted to build a mobile application and, after careful evaluation of available frameworks, selected React Native as the primary development platform. React Native's cross-platform capabilities make it an ideal choice, as it allows the application to be deployed seamlessly on both iOS and Android devices, ensuring accessibility for a broad user base. This compatibility is essential for creating an inclusive and user-friendly experience, as it eliminates the need to develop separate applications for each platform. Another key factor in choosing React Native is its primary programming language, Typescript, in which I already have prior experience. Leveraging my existing knowledge of Typescript not only accelerates the development process but also allows me to focus more on implementing core functionality and refining the user interface, rather than spending additional time learning a new language. Additionally, React Native offers a comprehensive ecosystem of pre-built components and libraries, making it easier to incorporate key features like geolocation, data visualisation, and integration with external APIs.

4.1.2 WeatherAPI

A key tool required for this project is a weather API to provide critical daylight data, such as sunrise and sunset times. Without an API, it would not be possible to reliably determine when daylight hours begin and end for a user's specific location. After evaluating several options, I chose to integrate WeatherAPI. This API is particularly well-suited to the project's needs, as it offers accurate and reliable information on sunrise and sunset times, which are critical for determining daylight hours. In addition to providing real-time data, WeatherAPI can also deliver forecasts for upcoming daylight hours, allowing the app to inform users about the optimal times for outdoor activities. Furthermore, the API can alert users to potential weather-related obstacles, such as cloud cover or precipitation, enabling them to plan their activities more effectively. This integration ensures that the app provides users with both current and forecasted daylight information, enhancing its functionality and usability.

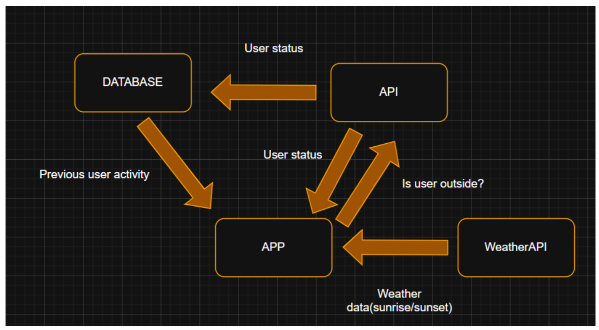


Figure 3: Initial System Architecture

4.2 Hosting

The app's main features depend on a back-end API that handles all the data—sending, storing, and retrieving it. To make sure users could access the app from anywhere at any time, I set up a server to host both the API and the database. This allows users to get real-time updates, store their activity, and see their progress easily.

I decided to use Amazon Web Services (AWS) for hosting. One of the biggest reasons was the 12-month free tier, which made it a practical choice while developing the project. Beyond that, AWS is well-documented and something I'd heard a lot about, so it felt like a good opportunity to learn more about it in a real project. It's also flexible enough for me to expand my EC2 instance in the future if I ever need to.

4.2.1 Database

For the database, I went with PostgreSQL. I've used it before in previous college projects, like in last semester's Cloud Computing module, so I was already comfortable setting it up and writing queries. PostgreSQL is reliable and easy to work with, and since it's open-source, I didn't have to worry about any costs or licenses.

There are two main tables in the database. One stores the data collected every five minutes from users—things like whether they were outside, the weather at that time, and the timestamp. This is the main dataset I used for analysis in this report and for generating the graphs shown in the app. The second table stores user feedback—specifically whether they thought the app correctly identified if they were inside or outside. This helps track how accurate the app is and where it might need improvement.

4.2.2 API

The app leans heavily on its API. It acts as the link between the app and the database—processing data the user sends, updating the database, and returning the information or graphs needed to display in the app.

These are the four API endpoints:

- `/check-location` – Checks whether the user is indoors or outdoors based on GPS data and accuracy.
- `/submit-feedback` – Lets users send feedback if the app's location check was correct or not.
- `/daily-visualisation` – Sends back the data needed to draw the daily arc showing time spent outside.
- `/weekly-time-outside-graph` – Returns a bar chart summary of how many minutes the user spent outside each day over the past week.

I'm running the API on an AWS EC2 instance so it can be accessed online. This makes it easy for the app to send and receive data no matter where the user is or what device they're on.

4.2.3 TestFlight

To test the app with real users, I wanted to share it with friends and family. Since most of them use iPhones, I chose TestFlight for beta testing. It's an easy way to share apps with testers without needing to go through the full App Store process. It also allowed me to send out updates quickly and collect feedback during development.

4.3 Data Considerations

4.3.1 Tracking Methodology

The plan is to use the users mobile phone signal strength, GSM(Global System for Mobile Communication) along with the WeatherAPI. By using GSM, the system can detect when a user is outside by analysing their location based on signal strength, which indicates whether they are in an environment with cellular coverage typically associated with being outdoors. This allows the app to estimate outdoor activity in real time, without requiring additional hardware or user intervention. In addition, WeatherAPI enhances this tracking by providing real-time data on sunrise and sunset times, along with weather forecasts that could impact sunlight exposure, such as cloud cover or rain. By integrating these technologies, the app combines both the tracking system and the user interface into one seamless product. This unified approach not only simplifies the user experience but also eliminates the need for additional devices, making the solution more accessible and user-friendly. The combination of mobile phone data and weather insights allows the app to offer a personalised and efficient tracking experience for users, helping them understand their daylight exposure patterns while providing valuable insights about their environment.

4.3.2 Limitations and Challenges

While this tracking methodology offers numerous advantages, accurately determining daylight exposure does present several challenges. One of the primary limitations is that the system cannot differentiate between users who are genuinely outdoors and those who may be inside but near a window or in a sunlit area. For example, if a user is sitting by a window with sunlight streaming in, they may appear to be inside according to the tracking system, even though they are not fully exposed to daylight. Similarly, if a user is wearing sunglasses or clothing that blocks sunlight, the system may falsely indicate they are receiving daylight when they are not. These factors introduce potential inaccuracies because the system primarily detects outdoor presence rather than accounting for the nuances of direct sunlight exposure. The app will not be able to measure light intensity or assess how much sunlight reaches the user's skin, which could lead to discrepancies in the data. However, these limitations are the chosen approach as it aims to minimize the need for additional devices or invasive measurements. Despite these challenges, the method still provides a valuable approximation of outdoor activity and daylight exposure.

4.3.3 Accessibility and Universal Appeal

A significant advantage of this methodology is its reliance on technology that is already widely available—smartphones. Nearly everyone has access to a mobile phone, making this tracking method highly accessible to a diverse and broad audience. Unlike wearable devices, which often come with additional costs and require users to wear extra hardware, this approach eliminates the need for additional devices, reducing both financial and physical barriers. The system's reliance on smartphones also enhances its convenience. By integrating both tracking and the user interface into a single application, the app provides users with an all-in-one solution that they can use on a device they already own and carry daily. This not only simplifies the overall user experience but also makes it easier for users to monitor their daylight exposure without the added complexity of managing multiple devices. This design approach ensures that the app is accessible to a wide range of users, regardless of their technical expertise or economic situation, and provides a level of universal appeal that is both practical and user-friendly.

4.4 Visualisation Software and Methods?

In the app, the main display will feature a graph that provides a clear and intuitive visualisation of the user's daylight exposure throughout the day, similar to the one below. This graph will display the possible hours of daylight the user can access based on real-time data from the WeatherAPI, highlighting sunrise and sunset times, as well as potential weather conditions that could affect sunlight availability. The graph will not only show the total daylight duration but also indicate the best hours for the user to go outside, based on factors like optimal sunlight intensity and weather conditions. By visually marking these peak daylight hours, the graph will serve as a helpful guide for users to plan their outdoor activities effectively.

In addition to the main graph, the app will include a series of supplementary graphs that display historical daylight exposure. For example, bar charts or line graphs will show previous hours of daylight the user has experienced, allowing them to track patterns over time. These visualisations will help users understand their exposure trends and make informed decisions about their outdoor activities.

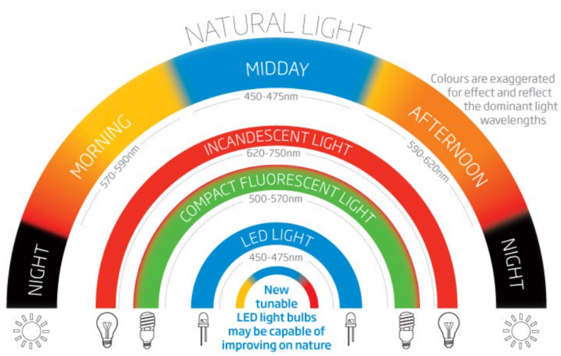


Figure 4: Sample visualisation

4.5 Behavioral change cycle

The overarching goal of this project is to encourage users to make positive behavioral changes by spending more time outside and increasing their exposure to natural daylight. The app's core aim is to help users become more mindful of their daylight habits and take actionable steps to integrate outdoor activities into their daily routines. To encourage this the plan is to provide users with real time information about the hours of daylight available each day, based on their location. Along with this, the app will also recommend an optimal daily amount of daylight exposure guiding users on how much sunlight they should ideally be receiving each day to support their health. As part of the behavioural change cycle, the app will incorporate motivational elements to increase user engagement and encourage consistency. One advanced goal of the project is to implement a reward system that incentivise users for reaching their daylight exposure goals. For example, users who achieve the recommended amount of daylight exposure for a certain number of days in the previous month could receive rewards or badges.

These rewards would act as positive reinforcement, recognizing the user's efforts and helping them stay motivated. Additionally, another advanced goal is a streak system. The app would track how long a user can consistently maintain the recommended level of daylight exposure, rewarding them for reaching milestones such as a streak of consecutive days with optimal sunlight exposure. This system taps into the psychology of habit formation, where maintaining a streak becomes a personal challenge, increasing user motivation to continue engaging with the app.

4.6 Design choices

In designing the app, one of my primary goals was to create a clear and user-friendly way for individuals to understand how much time they spend outside during the day. To achieve this, I implemented a visual representation in the form of an arc that spans from sunrise to sunset. Segments of this arc are filled in to indicate the periods when the user was detected to be outdoors. This approach offers a straightforward and engaging way for users to see how their outdoor time compares to the total daylight available, making it easy to grasp at a glance whether they are taking full advantage of natural light throughout the day.

This visualisation also helps users identify patterns in their daily routines. For instance, they may notice consistent gaps during peak daylight hours when they are indoors, which could encourage small lifestyle changes to spend more time outside—whether it's taking a walk during lunch or stepping out in the morning. The arc not only informs but subtly motivates users to make more health-conscious decisions regarding their daylight exposure.

Beneath the arc, the app displays the user's current status—whether they are inside or outside—along with the GPS accuracy reading, which serves as a threshold to determine location reliability. This transparency helps users understand how the app makes its determination. Additionally, a feedback mechanism is provided where users can indicate whether the app's inside/outside status is correct or not. This feedback is important for refining and improving the detection algorithm over time based on real user input.

The app's second tab presents a bar chart summarizing the total minutes spent outdoors for each day over the past week. This weekly view complements the daily arc visualisation by offering a broader perspective on outdoor activity trends, helping users reflect on their habits over time rather than just day by day.

In terms of design, the app adopts a colour scheme of orange, black, and white. This combination was chosen for its balance between visual appeal and practical function. The darker tones help reduce eye strain, especially during evening use, and limit disruption to the user's circadian rhythm, which can be affected by bright screens. The orange adds warmth and emphasis without overwhelming the user. Both the header and app icon were professionally commissioned to give the app a polished and cohesive visual identity that enhances the user experience.

5 Implementation

5.1 Process

5.1.1 Initial app creation

The app was built using React Native for cross-platform compatibility, leveraging Typescript and Expo for iOS deployment. My main goal was to find a solution that would support cross-platform development allowing me to build the app for both iOS and Android with a single codebase. While my short-term goal was focused on publishing the app to iOS, since that's the platform most of my friends and family use (and who would be testing the app), I wanted to keep the door open for a future Android release without having to rebuild the app from scratch.

In terms of deployment, my priority was to publish the app to TestFlight, Apple's beta distribution platform. I chose TestFlight because it offers a convenient way for testers to install and update pre-release versions of apps directly on their iPhones, without going through the full App Store submission process. It also allowed me to manage builds, collect tester feedback, and allowed for quick adjustments throughout the development phase.

Ideally, I would have used Xcode, Apple's official IDE, to handle the build and deployment process. However, Xcode is only available on macOS, and I was developing on Windows. This limitation forced me to look for a solution that would allow me to build for iOS without direct access to Xcode.

After weighing my options, I chose to use React Native as the development framework. React Native supports cross-platform app development and it integrates well with third-party tools for iOS and Android deployment. Despite the extra step required for iOS builds (since I couldn't use Xcode locally), React Native made it possible to develop and test the app as planned. I used services like Expo, and later EAS Build, to handle iOS builds remotely in the cloud, which allowed me to generate builds and publish them to TestFlight even without a Mac.

React Native's homepage includes a quick-start section for generating a base app template, which I used as the foundation for my project. This template gave me a pre-configured environment with essential files.

5.1.2 GPS Accuracy & API Setup

One of the most critical components of the project is the indoor/outdoor status check, as it serves as the foundation for all personalised daylight tracking. If I couldn't reliably determine whether a user was inside or outside, then the entire concept of tracking daylight exposure would fall apart. This made choosing an effective and efficient method for modelling location accuracy a top priority during development.

Initially, my first approach was to try detecting indoor or outdoor status based on signal strength, specifically looking at cellular signal quality or the number of satellites the phone could connect to at any given time. The reasoning was that outside typically offers better signal strength and a higher number of satellite connections. However, Apple's privacy restrictions prohibit access to raw signal data, necessitating an alternative approach using GPS accuracy. This limitation forced me to pivot to an alternative method.

The next best option I explored was GPS accuracy, which relies on the principle that when a phone is indoors, the GPS signal tends to be weaker and less accurate and when outside GPS signals tend to be stronger and more precise, which is a similar principle as the signal strength method. This method offers a low energy, privacy preserving way to check whether someone was outside making it well suited for the app which I intended on run periodically throughout the day.

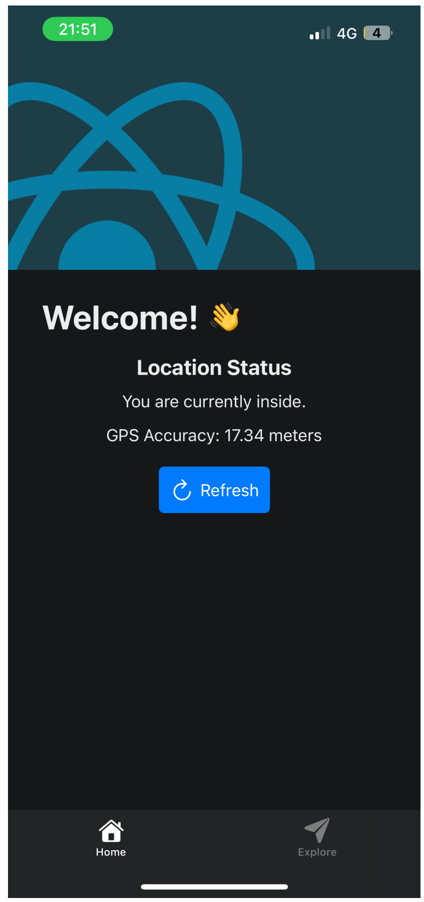


Figure 5: Early version

Implementing this involved used the expo-location library. This library provides access to the device's GPS location data while also returning an accuracy estimate measured in meters indicating how close the reported position is likely to be to the actual location. The result from this is a radius for how close the accuracy is eg. within 3 meters of the devices true location.

With this in hand the next step was to create a simple check. I started with if over 20 meters user is likely inside, if it was below that threshold, the user was likely outside. Knowing that the location check would just be the first of many data-handling functions, I built a lightweight Flask-based back-end API to manage all logic related to data processing. I chose Flask because I've used it in several college modules, including Cloud Computing, and I'm comfortable with its syntax and structure. It also offered the flexibility to expand and add more endpoints as the app grew. Initially, I ran the API locally alongside the app to test functionality quickly and easily. Over the course of testing I adjusted the GPS accuracy threshold. Through trial and error, I found that a threshold of around 15 meters generally gave me the best balance between false positives and false negatives.

5.1.3 Database and API Hosting

Once I had the tracking functionality set up and working reliably, the next step was to store the collected data so it could be used in future iterations of the app, like displaying visualisations to the user or support analysis in this write-up. I decided to use Amazon Web Services (AWS) to host a PostgreSQL database, mainly because I had experience with PostgreSQL from previous college modules, and AWS offers a 12-month free tier, which made it a cost-effective solution during development. After setting up the database on AWS, I used pgAdmin to connect to it and create the necessary tables. At this stage, I only needed one table to store and retrieve user data, such as location accuracy and timestamps.

For privacy and security reasons, I designed the app so that it doesn't connect directly to the database. Instead, all interactions go through the back-end API, which acts as a controlled gateway for data access and processing. To make the API accessible remotely—and to support deploying the app to TestFlight for external testing—I set up an AWS EC2 instance to host the API. I uploaded and ran my Python code on the server, which allowed the app to communicate with the back-end consistently and securely, without needing to run anything locally except during development and debugging.

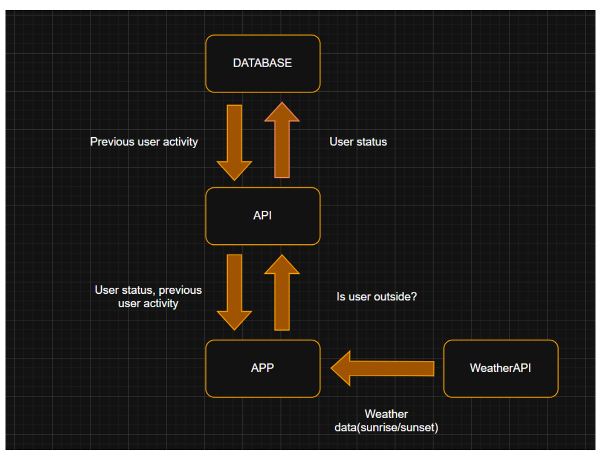


Figure 6: Final System Architecture

5.1.4 WeatherAPI

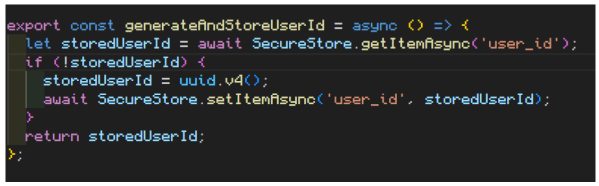
In addition to building my own custom API, I also integrated a third-party service called WeatherAPI to enhance the functionality of the app. WeatherAPI provides access to a wide range of real-time and forecasted weather data, including temperature, weather conditions and sunrise & sunset times. One of the reasons I chose WeatherAPI is that it offers a free tier, allowing up to 1 million API calls per month, which was more than sufficient for the scale of this project, especially during development and testing.

By incorporating this into the app I could send localised weather information based on the user location. This integration was particularly important because one of the core goals of the project is to encourage healthy daylight exposure, which is most beneficial between sunrise and sunset. By using

WeatherAPI to fetch sunrise and sunset times based on location, the app could determine whether a user's time outdoors was actually within the healthy daylight window. This ensures that the app only logs activity that aligns with the project's health focused goals.

5.1.5 User Identification

To ensure that users receive data unique to them, I implemented a system that generates a unique user Id the first time the app is opened. This ID is securely stored on the user's device using SecureStore, and is reused in all future API requests. By persisting this identifier locally and attaching it to each call to the back-end, the app ensures that each user's data remains consistent and isolated without requiring formal authentication.



```
export const generateAndStoreUserId = async () => {
  let storedUserId = await SecureStore.getItemAsync('user_id');
  if (!storedUserId) {
    storedUserId = uuid.v4();
    await SecureStore.setItemAsync('user_id', storedUserId);
  }
  return storedUserId;
};
```

Figure 7: User Id generation

5.1.6 TestFlight - Introducing Testers/Gathering Data

Getting the app onto TestFlight was a really important step in the project. Once it was up there, I could finally start sharing it with friends and family to test it out and start collecting real user data and feedback. The first build of the app was published to TestFlight on February 26th, and user data was collected continuously until April 18th, providing a valuable testing period of over seven weeks. That said, getting it onto TestFlight wasn't totally straightforward at first. Normally, you need to build the app using Xcode which is limited to mac device, which made that tricky. Luckily, Expo has a service called EAS Build that basically handles all the heavy lifting. By linking my Expo account to my Apple Developer account, I was able to build the iOS version of the app in the cloud and push it to TestFlight without needing Xcode at all. The first version of the app I released was very basic it could only tell if you were inside or outside. Not much had changed from the starter template at that point. It let me test the core feature in real world conditions. Through tester feedback, I identified critical issues early on, such as false positives in location detection caused by strong WiFi signals and inconsistencies with GPS accuracy thresholds in urban environments. These findings directly resulted in key improvements, such as the implementation of WiFi-based checks and adjustments to GPS accuracy settings. This also provided valuable insights into user behavior, feedback, and areas for further enhancement.

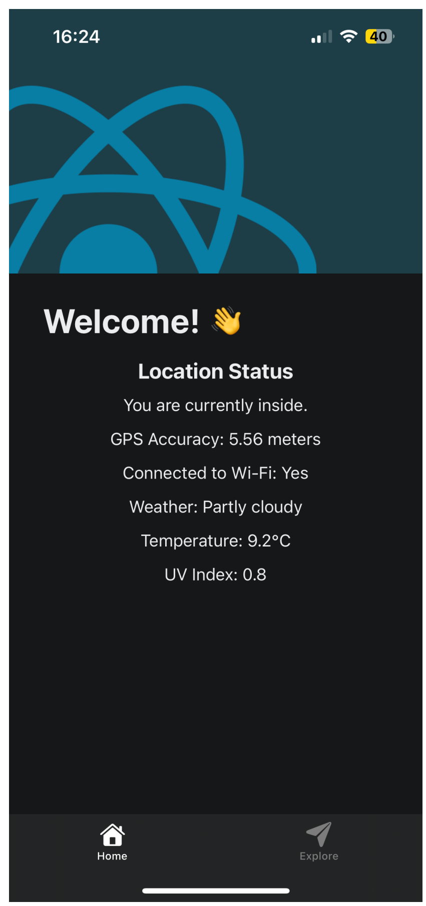


Figure 8: Weather data integration

5.1.7 Background tracking & Timed Checks

A key feature of the app is its ability to passively track the user's location throughout the day, not just when the app is actively in use. This is essential for giving users accurate feedback on how much time they actually spend outside. To get this working, the app needs two specific permissions, it must be allowed to run in the background and it must be granted access to the device's location Always, not just while using the app. This setup ensures that checks are performed regularly even if the user isn't actively interacting with the app. This is the best method I could find when implementing.

However, running constant background location tracking can be a huge drain on the battery. To balance accuracy with efficiency, I implemented a timed check system, location is only checked every 5 minutes. These timed intervals reduce battery consumption while still being as accurate as possible. If the app fails to get a location reading or if the phone has no signal, the interval between checks might become too long. To prevent the app from mistakenly logging long periods of outdoor exposure, I implemented a 10-minute cap, if more than 10 minutes have passed between checks, only 10 minutes are recorded as outdoor time. This prevents data spikes and improves the reliability of the recorded values.

Setting up this background system took a lot of trial and error. One of the biggest challenges was that background tasks can't be tested in a local development environment. The only way to test if the background checks were truly running correctly was to build and publish the app to TestFlight each time. This meant repeatedly using Expo EAS Build, which takes time and eventually costs money if you exceed the free quota.

To calcualte the time spent outside if the previous table entry is outside then the next entry as for the time_outside column is the current timestamp minus the previous timestamp. Before this is added it also confirms that the difference isn't more then 10 mins and is on the same day. This value is also added to total_time_for_given_day and total_time_outside.

Once the timed checks were running reliably, I could start calculating how long users were actually spending outdoors. If the previous database entry for that user showed they were outside, then the app assumes they have remained outdoors until the current check. It calculates the time difference between the two timestamps and, as long as the difference is less than or equal to 10 minutes (to respect the max cap), and both timestamps are on the same day (to avoid multi-day miscounts), it adds this duration to two columns time_outside for that entry and total_time_for_given_day, which keeps a running daily total. There is also a total_time_outside column to track all-time outdoor exposure for each user.

```
export const startBackgroundTracking = async () => {
  const { status } = await Location.requestBackgroundPermissionsAsync();
  if (status === 'granted') {
    await Location.startLocationUpdatesAsync(LOCATION_TASK, {
      accuracy: Location.Accuracy.BestForNavigation,
      timeInterval: 5 * 60 * 1000, // 5 minutes
      showsBackgroundLocationIndicator: true,
    });
    console.log('Background tracking started');
  } else {
    console.error('Background location permission not granted');
  }
};
```

Figure 9: Background tracking code

5.1.8 User Feedback

To help verify the accuracy of the app's tracking system and improve the overall user experience, I implemented a user feedback mechanism directly into the user interface. This feature enables users to manually confirm or deny the app's current determination of whether they are inside or outside. Two buttons, labelled "Correct" and "Incorrect", provide a simple and accessible way for users to provide real-time feedback.

This feedback system served two key purposes. Firstly, it allowed for a more objective evaluation of the app's accuracy in identifying inside vs. outside status based on GPS data. Secondly, it enabled iterative improvements to the tracking algorithm by highlighting potential edge cases or inaccuracies. For instance, discrepancies between the app's classification and the user's actual location helped reveal situations where the GPS accuracy threshold was either too lenient or too strict. As a result, I was able to fine-tune this threshold to better suit a broader range of users and real-world conditions.

One of the most significant insights gained through user feedback was the impact of WiFi connectivity on GPS performance. During testing, several users reported that the app incorrectly identified them as being outside while they were indoors. Upon further investigation, it became clear that the presence of a strong WiFi signal was interfering with the GPS reading, creating misleading location data. In response to this finding, I introduced an additional layer to the classification logic, if a user is currently connected to a WiFi network, the app now automatically assumes they are indoors. This assumption is based on the common behaviour pattern that people are more likely to connect to WiFi networks while inside buildings. This change significantly reduced false positives in inside/outside classification and improved the overall reliability of the app's detection system.

5.1.9 Visual data

With user data now being properly recorded and stored through the back-end system, I was able to progress to one of the most important parts of the project visually representing this data within the app. This step marked a key milestone in the implementation process, as it directly addressed one of the core goals of the project providing meaningful, feedback to users about their daylight exposure habits. Visualising the data not only improves engagement but also helps users better understand their behaviours in relation to their time spent outside. Each visualisation was designed to answer a specific question for the user, helping them make better decisions and create healthier routines.

Daily Visual

The Daily Visual is the primary feedback mechanism and is what users are presented with upon opening the app. The goal of this visual is To quickly inform users about how much time they have spent outside during the day, how their activity aligns with daylight hours, and whether they are on track to meet their recommended outdoor exposure goal. This data is displayed in the form of an arch, visually representing the time window between sunrise and sunset for that specific day. The final version of the Daily Visual includes the following key features:

- Orange segments indicating the periods when the user was detected to be outside.
- A moving dot indicator that shows the current time along the arch.
- Labelled markers for sunrise and sunset times, giving users contextual understanding of their day.
- A Recommended outdoor time goal, which acts as a target to guide user behavior.
- A summary label indicating the total time the user has spent outdoors for the current day.

To generate this visualisation, the required inputs (current time, sunrise time, and sunset time) are supplied by the app and passed to the API. The visual is created server-side using the matplotlib library. The arch is built by mapping the time range from sunrise to sunset to a 0-180° scale, representing a half-circle. Outdoor activity is layered on top using semi-transparent segments, which are calculated based on the time intervals logged in the database via time_outside. Each orange segment's start and end angles are calculated in relation to the full arch's timespan, then rendered accordingly. This layered approach not only conveys quantity but also when during the day users were most active outside.

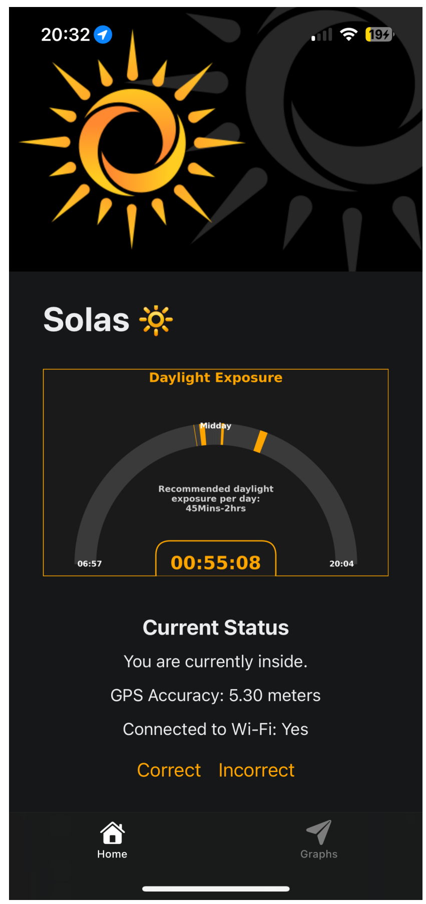


Figure 10: Initial daily visual interface

Weekly Visual

The Weekly Visual is accessible via the second tab in the app and provides a broader overview to help users track trends over time, encouraging reflection and promoting consistency in daylight habits over the course of a week. Unlike the more stylistic Daily Visual, the Weekly Visual is structured as a traditional bar chart for clarity and easy trend recognition. To generate this view, the back-end compiles the total outdoor duration for each day of the past week using the total_time_for_given_day field in the table. The data is presented in descending order starting from the current day (e.g., today, yesterday, etc.), allowing users to quickly see their most recent activity.

Each bar represents the total amount of time spent outdoors for that particular day. A goal threshold is also visualised across the graph, with the user's daily goal set at 45 minutes of outdoor time. If the user meets or exceeds this goal on any given day, a check-mark appears on the corresponding bar, offering a quick and encouraging visual cue. This visual was also implemented using matplotlib in the back-end. Once generated, the resulting image is sent back to the app where it is displayed seamlessly within the interface. This setup allows the app to remain lightweight while offloading more intensive rendering tasks to the API layer.

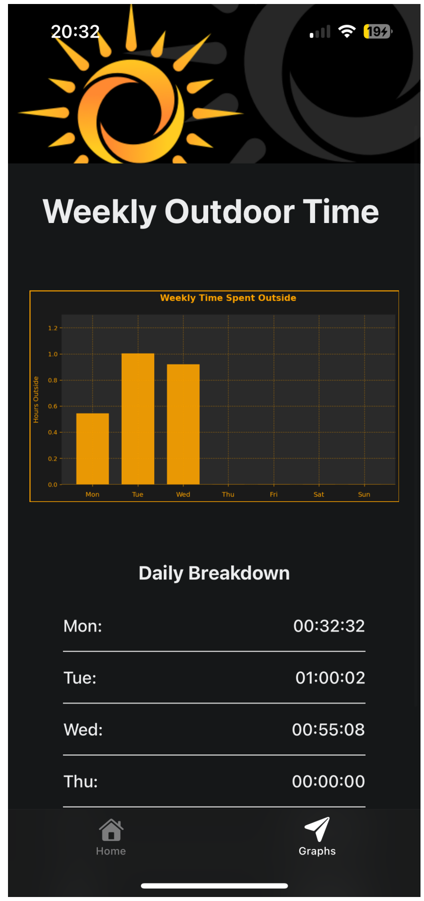


Figure 11: Weekly progress visualisation

5.1.10 App Design and look

The final app interface was designed with a focus on clarity, usability, and aesthetic consistency. The primary goal was to create a layout that delivers quick at a glance insights while also offering users the option to explore their data in more detail if desired. The main screen of the app features the Daily Visual at the top, prominently displaying the user's outdoor activity for the current day. Directly beneath the visual, three key elements are shown:

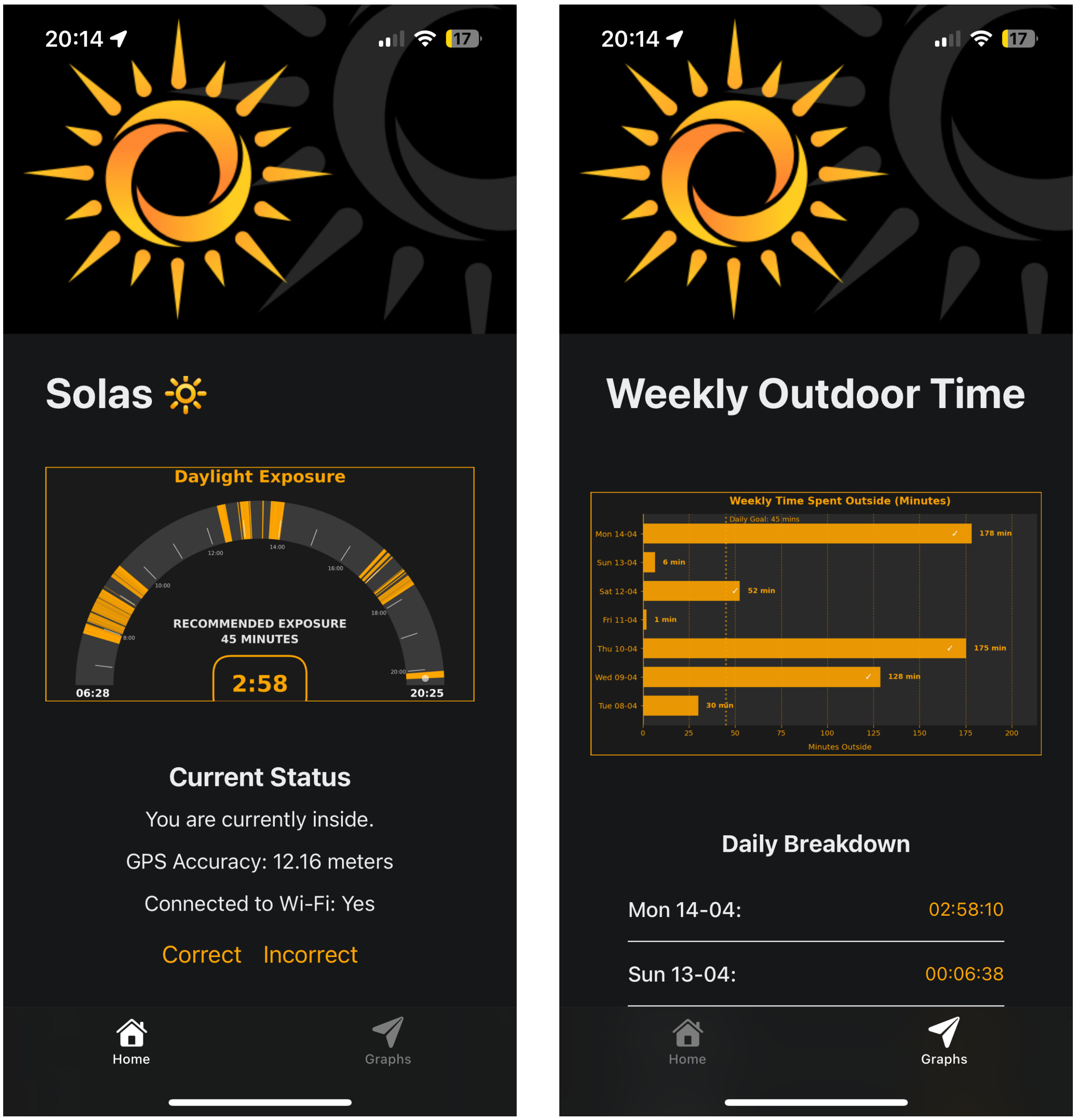
- **GPS Accuracy Indicator** – Displays the current GPS accuracy value to help users understand the confidence level of the location data.
- **WiFi Connectivity Status** – Indicates whether the user is connected to WiFi, which, as discussed earlier, affects the inside/outside classification logic.
- **User Feedback Buttons** – "Correct" and "Incorrect" buttons allow users to provide real-time feedback about the app's current location determination.

The second tab of the app contains the Weekly Visual. Directly beneath the graph, users can find a more detailed breakdown of their outdoor activity for each corresponding day. This breakdown is ordered in the same sequence as the graph and presents the data in a more precise format—hours:minutes:seconds to give users a clearer understanding of their time spent outdoors. This dual-level approach balances quick visual insights with detailed information, supporting both casual users and those who want to dive deeper into their data.

The layout was chosen to prioritize simplicity and intuitiveness. By placing the most relevant, time-sensitive data front and centre, users are immediately presented with actionable insights about their daily activity. The second tab acts as a supplementary view, giving users the ability to explore longer-term patterns without cluttering the main interface.

When it came to choosing a colour scheme, I opted for a combination of orange and black. This decision was influenced by both aesthetic and functional considerations. Orange is often associated with sunlight which is closely tied to the core goals of the app. Black, as the background colour, provides strong contrast, making the visuals easy to read while also reducing eye strain

As the visualisations became a more prominent part of the app, I decided to update the overall app design to match their look and feel. This included modifying interface elements such as the feedback buttons to align with the orange-and-black theme. To further enhance the app's presentation and usability, I commissioned a new app logo in the same colour palette. This logo not only visually aligns with the rest of the app but also contributes to a more polished and user friendly appearance. Considering visual appeal is a key factor in user retention and engagement, this step helped ensure the app is not only functional but also approachable and visually appealing.



(a) Final daily visualisation interface

(b) Final weekly progress visualisation

Figure 12: Final version of app, both tabs

5.2 Challenges

Developing this app came with a number of challenges—both technical and policy-related—that significantly influenced its final design and functionality. One of the first major obstacles was related to the method used for tracking whether a user was indoors or outdoors. The original idea was to use mobile signal strength as an indicator, but this approach had to be abandoned early on due to Apple's strict policies prohibiting access to signal strength data for privacy reasons. As a result, GPS accuracy was chosen as an alternative metric, as it was accessible within Apple's guidelines and provided a reasonable proxy for determining indoor versus outdoor status.

Another recurring challenge involved Apple's privacy policies during the app publishing process. Early versions of the app were rejected because they lacked the appropriate privacy policy declarations in the app.json configuration file. This issue became particularly problematic when background tracking functionality was introduced—something that was key to allowing users to passively collect data throughout their day. Each time this functionality was added, the builds were repeatedly rejected until the necessary privacy disclosures were properly included.

Even after meeting the policy requirements, another usability issue arose. Background tracking triggered Apple's persistent location indicator, which impacts user experience but was unavoidable under platform guidelines. This resulted in a persistent blue indicator appearing at the top of the screen whenever the app was running in the background. While this behaviour complies with Apple's transparency policies, it can be visually intrusive and discouraging for users, especially when the app is only checking GPS accuracy at five-minute intervals. Unfortunately, this interval is still considered too frequent under Apple's guidelines, meaning the indicator remains visible at all times during background activity.

Despite these challenges, each obstacle contributed to refining the app's design, making it more adaptable and mindful of user privacy. These experiences helped improve the app's functionality and ensure it met both platform requirements and user needs.

5.3 Accuracy

During the evaluation phase of the project, it became clear that achieving reliable accuracy in detecting whether a user was indoors or outdoors was one of the most challenging aspects. Several iterations and refinements were made to improve the system's accuracy without compromising performance or user experience. The first significant improvement involved the introduction of a WiFi connectivity check. Early feedback and testing revealed that users connected to WiFi were often inaccurately flagged as being outdoors. However, in most real-world scenarios, WiFi connectivity strongly correlates with being indoors. By integrating this check, the app could more confidently classify users as indoors whenever they were connected to a WiFi network, thereby increasing reliability.

Initially, I set the GPS accuracy threshold to 15 meters, which provided a reasonable balance between precision and flexibility. For a period, this configuration performed well. However, once users began to see their outdoor activity visualised within the app, it became evident that some outdoor time was not being accurately captured. In response to this, the threshold was increased slightly to 18 meters to account for this issue. Despite the adjustment, further testing uncovered more complex challenges. Specifically, GPS readings for some indoor and outdoor locations were overlapping in their accuracy values, particularly in certain areas around my local environment. This overlap made it difficult for the system to consistently differentiate between indoor and outdoor contexts.

The GPS accuracy data was being managed using a library that offered three accuracy tiers Balanced, High, and Best. Initially, I opted for the Balanced setting to maintain a good trade-off between accuracy and battery consumption. However, after observing continued inaccuracies, I switched to the Best accuracy tier, which offers the highest possible precision. In conjunction with this change, I also adjusted the GPS threshold to 10 meters, narrowing the margin of error and reducing overlap between indoor and outdoor readings. While the Best tier is typically more demanding in terms of power usage, I was fortunate to find that in practice, this change did not have a noticeable impact on the app's overall energy consumption. These combined changes WiFi detection, threshold tuning, and switching to the highest GPS accuracy tier resulted in a significantly more reliable classification system.

6 Results/Evaluation

6.1 Evaluation Metrics

To properly assess the efficacy and success of the Daylight Personalisation Tracker, I used four main evaluation metrics, drawn from the objectives outlined in the Abstract:

- Functional Accuracy: To verify whether the app could accurately track outdoor daylight exposure using GPS accuracy and WeatherAPI data.
- Efficacy of Visual Displays: To assess whether the app's visualisations (Daily Arch and Weekly Bar Chart) helped users better understand their daylight habits. This was evaluated through a survey and structured feedback during and after testing.
- Validity of Exposure Tracking: To ensure that the outdoor tracking results accurately reflected real world user experiences
- Usability: To evaluate whether the app interface was easy to navigate, understand, and engage with.

These metrics were chosen because they directly reflect the project's goals. Ensuring high performance across these areas would indicate that the solution is practical, reliable, and capable of promoting healthier daylight exposure habits.

6.2 User Testing During Development

Once a working version of the app was uploaded to TestFlight, I was able to begin the process of user testing with a small group made up of friends and family. These testers were people I interacted with regularly, which allowed for frequent, informal feedback. Unlike the passive sensing approach in [1], our active feedback loop during development allowed for real time refinement of detection algorithms based on user reported edge cases. While my own testing at home had been useful for catching major bugs and confirming basic functionality, external testers were able to highlight problems that I hadn't considered. For example, they encountered issues in different environments such as while commuting or in dense urban areas that revealed limitations in GPS accuracy and detection logic that wouldn't have surfaced from testing in a single, static location.[14, 20]

Testers also provided feedback on usability aspects, such as how intuitive the visuals were, how clearly the data was presented, and whether the interface made sense at a glance.[9] This kind of feedback helped refine both the functionality and the design of the app. Furthermore, real-world testing in different routines and daily schedules gave me better insight into how the app performed under varying conditions for instance, indoors vs outdoors, stationary vs mobile, and across different times of day. In summary, user testing throughout the development process was invaluable in shaping the final version of the app. It revealed practical issues that might not have been caught in controlled testing alone and directly influenced several improvements in detection accuracy, visual design, and user experience.

6.3 Final Evaluation of Completed App

While there is always room for improvement, I reached a stage in development where I was confident in the core functionality, accuracy, and usability of the app. With this stable version, I began the final evaluation phase. I released one last build through TestFlight and asked a group of testers to use the app over the course of a week, paying close attention to any abnormalities or inconsistencies. Testers were instructed to specifically monitor key areas such as:

- Performance: Whether any noticeable battery drain occurred as a result of background GPS tracking, and whether the app maintained smooth operation during typical use.
- Feedback (Visualisation Effectiveness): The accuracy, clarity, and responsiveness of the daily visual feedback, including whether users felt the visualisations effectively represented their real-world outdoor activity.
- Usability: The overall user experience, including how intuitive and easy the interface was to navigate, and how responsive the app was during interaction.
- Accuracy of Indoor/Outdoor Detection: Whether the app reliably detected when users were indoors or outdoors, and how closely this matched their actual environment throughout daily activities.

After the one-week testing period, I distributed a survey to collect structured feedback. This survey captured both quantitative responses and open-ended comments to get a complete picture of the app's performance and user experience. Specifically, the survey asked testers to evaluate:

- The accuracy of the app's detection of indoor versus outdoor status.
- The usability and clarity of the app's interface and visualizations.
- The impact on device battery life caused by background tracking.
- Whether the app motivated them to spend more time outdoors (user engagement).
- Suggestions for future improvements to functionality, design, or features.

This structured feedback helped identify strengths, such as the reliability of detection and the intuitive design, as well as areas for improvement, such as better handling of detection during transport.

6.3.1 Detection Accuracy and Reliability

Feedback from testers showed that the app was generally successful when determining if users were inside/outside. Almost all testers stated that the detection was correct most of the time however one tester responded saying that there is issues with the detection when it comes to transport, a known limitation of GPS-only systems without inertial sensor integration.[11] I myself also noted that when travelling the app detects users as outside despite being in a vehicle. With such positive results overall its clear that updating to Best was the correct dissension.

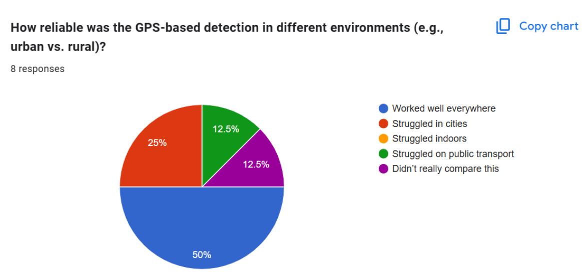


Figure 13: GPS Reliability

6.3.2 Interface and Usability

The final app interface was well received by testers. Most users found the layout intuitive and easy to navigate. The use of an orange and black colour scheme was particularly well received, with all users noting that it was visually appealing and helped reduce eye strain. Testers appreciated the structure of the app, particularly the division between the daily arch view and the weekly bar chart.

6.3.3 Battery Impact

When it came to battery impact feedback was mixed. Most users found the app impacted their battery only moderately with only a few saying the drain was sever. There was one user who didn't notice the app effecting their phone battery at all. These results are properly varied due to each users phone battery health with those with poor battery health noticing it more then tester with good battery health. Although battery performance did not negatively affect most users, it is an area that could benefit from further optimisation.

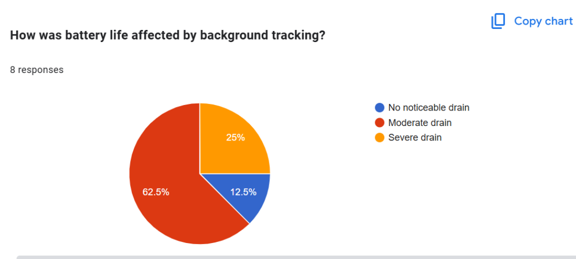


Figure 14: Battery Impact

6.3.4 User Engagement

Testers were consistently engaged with the app, with all participants checking it at least once per day, and several checking multiple times. The visualisation of daylight exposure appeared to be a motivating factor, supporting evidence that data visualisation drives behaviour change, with most users reporting that it encouraged them to go outside more often.[9, 18] While most users said they were slightly more motivated, one reported a significant increase in outdoor activity, showing the app's potential to positively influence behaviour through visualisation.

6.3.5 Suggested Improvements

Within the survey I left an open ended question for testers to give me suggested improvements to the app for future updates if I wanted to advance it more. Some of these improvements were already advanced goals that I never managed to implement. These included rewards system to encourage further use, notifications if you haven't reached the recommended amount of sunlight before a certain time in the day, manual input of time spent outdoors, e.g. if phone is dead and finally some sort of indicator showing above or below my usual averages. One particularly insightful suggestion that I hadn't previously considered was adding the option to manually enter your hours in cases where the app fails to detect them accurately. Additionally some minor improvements were requested such as trying to improve detection when on public transport and increasing font size.

6.3.6 Overall Reception

The final user feedback was overwhelmingly positive. Every tester indicated they would recommend the app to others. Despite my initial concern that the always-visible location indicator might be a major issue, almost all users were either unbothered by it or barely noticed it at all. Comments praised the concept, the clean and simple interface, and the motivational value of the visual feedback system. The app was seen as a helpful tool for improving awareness of time spent outdoors, and the final version achieved the goal of being both functional and user friendly.

6.4 Core and Advanced Goals

6.4.1 Core Goals

All of the core goals set at the beginning of the project were successfully completed. These formed the foundation of the app and ensured it delivered on its primary purpose to help users monitor and reflect on their time spent in daylight.

6.4.2 Advanced Goals

Although the advanced goals were not completed during this project phase, they remain valid and achievable extensions of the current system. The focus throughout the project was on delivering a robust, accurate, and user-friendly core experience. Given the time constraints and the complexity involved in some of the advanced features, such as notification systems, these were de-prioritised in favour of refining the core functionality.

However, the project did exceed the original scope in several key areas. Notably, the app was successfully deployed via TestFlight, enabling real world iterative testing with users. This allowed for faster feedback loops, refinement of the app's features, and improvements to accuracy and usability that evolved over time — going beyond the initial expectation of a single final build.

The app is now in a strong position for future development, and these advanced goals along with the user suggestions provide a clear roadmap for potential enhancements that would further personalise and improve the app.

6.5 Limitations & Observations

The app successfully full-fills its core functionality, accurately tracking outdoor activity and presenting this information through visuals. It performs reliably under normal usage conditions and meets the primary goals set for the project. However, as discussed throughout this evaluation, the app is not without its limitations. These limitations, while not critical to the app's overall functionality, do impact its precision and potential to scale in future iterations.

6.5.1 GPS and Detection Accuracy

While the app's detection accuracy is generally strong, as highlighted earlier, there are still several notable limitations that affect its precision. The most significant issue is its tendency to misclassify users as being outside while they are travelling in a vehicle. Since GPS does not inherently differentiate between being physically outdoors and simply moving, this leads to occasional false positives during commutes or public transport use. Another core limitation is the app's overall approach to measuring light exposure. While it operates under the assumption that being outdoors correlates with sufficient daylight exposure, this method is inherently indirect and not always reliable, as observed in light exposure measurement studies.[16] For example, users could be outdoors but in shaded or overcast environments, or indoors near large windows with ample natural light both of which the app may mis-classify.

Additionally, the app only performs location checks every five minutes to conserve battery life, a common compromise between accuracy and battery life which means short periods of outdoor exposure may not always be recorded.[15] Though less frequent than [1] continuous sensing ideal, our interval based tracking balances utility with battery constraints a trade off for real world integration. This interval-based detection was a design trade-off intended to balance power efficiency with reasonable tracking accuracy. If energy constraints were not a concern, a more advanced system could be developed. This might include integrating additional data points such as ambient light sensor readings, movement patterns, or even smartwatch integration to gain a more comprehensive picture of a user's light exposure throughout the day.

6.5.2 Battery and Performance

Although user feedback indicated that the battery drain was generally moderate and acceptable for daily use, it remains a noteworthy concern. Ideally, a background tracking app such as this should have minimal to no noticeable impact on battery performance. Given that the app periodically uses GPS at high accuracy and keeps track of user location every five minutes, some power consumption is unavoidable. However, optimising this further would be necessary for long term use.

A significant contributor to the persistent battery usage stems from Apple's privacy and transparency policies. Specifically, when an iOS app requests frequent location updates, the system displays a location indicator in the status bar, a necessary trade-off for transparent data collection.[3] This not only signals to the user that location services are being used but also may give the impression that the app is always active, even when it is running efficiently in the background. This visual cue could lead to concerns about privacy or drain, even if the actual usage is minimal.

Ultimately, while the app performs well within acceptable limits, optimizing for performance and battery efficiency remains a critical area for refinement if the app were to be released to a broader public audience.

6.5.3 Platform and Evaluation Constraints

At this stage, the app has only been made available through Apple TestFlight, which inherently restricted the testing process to iOS users, highlighting the need for cross-platform validation.[5] This limitation excluded Android users entirely, reducing the diversity of both the devices used and the user experiences reported. Testing across multiple platforms would be crucial in understanding how different hardware and operating system behaviours impact the app's performance, particularly regarding GPS accuracy, background services, and battery efficiency. In addition to platform constraints, the test group primarily consisted of friends and family members. While this group provided consistent feedback throughout the development process, the familiarity between developer and testers may have introduced bias, whether consciously or unconsciously into their survey responses.

Another constraint is the limited duration of the final testing period. Although some users engaged with earlier builds of the app throughout its development, the final evaluation of the completed app was conducted over just a one week period. This short time frame made it difficult to evaluate the app's long term performance, consistency across varying weather and light conditions, and potential fatigue in user engagement. To achieve a more robust and representative evaluation, future testing phases should include a wider range of users across platforms. A longer evaluation period ideally a month or more would also offer deeper insights into user behaviour, sustained engagement, and more subtle performance or usability issues that might not be evident during shorter trials.

7 Future Work

There are several possible directions for future development of the app, both in terms of accessibility and functionality. One of the main goals would be to fully publish the app on the App Store and also make it available to Android users via the Google Play Store. Expanding to both platforms would allow a wider range of people to benefit from tracking their daylight exposure and improving their health.[5, 11] It would also increase the diversity and volume of data collected, which could be useful for future studies on behaviour and daylight exposure trends.

In terms of functionality, one area that could be improved is how the app determines whether a user is indoors or outdoors. At the moment, it relies primarily on GPS accuracy. While this works in many cases, it's not always reliable especially in urban areas. In the future, the app could incorporate additional methods for determining location status.[19, 20] For example, it could use the phone's built-in light sensors to detect ambient brightness, or even use map data (based on longitude and latitude) to cross reference known buildings and open spaces. Combining multiple signals would allow for more accurate and robust detection.

Another important area that needs improvement is background tracking. Currently, due to Apple's policies, the app shows a persistent blue bar at the top of the screen when running in the background. While this is expected behaviour, it can be distracting or off putting for users. Future versions of the app would need to find a way to handle location tracking in a way that complies with Apple's guidelines while offering a better user experience—possibly through optimisations in how and when tracking occurs.[15, 3]

In addition to technical improvements, there's also room for adding educational and motivational features. For example, the app could include interesting facts about daylight and its benefits such as its impact on circadian rhythms, sleep quality, mood, and vitamin D levels.[2, 8] These small bits of information could help users better understand why the app is encouraging them to get outside.

Lastly, referencing the advanced goals, for future versions could include game features. Users could earn badges or rewards for meeting recommended daily outdoor time consistently over a number of days.[1, 13] The app could also provide smart notifications—such as suggesting the best times to go outside based on upcoming weather and daylight hours, or warning users about poor conditions.

These improvements would enhance the app's accuracy, usability, and overall appeal, making it more intuitive and reliable for users.[18, 4] By offering clearer insights, smarter tracking, and a more engaging experience, the app would be better positioned to support lasting behaviour changes and encourage users to adopt healthier daily routines centred around increased daylight exposure.

8 Conclusion

This project set out to develop a smartphone based tool for tracking outdoor daylight exposure using GPS and weather data, with the goal of encouraging healthier circadian rhythms through increased awareness and behavioural change. The app monitors users activity by using GPS accuracy to infer whether the user is outdoors during daylight hours. It then visualises this data through two main views a daily arc that maps activity throughout the day, and a weekly bar graph showing trends over the past couple days. Based on personal testing and user feedback, the app is largely successful in accurately identifying outdoor activity and presenting the information in a format that is both efficient and visually engaging. The project has successfully achieved its core goals of usability, user satisfaction, and performance. While the core functionality works well, several limitations remain including minor battery drain and the constant display of location tracking due to Apple's policy on background GPS usage.

Despite these challenges, the app is now in a state ready for publication on the Apple App Store, with clear opportunities for future features such as reminders, weather alerts, and progress rewards to further promote healthy habits. By bridging gaps between mobile technology and circadian science, this project lays groundwork for accessible, privacy focused health tools empowering users to harness natural light for wellbeing.

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