Designing a Mobile Application to Promote Better Sleep Habits Using NFC-Assisted Routines

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Abstract

Background

With an increasing prevalence of sleep disorders and the continued impact of mobile phone overuse on sleep quality, there is a need for technological interventions that effectively promote sleep health. Utilising the potential for mobile devices to better promote sleep habits, whilst understanding and mitigating the negative impact those same devices can have on sleep hygiene, this study aimed to implement a solution that balances these two ideas whilst implementing a novel approach of Near-Field Communication (NFC) assisted sleep routines.

Methods

The project adopted a user-centric approach to design, combining a comprehensive literature review, user requirements survey and extended-use user testing. The research explored the current understanding of sleep hygiene and health, habit formation and routines, the effects of mobile devices on sleep and routines, and NFC technology as a tool for behaviour change. The online user survey was conducted on 33 participants and explored their existing routines, mobile phone usage and interest in change. Of the 33 participants 6 were then evaluated using a prototype application across 6 days and were surveyed and interviewed to understand their experience.

Results

The prototype application showed promising potential for improving sleep routines, and moreover NFC technology demonstrated both the feasibility and potential effectiveness to promote better sleep habits. The user-centric approach resulted in an application that was both well received by the participants and had a positive impact on their sleep hygiene. In addition, the importance of designing interventions that consider individuals sleep patterns and behaviours was highlighted.

Conclusions

NFC technology has a promising role when integrated into the design of behaviour change applications, specifically those targeting better sleep routines. A mobile application when designed with research based and user-led requirements, can be an effective tool in improving sleep hygiene. Future interventions should look to individualise solutions further to provide personalised and adaptive sleep hygiene tools, which can cater for a diverse set of sleep patterns and preferences.

Acknowledgement

I would like to thank Dr. Katarzyna Stawarz for the continued support and guidance throughout this project as well as the freedom to explore my interests within this subject area. I would also like to thank my friends and family for the continual support throughout my academic journey.

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Introduction

There has been a worrying trend of an increased prevalence of sleep-related disorders in recent years, particularly exacerbated by the Covid-19 pandemic. Many behavioural changes happened during this period, the long-term effects of which have not fully been understood (Gupta et al. 2020). The importance of sleep hygiene and the significant impact it has on both physical and mental wellbeing is clear, however despite this knowledge, increased use of technology and a modern lifestyle continues to negatively impact sleep quality (Li et al. 2020).

Mobile device usage, particularly prior to sleep has been identified as a key contributor to overall sleep quality (Rafique et al. 2020). Mobile phone addiction has also been shown to have a negative impact on sleep quality (Sahin et al. 2013), and with an increased prevalence in younger people it is a worrying trend which needs to be addressed (Sahu et al. 2019). Finding ways to reduce mobile phone usage both prior to sleep and near the bed provides a potential for increasing sleep hygiene and consequently overall health.

Previous research into habit formation has shown that there is a disconnect between mobile applications described as habit forming and successful long term behavioural change (Stawarz et al. 2015). This contradiction is particularly acute in apps that promote habit formation around sleep, as the very device intended to improve upon sleep hygiene is also contributing to poorer sleep.

Therefore, this project aims to approach this problem by developing an application which can promote improved sleep hygiene, whilst considering the importance of the worrying trend of mobile phone overuse. The goal is to produce an application which can harness the habitual nature of mobile phone use in a way that enhances sleep quality as opposed to reduces it.

Aim and Objectives

The primary aim of this project is to develop a prototype mobile application to help promote the formation of better sleep routines. The application will utilise Near-Field Communication (NFC) technology and evidence-based features, to deliver clear and actionable routines that will facilitate the formation of improved sleep habits.

To achieve the aim mentioned above, several objectives have been created:

- Comprehensive research review into current science and technologies:
    - Literature review of habit formation, behavioural routines, and sleep hygiene.
    - Review of NFC technology and current research around evidence-based applications habit applications.
- Conduct user requirement analysis:
    - Understand existing routines and behaviours prior to sleeping, specifically with the use of mobile phones, through an online survey.
    - Combine the research gathered to define a set of evidence backed user requirements for the application.
- Develop a prototype application:
    - Create an MVP mobile application.
    - Design and implement a feature set for the application.
    - Integrate NFC technology into the application.
    - Test and iterate over the prototype to validate the useability.
- User testing and evaluation:
    - Conduct a workshop involving extended use of the application to understand its effectiveness.
    - Review the effectiveness of using NFC-assisted routines in promoting habit formation.
    - Refine the application based of the feedback given, if possible, or incorporate it into future development.
- Documentation:
    - Document the development of the application and any findings from the process and research.
    - Refine those findings into a final report which summarises the research.

Through both the aim and objectives this project seeks to make a viable contribution to the selection of applications promoted towards behaviour and routine improvement. As well as further the research into novel approaches for promoting habit formation.

Approach

When deciding on the research, studies and testing it was important that the end user of the application was at the forefront of those decisions. Ultimately the final Prototype application needed to be one that was easy to use and effective in its purpose, so a human-centric approach was necessary for achieving this.

While NFC technology was at the centre of the application design it was important that the approach taken wasn't a purely technological exercise and the idea of integrating NFC-assisted routines into the application didn't overwhelm the rest of the project.

To achieve both goals the project was broken down into three phases:

Pre-design

During this phase it was important to develop a deep understanding of the science behind habit formation and behaviour, existing technologies and their uses, as well as gain a robust set of user requirements to inform the application design. The chosen approach to achieve this was:

- **Literature Review** – Due to the extensive research into habit formation applications and their efficacy, the focus of the pre-design phase involved a thorough evaluation of the existing literature in this area. This approach aimed to consolidate the conclusions of well-regarded studies to form a basis for further design exploration.
- **User Survey** - This survey aimed to capture specific user requirements and attitudes concerning the intersection of sleep habits and mobile phone usage. By combining the user feedback with the academic literature, this project was able to create a more nuanced understanding of how mobile technology can be effectively employed to improve sleep habits.

Design

- **User Stories and Requirements** – This was the final step before the building of the prototype took place which will be detailed in a later chapter. It involved creating a roadmap based off the gathered requirements and literature analysis. The requirements were broken down into issues, and a Jira board (Atlassian 2023) was created to manage the development process.

Development

- **Minimum Viable Product (MVP) application** – Due to the lack of experience in developing a mobile application through to production, the first step of developing a production ready MVP mobile application was essential. This provided confidence that the extended-use study would be viable.
- **Iterative Prototype** – Upon establishing the MVP an iterative approach to design was taken to introduce the most essential features first and build the application out using this approach. Across 4 weeklong sprints the workload was broken down and individual issues created to enable the completion of the stated designs.

Testing and User Analysis

- **Extended-Use Study –** The application was designed with an aim to assess its potential for habit formation and behaviour change. Therefore, it was important that a longer study was performed at the end of the design phase. Whilst a shorter usability study would have provided some insight into the design choices, to gain detailed insight into how effective the application was at altering behaviour a longer study was needed. Due to time constraints restricting the length of the study an extended-use study across 6 days was used. This study would provide the basis for the analysis and ultimate effectiveness of the project.

Literature Review – Sleep, Habits and Technology

This literature review aims to explore the interplay between sleep, habits, and technology. The impact of sleep and behaviour on one another has been well documented. (Curcio et al. 2006) described the relationship sleep has on behaviour and learning, and there has been ever increasing research into both the positive and negative effects of sleep. Of interest was whether sleep plays a role in habit formation, and whilst it influences many neural processes including memory consolidation it is not clear whether there is a direct influence on the mechanism of habit formation (Lazarus et al. 2013). Due to the continuing development of wearable technology and mobile devices, the interactions between those technologies and sleep, both in a positive and negative way continues to expand. There has also been a significant increase in how technology can be used to alter behaviour and introduce new habits (Bruni et al. 2015).

Sleep Hygiene and Health

Sleep is an essential human process which has a wide range of positive benefits, both for physiological health and cognitive wellbeing (Worley 2018). Of particular interest is the positive role sleep plays in the learning and formation of new habits (Walker and Stickgold 2004).

Sleep hygiene as is known today was originally defined by (Hauri 1991) in 1977 when outlining a set of rules intended to address individuals suffering from insomnia. Whilst some of these rules need updating to reflect the different technological world we currently have, many of them still apply today. For example, reducing distraction before bed, particularly noise and purposeful sleep and wake times. Since that point there has been myriad research into the positive effects of sleep and the need for good sleep hygiene. Sleep has been shown to improve memory consolidation, improve recovery, increase motor and cognitive function as well as reduce stress. The benefits sleep provides are not trivial and are an important aspect of a healthy lifestyle (Walker 2017).

In contrast there has been less research into the negative effects of poor sleep health, however that has changed in recent years due to the changes brought about by the Covid-19 pandemic (Alimoradi et al. 2021). These concerns are warranted as the impact poor sleep has on health is just as significant as the positive effects. Apart from the immediate negative effect sleep has on cognitive performance, weakened immune response, disruptions to glucose and appetite regulation, there is also a problem with chronic sleep problems leading to other chronic psychological conditions (Chokroverty 2010). (Johnson et al. 2006) identified potential links between insomnia, depression, and anxiety, with anxiety becoming a precursor to insomnia and insomnia becoming a precursor to depression. (Hertenstein et al. 2019) also showed a key link between insomnia and other psychological disorders.

In recent years there has been a noticeable increase in the research and information around the effects of poor sleep hygiene and the subsequent negative health impacts. A quick search of “sleep pandemic” reveals a vast literature detailing the concerns those years in lockdown had on sleep hygiene around the world. A meta-analysis on sleep problems

performed during the first half of the covid-19 pandemic revealed a prevalence of around 40% across 54,231 participants (Jahrami et al. 2021). Whilst the negative effects of poor sleep are concerning and whilst there has been increasing research into this area it remains an area often ignored (Alfonsi et al. 2021).

Sleep is one of the most important factors when it comes to health and one that can be overlooked when people make a change towards healthier living (Leger 1994). Often when deciding what to do regarding health, people don't make effective positive decisions (Ram et al. 2010). The science around sleep hygiene is robust however in everyday life it can be difficult to implement. Sleep is often neglected in favour of other things, and this is ever increasing with the advancements in technology that have invaded the bedroom.

Habits and Routines

Habits and routines are terms which often get used interchangeably when referring to automatic or repetitive actions, however, it is important to be able to separate them and understand the influence each has on behaviour. A habit is an individual repeated action which is often performed unconsciously, whereas a routine refers to a series of habits or actions that are performed regularly and often in a specific order (Southerton 2013).

Habit formation is the process of taking an action or activity and turning it into an unconscious and automatic behaviour. This is a complex and difficult process which can be disrupted and interrupted as the time taken can vary considerably. (Lally et al. 2010) showed it can take between 18 to 254 days for habit formation to occur with an average of around 66 days.

Figure 1 provides an overview of the stages required in habit formation:

- Stage 1 requires conscious thought and decision to initiate a new behaviour.
- Stage 2 involves planning and adjusting of resources both internally and externally through adjustments to the environment.
- Stage 3a requires continued motivation and consistent repeatable action.
- Stage 3b is more automatic and involves the anchoring of a habit to a specific cue which over time becomes a non-conscious process.

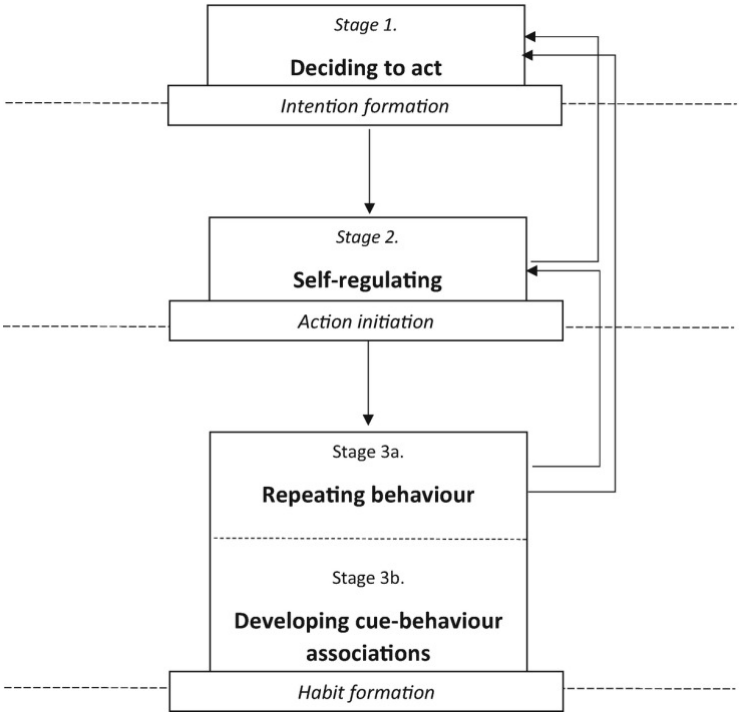


Figure 1: (Gardner and lally 2018) A holistic view of the stages of habit formation.

As shown in Figure 1 a person may move back a stage for several reasons, for example a lack of motivation. The behaviour may also span more than one stage, particularly 3b defined by cue-behaviour associations which needs to be developed jointly with 3a.

The idea of triggers and cues for habits is of particular interest in this project. Habit triggers and if/then approaches to habit formation have been shown to be effective in changing behaviour (Stawarz et al 2015), as well as the chaining together of habits and triggers to link multiple habits (Judah et al. 2013). Specifically, the use of visual based cues in habit formation has been shown to have a strong effect on the formation of a new habit (Khan et al. 2021). Goal setting is another key area to look at when understanding habit formation. There is evidence that goal setting can help improve a person's ability to create new habits (Peng et al. 2021). However, as described habit formation requires both conscious and unconscious processes, habits form when goal setting (a conscious process) becomes less prominent (Carden and Wood 2018).

An area emerging more recently which requires attention is that of context and individuality in habit formation (Zhang et al. 2016). However Individualising habit formation is a complex problem which still has several difficulties including behavioural understanding, contextual awareness, and mood recognition (Pinder et al. 2018).

Mobile Devices and Sleep Habit Formation

Technology, specifically mobile phone use is often associated with worse sleep quality, however, there is potential to use technology to improve on sleep behaviours (Yang et al. 2020). Smart phones and digital devices are often associated with poor sleep quality, and as such are not looked at as often for being the solution to the problem (Rafique et al. 2020).

Most solutions involve removing the device completely or limiting the amount the device is used (Zhang et al. 2022), there is room to explore more intentional use of the device around sleep behaviour.

Many habit-focussed apps present in mobile apps stores primarily implement features such as reminders, habit tracking and streaks. These features are reviewed positively in app stores but don't have the scientific foundation to effectively form new habits. While these features provide some benefit through reinforcing repetition, there is also a negative effect on habit formation due to the introduction of a dependency on the application itself (Renfree et al. 2016). Despite this, the concept of combining repetition with environmental cues in a mobile application has been proposed as a potential method for inducing behavioural change. According to (Carden and Wood 2018), this approach, alongside modifications in the user's environment to minimize distractions and enhance the accessibility of habit triggers, could effectively facilitate the development of positive habits.

Some of these apps, whilst not explicitly marketed as habit applications, make use of the mobile phones accelerometer to track sleep movement and improve sleep behaviours. However, this contradicts findings by (Rafique 2020). His research identifies the proximity of phones in bed and usage within 30 minutes of turning off the lights as major contributors to poor sleep quality. The prevalence of these apps and the current lack of understanding of their effectiveness is a concern. Users are advised to monitor and improve their sleep by having the phone close to their bed, which in turn negatively impacts their sleep hygiene. Currently there is limited research into the validity and effectiveness of these applications when compared to gold standard medical devices. Often there are large discrepancies in the accuracy of data collected, particularly when identifying awake times and disrupted sleep (Halson 2019).

Near Field Communication (NFC) Technology

NFC is a short-range wireless communication technology that was developed in the early 2000's (NFC Forum 2004). Since then, it has become a widely used technology most notably in wireless payment transaction used by mobile smart phones. In recent years mobile payments have been an increasing trend looking to replace physical currency (Liébana-Cabanillas et al. 2019).

NDEF is a standardized data format used in NFC, it ensures compatibility, efficiency, and interoperability. Figure 2 shows the structure of a single NDEF record. The record is comprised of a header containing the metadata, and the payload itself which contains the content of the message. Without going into the detail of the whole data structure it is important to know that NDEF payloads are small, and transactions happen quickly by tapping two NFC compatible objects together. The size of an NFC data exchange is limited by the speed of the transaction, the time the two devices are close together and the capacity of the NFC enabled object.

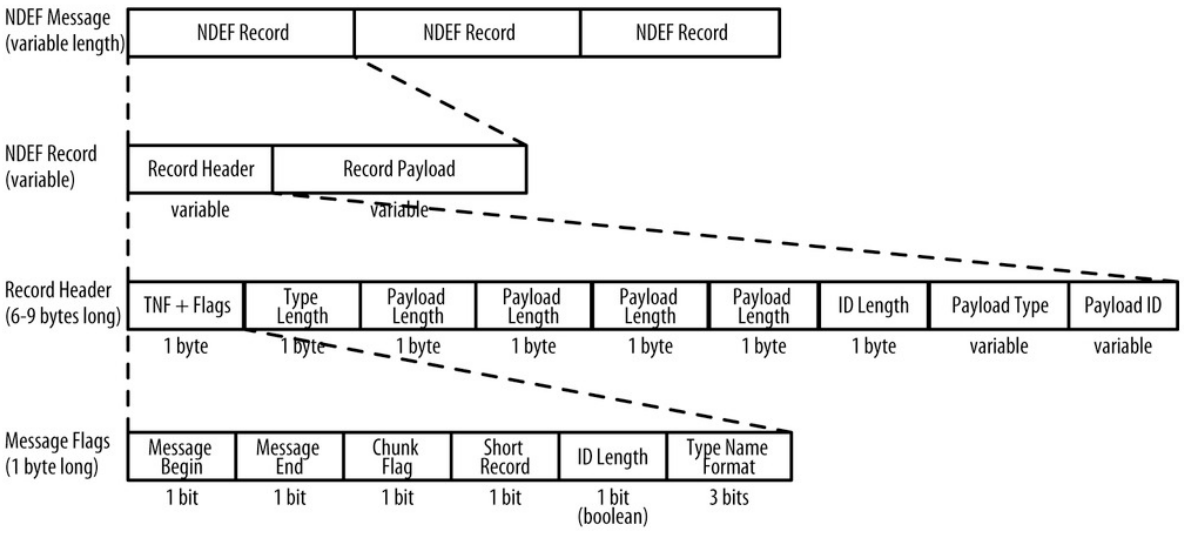


Figure 2: (O'Reilly Media, Inc. 2023) Structure of Near Field Communication Data Exchange Format (NDEF)

NFC tags are small smart objects, which are capable of wireless communication and storing a data payload without the need for an internal battery. Figure 3 shows examples of different NFC tags compared to objects such as shirt buttons and coins. The communication NFC tags use is through a 13.56MHz radio frequency with a range of around 2cm (NFC Forum 2023). This makes them extremely versatile and flexible in their application and the limited range provides benefits such as precision and limited accidental connections, though obviously has its drawbacks in that the user is required to be close to perform the transaction, limiting its use cases.

Figure 3: Example of NFC tags with size comparisons (NFC Forum 2023).

When discussing NFC technology, it is important to compare its use cases to a similar technology, QR-Codes. QR codes use a mobile phone camera to read an image and retrieve the data stored. Both QR codes and NFC have a lot of similar function with the main benefit of QR codes being they are cheap and easy to produce in comparison to NFC tags. However, the precision and accuracy of NFC tags was the ultimate deciding factor when approaching this project. QR codes are required to be well illuminated and visible to be scanned, in contrast NFC tags can be scanned in darkness and are not required to be visible (Deliyannis 2012). As this project is concerned with improving sleep habits the use case of scanning the tags in low light situations ultimately ruled out QR codes. The flexibility and versatility of the NDEF data structure also contributed to the decision.

Through this literature we have seen the importance of sleep and the worrying trend of mobile device overuse and sleep disorders. We have understood the mechanisms of habit formation and routine development as well as how mobile applications often don't implement features which support this. We have explored the technology of NFC and understood the reason it was chosen over other technologies, later in this paper this will be expanded on to provide a more detailed understanding of why this technology was chosen based on the user requirements and habit formation research.

User Requirement Analysis

Survey

Through the previous chapters we have understood the potential for mobile applications to inform routines and behaviours, as well as explored the efficacy of using NFC technology to promote habit formation. As habit formation and routines are very specifically linked to an individual (Zhang et al. 2016) and after exploring current research into individualising habit formation, it was important to involve the end users in the early design and requirements gathering of the prototype.

Methodology

The survey was hosted online for ten days and consisted of seven questions in total, the details of the survey questions are shown in Appendix A. The survey was intentionally designed to be quick and easy to answer to maximise the number of participants, as often long surveys can be a barrier to entry for a participant (Galesic and Bosnjak 2009). Questions within the survey were short and simple to answer reducing the time a participant spends thinking about a question, which could have potential negative effects on the quality of answers provided, whilst still gathering enough useful information to be able to convert into requirements for the prototype (Kost and Rosa 2018). Prior to beginning the survey, all participants were presented with a consent form detailing the research aims, voluntary nature of participation, and data storage protocols. Respondents needed to confirm their understanding and agreement to each point before proceeding to the main survey questions. The survey targeted participants over the age of 18 who were recruited through social media posts, of which 33 participated in the survey. To ensure data privacy and ethical standards, the survey was granted a favourable opinion by the School of Computer Science and Informatics Ethics Committee at Cardiff University.

The survey was broken down into three main sections each with one to two questions:

- Pre-sleep routines
- Mobile phone usage
- Interest in improvement

Results and Analysis

Pre-sleep routines

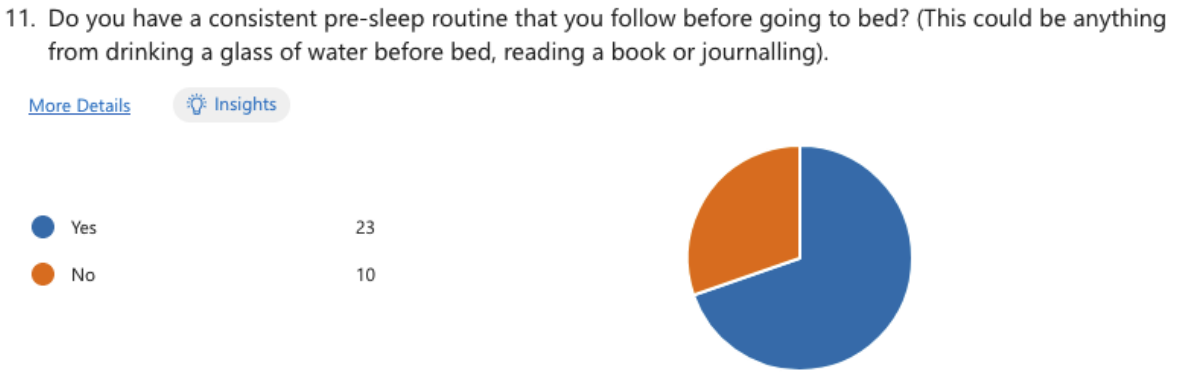


Figure 4: Results from question 11 of user survey.

An important area to understand was whether the participants currently had a routine they followed prior to going to sleep. Through understanding what participants already did prior to going to sleep it would help to inform how useful the NFC technology would be in enhancing or building upon any pre-existent routines. Of the 33 participants 70% answer yes to having a current pre-sleep routine. However, of those who answered yes, the details of their routines varied considerably. The question asked to the participants was intentionally vague to try to capture as wide a range of routine as possible and not dissuade anyone from putting down a simple routine such as drinking a glass of water. Interestingly there were still 10 participants who either felt they didn't consistently do anything before falling asleep or weren't aware of a routine they currently had. This aligns with research showing that often routines are subconscious, and the lack of awareness makes them even more difficult to change (Verplanken and Orbell 2022). Two of the participants who answered no, provided further details with one stating "I work late most evenings, and when project deadlines are looming, you pretty much shut your computer, lock the house and head to bed." and the other "Can't make anything stick and wake up tired". A consistent answer when participants were asked to provide further details of their existing routine was brushing teeth, this was useful in finding a consistent entry point into the sleep journey for the participants of the study described later.

Mobile Phone Usage

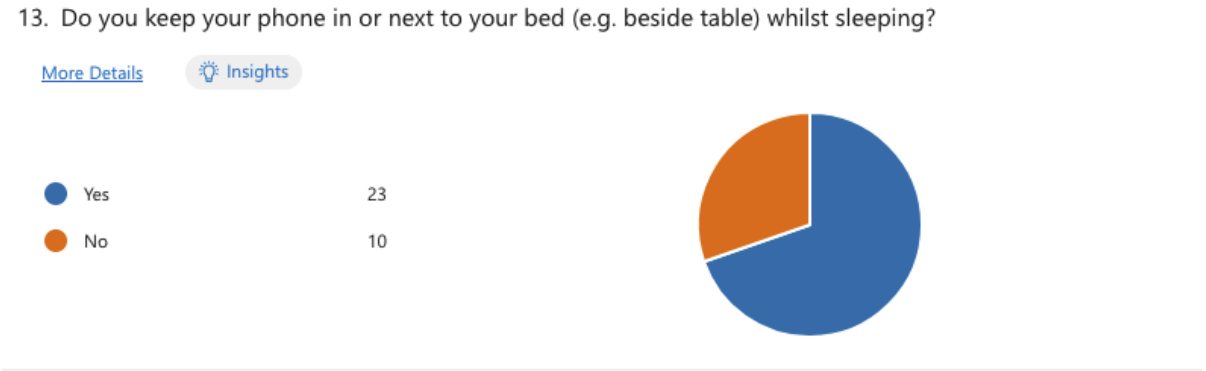


Figure 5: Results from question 13 of user survey.

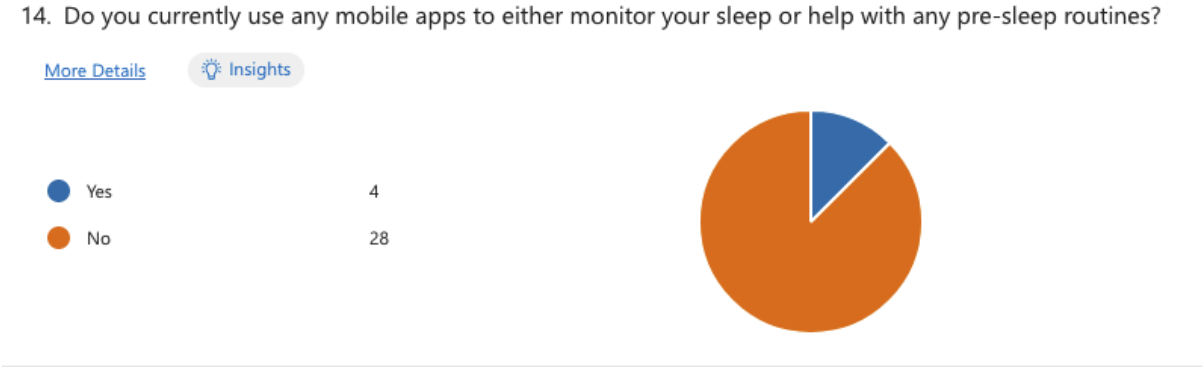


Figure 6: Results from Question 14 of user survey.

As stated earlier one of the most detrimental habits for sleep health is to have a phone within arm's reach of you while you sleep (Zhang et al. 2022). Around 70% of the respondents kept their mobile phones either in or next to their bed while sleeping. Contrasted with only 13% using that device in some way to improve their sleep habits or monitor their sleep. This was a surprising contrast as prior to running this study I was expecting the number of yes answers to both those questions to be high, due to the prevalence of several sleep monitoring apps which require the phone to be in or next to the bed. This shows there is significant gap in which mobile devices can be used to promote healthy sleep habits, as well as distancing them from a person while they sleep.

Interest in Improvement

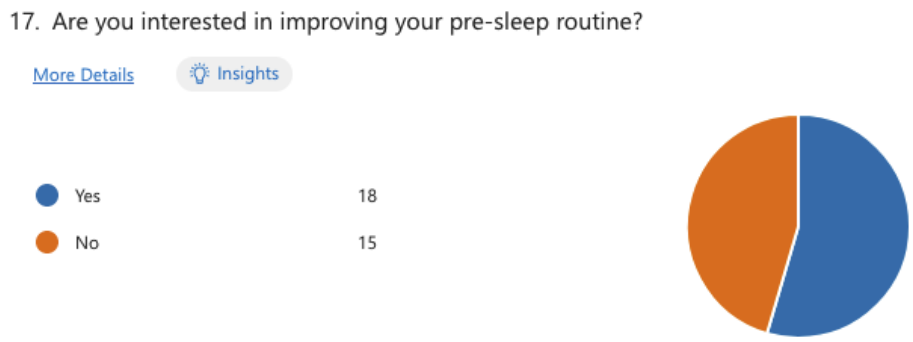


Figure 7: Results from question 17 of user survey.

Only around 55% of respondents expressed interest in improving their pre-sleep routine, whilst this shows there is a demand for improving behaviours and habits prior to going to bed, it also shows that there is a reluctance to change, creating a higher barrier for intervention. Out of those who answered no to this question some of the reasons they gave were:

- “Too busy.”
- “Had years of interrupted sleep so am used to it.”
- “Don't think I'm the sort of person who can change. I'm career focussed.”

These responses fall into two categories, perceived lack of time and a resignation to change often after extended periods of poor sleep.

In summary, the investigation into attitudes and behaviours prior to bed produced some informative results.

- A significant number (70%) of people engage in some form of pre-sleep routine, though the activities involved in these routines varied considerably, emphasising the potential for building on pre-existing behaviours but also the individuality required.
- Mobile phone usage in bed was very prevalent (70%) but surprisingly only a small fraction used the device to help with sleep improvement, identifying an opportunity to both remove the device from the bed and improve on sleep hygiene.
- Interestingly only just over half of the participants indicated a want to improve current sleep routines. This reluctance highlights a potential challenge when designing the prototype and shows any intervention needs to be easy to integrate into current lifestyles.

Building on the information gathered so far, the following section will refine these requirements into a set of user personas each highlighting a specific set of needs for a user. By creating these detailed profiles, the aim is to inform the design process more accurately, to personalise and individualise the implementation.

User Personas

From the information gathered through the user requirements and literature research a set of four user personas were created to help drive the direction of design for the prototype and ensure user needs were met throughout development.

Sarah, the Sleep Enthusiast:

- Age: 28
- Background: Works as a fitness instructor
- Habits: Sarah follows a strict pre-sleep routine involving meditation, reading, and journaling. She values a good night's sleep and is always looking for ways to enhance her sleep quality.
- Smartphone Usage: Keeps her phone on her nightstand but doesn't use any sleep monitoring apps.
- Interest in Improvement: Highly motivated to improve her pre-sleep routine for even better sleep quality.

Mark, the Busy Professional:

- Age: 35
- Background: Software engineer with a demanding job
- Habits: Mark has erratic pre-sleep routines due to work deadlines. He often falls asleep with his phone next to him, and his sleep is frequently interrupted.
- Smartphone Usage: Keeps his phone within reach at night but doesn't use any sleep apps.
- Interest in Improvement: Interested in improving his pre-sleep routine but finds it challenging due to his busy schedule.

Emma, the Reluctant Change-Averse:

- Age: 40
- Background: Senior manager in a corporate setting
- Habits: Emma has struggled with her sleep for years and has resigned herself to interrupted sleep patterns. She keeps her phone nearby but doesn't use it for sleep-related purposes.
- Smartphone Usage: Keeps her phone near her bed but hasn't explored sleep improvement apps.
- Interest in Improvement: Initially resistant to change due to career focus and prolonged sleep issues.

David, the Tech-Savvy Student:

- Age: 21
- Background: College student majoring in computer science
- Habits: David follows a somewhat regular pre-sleep routine but is open to trying new technologies to optimize his sleep. He keeps his phone on his bedside table.
- Smartphone Usage: Uses a sleep monitoring app to track sleep patterns and is interested in integrating NFC technology to further improve his pre-sleep routine.
- Interest in Improvement: Highly interested in enhancing his sleep habits through technology.

Use Cases

Following on from the previous exploration of the user personas, a set of use cases were designed to illustrate more specifically how individual users will interact with the application. Figure 8 provides an outline for the functionality and interactions within the prototype and below the individual use cases are more thoroughly examined to provide a clear roadmap for the specific actions taken by a user.

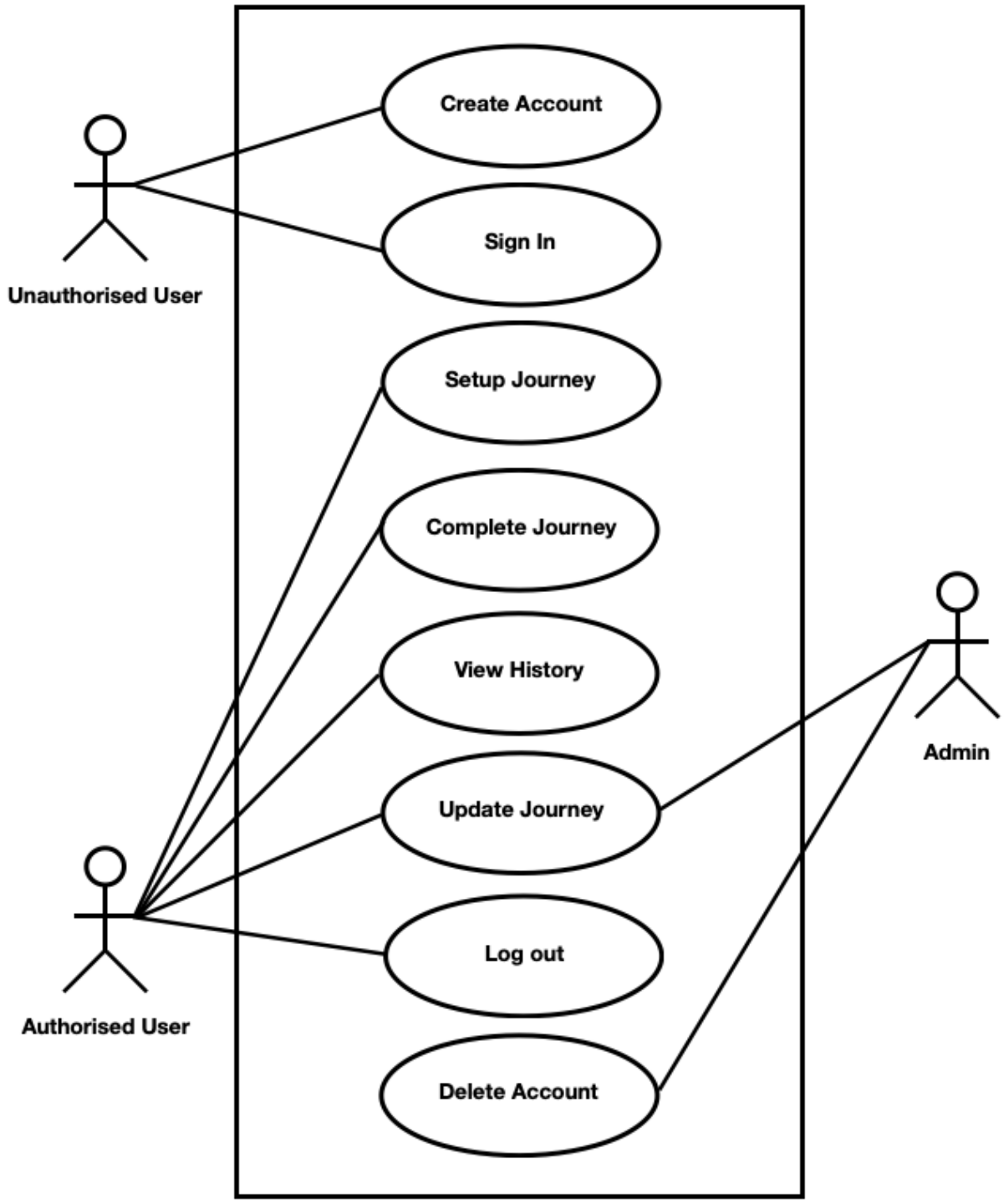


Figure 8: Use case diagram showing the interactions between users and the application.

Use Case 1	Create Account
Main actor	Unauthorised User
Description	An unauthorised user can create a new account.
Pre-condition	Unauthorised user does not have an existing account.
Basic Flow	1. Navigate to the create account screen. 2. Input email. 3. Input password. 4. Input confirm password. 5. Submit account creation form. 6. Return to sign in screen.
Post-condition	Account created in database.

Use Case 2	Sign in
Main actor	Unauthorised User
Description	An unauthorised user can enter their account details and become an authorised user.
Pre-condition	Unauthorised has an existing account.
Basic Flow	1. Navigate to sign in screen. 2. Input email. 3. Input password. 4. Submit sign in form. 5. Unauthorised user is authorised if form passes validation. 6. Home screen displayed
Post-condition	Unauthorised user is set to authorised and access granted until user logs out.

Use Case 3	Setup Journey
Main actor	Authorised User
Description	An authorised user sets up a new sleep journey.
Pre-condition	Authorised user hasn’t set up a sleep journey before.
Basic Flow	1. Navigate to the journey setup screen. 2. Press add habit button. 3. Input habit name. 4. Press create habit button. 5. Scan new NFC tag. 6. Repeat steps 3 – 5. 7. Return to journey setup screen.
Post-condition	Journey added to database and data transferred to NFC tags.

Use Case 4	Complete Journey
Main Actor	Authorised User
Description	An authorised user completes a sleep journey.
Pre-condition	Authorised user has a sleep journey created on the setup screen.
Basic Flow	1. Navigate to the home screen. 2. Press time for bed button. 3. Scan first habit NFC tag. 4. Press continue button. 5. Scan next habit NFC tag. 6. Press continue button. 7. Scan final habit NFC tag. 8. Return to Home screen.
Outcome	Completed journey and associated data stored in database.

Use Case 5	View History
Main Actor	Authorised User
Description	An authorised user can view the information about completed sleep journeys.
Pre-condition	Authorised user has completed a sleep journey.
Basic Flow	1. Navigate to the history screen. 2. View information about previously completed journeys.
Post-condition	Previous journey data retrieved from database and shown to user.

Use Case 6	Update Journey
Main Actor	Authorised User
Description	An unauthorised user can update a previously created sleep journey.
Pre-condition	Authorised user has a previously created sleep journey.
Basic Flow	1. Navigate to the journey setup screen. 2. Press edit button next to a sleep habit. 3. Input new habit name. 4. Press confirm button. 5. Press edit button next to another habit. 6. Press delete button. 7. Press confirm delete button. 8. Return to journey setup screen.
Post-condition	Journey updated in the database with one habit deleted and one habit name updated.

Use Case 7	Log out
Main Actor	Authorised User
Description	An unauthorised user can logout of the application and become unauthorised.
Pre-condition	Authorised user is current signed into the application.
Basic Flow	1. Navigate to the settings screen. 2. Press sign out button. 3. Confirm sign out. 4. Return to sign in screen.
Post-condition	Authorised user is marked as unauthorised in database.

User Stories

Finally, combining all the information gathered so far from the user personas, use cases and literature research, a set of actionable user stories were developed to guide the design of the prototype and maintain a user centric approach to the subsequent stages of the project. Below are the refined user stories with a clear set of acceptance criteria for which the scope of each story is set.

# 1	Related Use case - 1
As an unauthorised user I want to be shown an onboarding screen so I can understand how to use the application.	
Acceptance Criteria: User should be shown information about how the application works. User should be able to skip the onboarding screen using the (Skip) button. User should be able to navigate to the sign-up screen using the (Done) button.	

# 2	Related Use case - 1
As an unauthorised user I want to create an account so that I can sign into the application.	
Acceptance Criteria: User should be able to input email and password. User should be notified if email or password do not meet validation requirements. User should be immediately signed in on account creation. User should be redirected to home screen after account creation.	

#3	Related Use case - 2
As an unauthorised user I want to sign into the application so that I am granted access to the application.	
Acceptance Criteria: User should be able to input email and password. User should be notified if email or password do not meet validation requirements. User should be immediately signed in on form submission. User should remain signed in until user signs out.	

#4	Related Use case - 3
As an authorised user I want to add a habit so that I can create my sleep journey.	
Acceptance Criteria: User should be able to press the add habit button. User should be able to input a habit name. User should be able to press the create habit button. User should be prompted to scan the NFC tag. User should receive confirmation of successful habit creation. User should be redirected to journey setup screen. User should see the previously created habit.	

#5	Related Use case - 6
As an authorised user I want to edit my habit so I can update my sleep journey.	
Acceptance Criteria: User should be able to press the edit habit button. User should be able to input a new habit name. User should be able to press the update habit button. User should be prompted to scan the NFC tag. User should be notified if NFC tag scanned is not the tag with the associated habit. User should receive confirmation of successful habit update. User should be redirected to journey setup screen. User should see the updated habit.	

#6	Related Use case - 6
As an authorised user I want to delete a habit from my journey so that I can have a shorter sleep journey.	
Acceptance Criteria: User should be able to press the edit habit button. User should be able to press the delete habit button. User should be asked to confirm deletion. User should be prompted to scan the NFC tag. User should receive confirmation of successful habit deletion. User should be redirected to journey setup screen. User should no longer see habit in the sleep journey.	

#7	Related Use case - 4
As an authorised user I want to scan my habit NFC tag so I can start my sleep journey.	
Acceptance Criteria: User should be able to scan any habit tag to launch app. User should be able to scan first habit tag to launch app and start sleep journey. User should be able to press time for bed button. User should be prompted to scan first habit tag. User should be notified if tag scanned is not first habit.	

#8	Related Use case - 4
As an authorised user I want to complete my habit journey so that I can turn off my phone and sleep.	
Acceptance Criteria: User should be able to press (Press To Continue) Button. User should be prompted to scan next habit NFC tag. User should be notified if tag scanned is not next habit. User should be Taken immediately to completed journey screen on last tag scan. User should be redirected to home screen after completed journey screen.	

#9	Related Use case - 5
As an authorised user I want to view the history screen so that I can see information about my previous sleep journeys.	
Acceptance Criteria: User should be able to navigate using the bottom tab from any screen. User should be shown a calendar of all previous sleep journeys. User should be able to view information about times they went to bed. User should be able to view any streaks of consecutive days they completed journeys.	

#10	Related Use case - 7
As an authorised user I want to view the settings screen so that I can log out of the application.	
Acceptance Criteria: User should be able to press the settings button from any screen. User should be shown information about the application. User should be able to press the sign out button. User should be able to cancel or confirm log out. User should be redirected back to the sign in screen.	

In summary, this chapter has brought together and refined specific user needs for the application. Key findings include, simple and intuitive user interfaces, the importance of customisation and flexibility to appeal to a wide user group and the need to implement features which do not contribute to smart phone overuse. The next chapter will take these findings and the actionable requirements and begin turning them into practical design features.

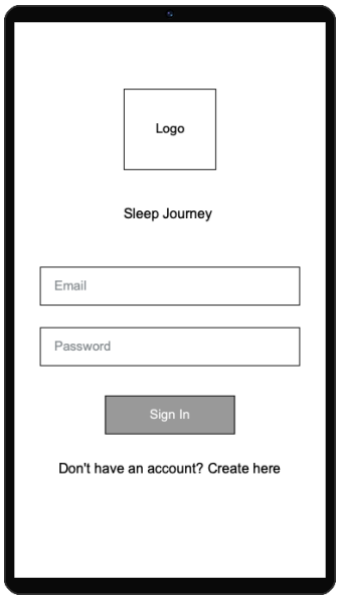
Design – Visualising the User Experience

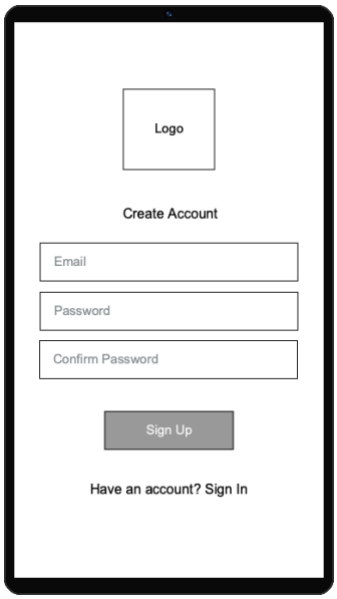
Using the information gathered through the user requirements analysis, it was now possible to begin designing and understanding the user experience that the application can offer. It was important that the detail gathered was not lost through this process so an initial point of entry was to generate a set of foundational wireframe designs from which the application design could progress as well as begin to visualise and understand the navigation and user flow required for the application to function effectively.

Wireframes

The wireframe designs are used to introduce initial design ideas as well as visual the layout and user experience. Validation, error handling and unhappy paths would be handled later in the process, as well as much of the NFC specific features which are difficult to represent in a static wireframe. These designs allow for those elements to be more effectively handled at a later point. Below is a list of the screens for the application, shown as wireframe models, with an explanation of the design choices made as well as how they relate to the user stories previously defined. Authorisation was handled using a backend database explored later, users who have an account stored in the database can sign in to become authorised, enabling access to screens past the sign in screen.

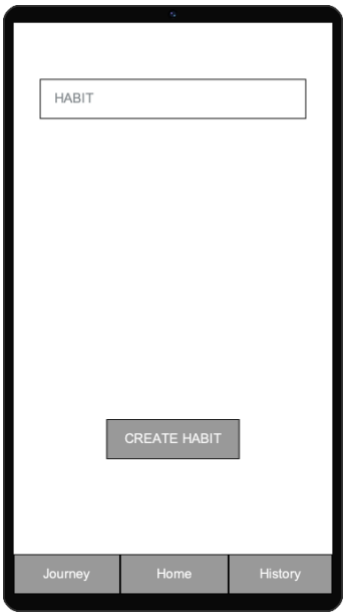
<table>
<tr><th>Onboarding Screen</th><th>User Story 1</th></tr>
<tr><td>The initial screen shown to the user upon first downloading the application. Providing some brief detail about the applications purpose, and how to get started using the application. There are navigation options at the bottom of the screen and the user would not return to this screen after the initial launch. The screen serves as an important entry into the application and needs to provide enough information to make the process of setting up seamless, whilst not overloading the user.</td><td colspan="2"> 
</td></tr>
</table>

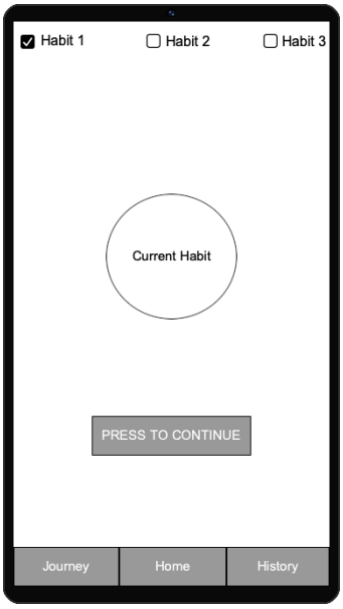
Sign In Screen	User Story 3
The screen an unauthorised user would see whenever they launch the application after the first time, or upon navigating from the onboarding screen. It contains inputs for an email and password and a button to sign in. There is also a pressable text element for users who have not created an account yet allowing navigation to the sign up screen.	

Sign Up Screen	User Story 2
A user would navigate to this screen after touching the pressable text element on the sign in screen. Here the user would be able to provide an email and password to create a new account for the application. The password needs to be entered twice to ensure there are no mistakes on the password input. There is a button to sign up which authorises that user and takes them to the home screen. There is also an option to return to the previous Sign In screen in case of navigating to this screen by mistake.	

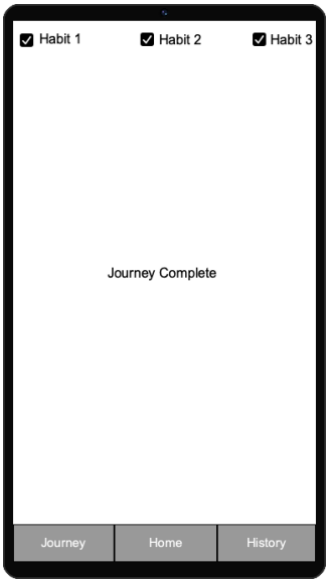
Home Screen	User Story 7
The home screen is the central screen for the application, it contains a bottom navigation tab bar which is visible on all authorised screens for easy navigation within the application. It is also where a user can access the settings screen for the application. It contains one of the entry points for the sleep journey (time for bed button). This enables an authorised user to begin a sleep journey when launching the application quickly and easily. A key feature identified in the user personas and the literature review.	

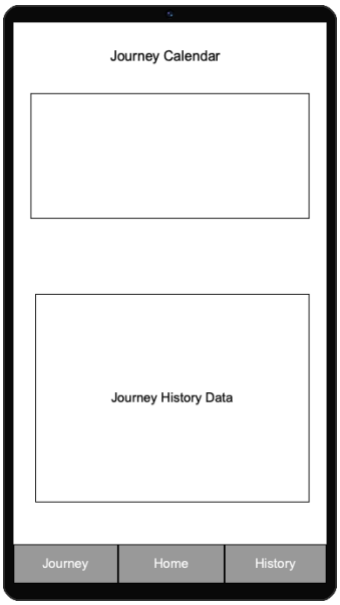
Journey Setup Screen	User Story 4
The journey setup screen allows a user to create a sleep journey. It displays a list of habits which have been associated to NFC tags for the user to see, as well as an add habit button for the setting up of the sleep journey. There is also an edit button to allow a user to update a sleep journey. These features enhance the personalisation and customisation of the application.	

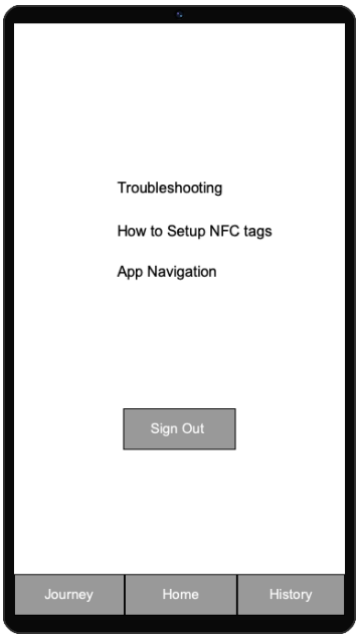
Create Habit Screen	User Story 4
After pressing the add habit button the user is shown the create habit screen. The user can input a habit name and press the create habit button to add a habit to a sleep journey. Upon pressing the button, a user is required to scan an NFC tag which adds the habit to the sleep journey and returns the user to the journey setup screen.	

Journey Screen	User Story 8
The journey screen is shown to the user upon pressing the time for bed button on the home screen. It displays the current habit the user has scanned as well as the list of habits within the journey. There is a button for the user to press to indicate they want to move onto the next habit, as each habit is scanned the screen marks it as done and displays that to the user.	

Update Habit Screen	User Story 5 and 6
After pressing the edit button on the journey setup screen, the user is taken to the update habit screen. The current habit stored in the NFC tag will be displayed to the user in the text input and the user can input a new habit name. Pressing the edit habit button will update the habit in the sleep journey. The user will be returned to the journey setup screen after scanning the NFC tag and the new habit will be displayed in the list. There is also an option to delete a habit. Upon pressing the delete habit button, the user will be shown a confirmation and returned to the sleep journey screen and the habit will no longer be shown in the list.	

Completed Journey Screen	User Story 8
Upon scanning the final tag in the sleep journey, the user is immediately shown the completed journey screen, which notifies the user they have completed the sleep journey and can now finish using the application and go to bed. This feature is intended to create a definite end to the sleep journey and prevent the user from continuing to use their device. It is a deliberate and conscious action to turn off the device.	

History Screen	User Story 9
The history screen is navigated to using the bottom tab navigator and displays previously completed sleep journeys. It provides a minimal overview of the data collected about each sleep journey for the user to view. There are no interactive or pressable elements on this page as the user is not intended to spend long periods of time viewing this page. It should provide a quick snapshot of the user's progress. This screen was focussed on the user personas of Sarah and David who have interest in both information about their sleep habits and the details of the technology.	

Settings Screen	User Story 10
The settings screen is accessible from the header of the home screen and allows the user to view information about the application, as well as sign out of the application. Upon pressing the sign out button the user is taken back to the sign in screen and is no longer an authorised user.	

Flow diagram

Navigation, especially navigation involving NFC tags was a crucial feature to ensuring the prototype functioned properly and met the user's needs. Figure 9 shows the flow diagram used to better visualise the user journey taken through the application.

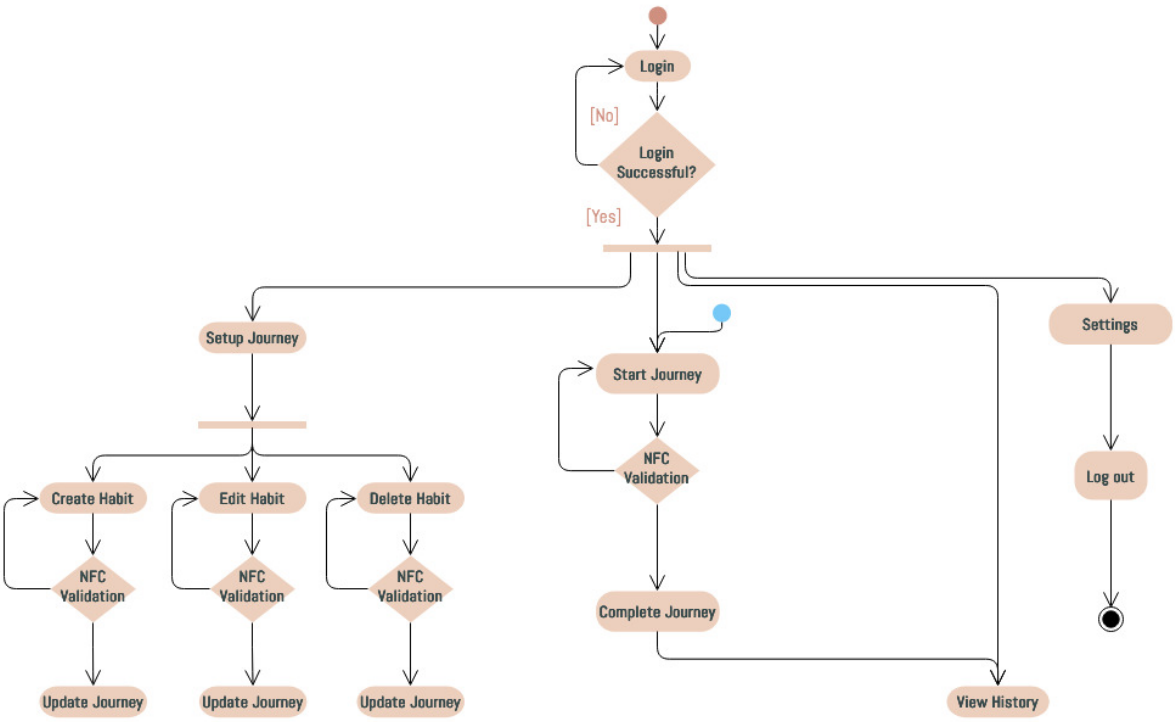


Figure 9: Flow diagrams showing the actions and routes a user can take through the application.

The prototype contains an initial entry point when a user opens the application and is unauthorised. There is also a second entry point represented as a blue circle, for when a user launches the application from the NFC tag itself, this was an important feature to reduce the friction of using the application. This feature was specifically targeted at the user personas Mark and Emma to allow the app to be integrated into a busy schedule. A user can scan the first NFC tag in their journey and be taken directly to the start of their sleep journey if authorised, if not, the user is taken to the sign in screen. The entry point for the journey should be as quick and easy as possible to get the user started on the sleep journey. The second entry point of simply scanning a tag achieves this. There is a single exit point from the application through the settings screen. Details of the NFC validation used will be explored in the implementation chapter next.

Implementation

Upon finalising the design and requirements for the project, it was important to select a set of technologies that would be most effective in achieving the intended prototype. These decisions were crucial as they allow for the user-centric data collected to be translated effectively. The first decision to pursue the development of an android prototype was made for several reasons:

- Firstly, as an Android phone owner and due to the lack of ability to test NFC capabilities on an emulated device, it was essential to have real-world testing to ascertain the accuracy and effectiveness of the NFC integration.
- Secondly due to limitations with the hardware used, XCode a software application critical to IOS development was not available and therefore restricted the approach.

It should be emphasized that this choice was not merely a matter of personal convenience, but a decision made due to technical feasibility and the aim of delivering an optimal prototype.

Android Studio

Android Studio (Google 2022) was the IDE of choice for developing this prototype. The app would be developed with a goal of launching on the Google Play Store and as such the vast suite of tools that Android Studio provides was invaluable.

Gradle (Gradle Inc. 2023) a build system used by Android Studio was used to manage dependencies, introduce automation, and prepare the application for release. An essential part of the development process, particularly when producing an application bundle at the end of development and continuing to iterate on those releases. Android Studio provides an extensive set of resources for managing this.

As will be described later Firebase (Google 2023a) would be used to handle the database, authentication and backend configurations, the integrations that Android Studio provides were useful in seamlessly introducing this part of the project.

React Native

React Native (Meta Platforms, Inc. 2023) a framework that uses JavaScript and React to develop mobile applications was chosen. React Native is developed by Facebook and provides an extensive and detailed set of libraries and plugins to use in development. There were two key factors when deciding on the selection of this framework:

- React-Native-NFC-Manager was a key deciding factor (Revteltech and Whitedogg13 2023). The rich and detailed library that has been developed for use with React Native was foundational to successfully integrating advanced NFC processes.
- Previous experience in both JavaScript and TypeScript reduced the learning curve and barrier for entry when starting out with React Native.

Alongside that, the other factors included:

- Not closing the door on IOS development and the ability to transition in that direction more easily than with native development.
- Native code integration and flexibility. Due to uncertainties around the capabilities and potential iterations of the prototype having the ability to code natively in the future was important, especially where NFC integrations were concerned.
- Hot reloading, whilst not exclusive to React Native, was a feature which proved almost essential in the development process. The relatively short development window and the ability to work iteratively with quick feedback loops on feature changes was instrumental in the efficiency of the project.

Firebase

Firebase was chosen to provide the backend for the application (Google 2023a). There were many reasons why firebase was the most appropriate tool for this prototype:

- Cloud Firestore – A NoSQL database which stores data as documents organised into collections. The documents are individual units which contain fields of values. These documents can also contain subcollections particularly useful when attaching data information to an individual user. Also of importance was the atomic nature of the transactions, especially where NFC driven data transfers were involved. Data integrity was of key importance to the success of the database integration. Finally due to the ever-evolving nature of a prototype application and the agile approach being taken to development. The flexibility a NoSQL database offers was a highlight feature.
- Firebase Authentication – Firebase has a pre-built authentication library which can be seamlessly integrated with the database. It was important for the application to have some level of authentication and this solution is both reliable, fast, and easy to implement.
- Firebase security – Security was very important when looking at implementing a backend service, and the robust and detailed security options available for both the database and authentication library were very effective in this use case.

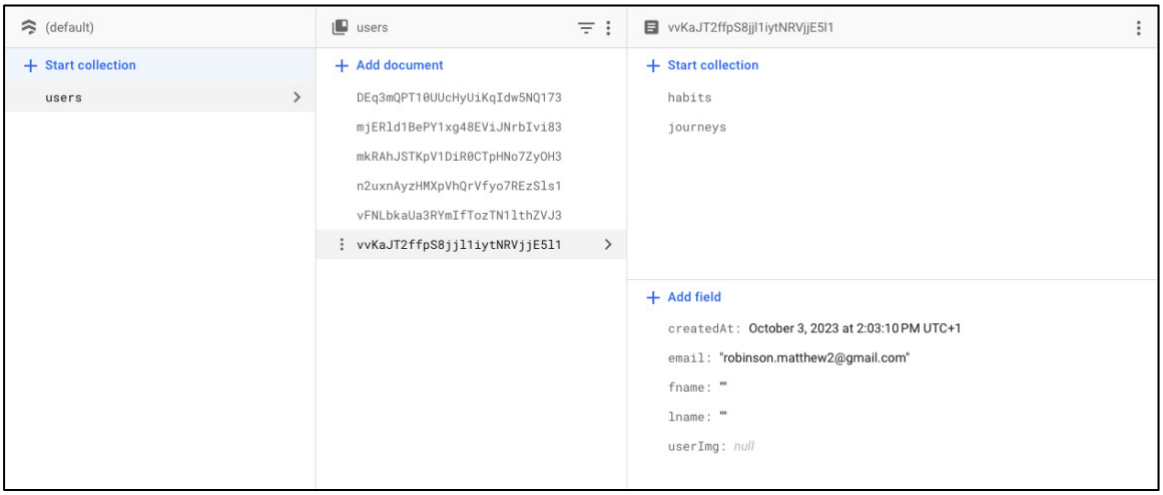


Figure 10: User documents created through Firebase authentication integration with Firestore.

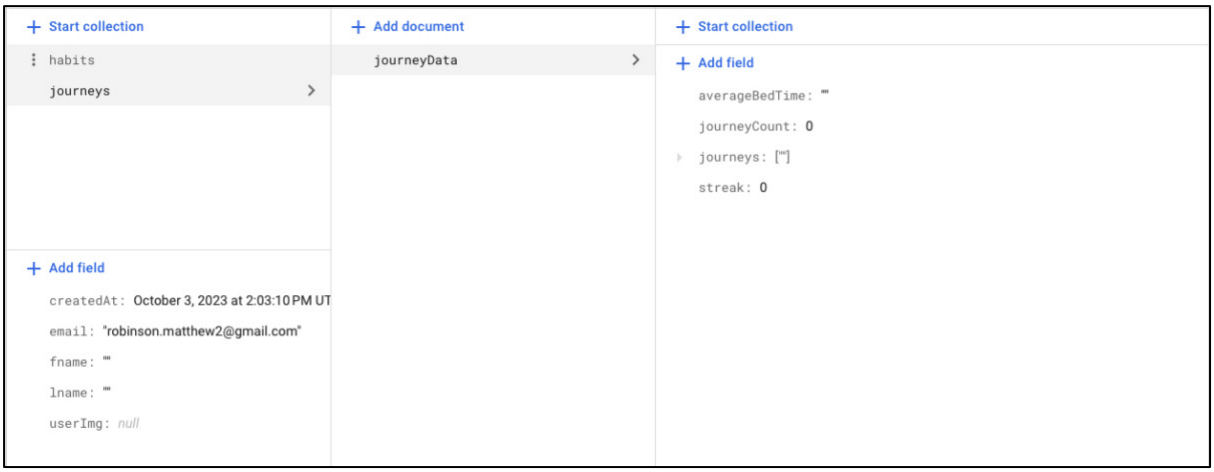


Figure 11: Structure of the sleep journey data stored by the application.

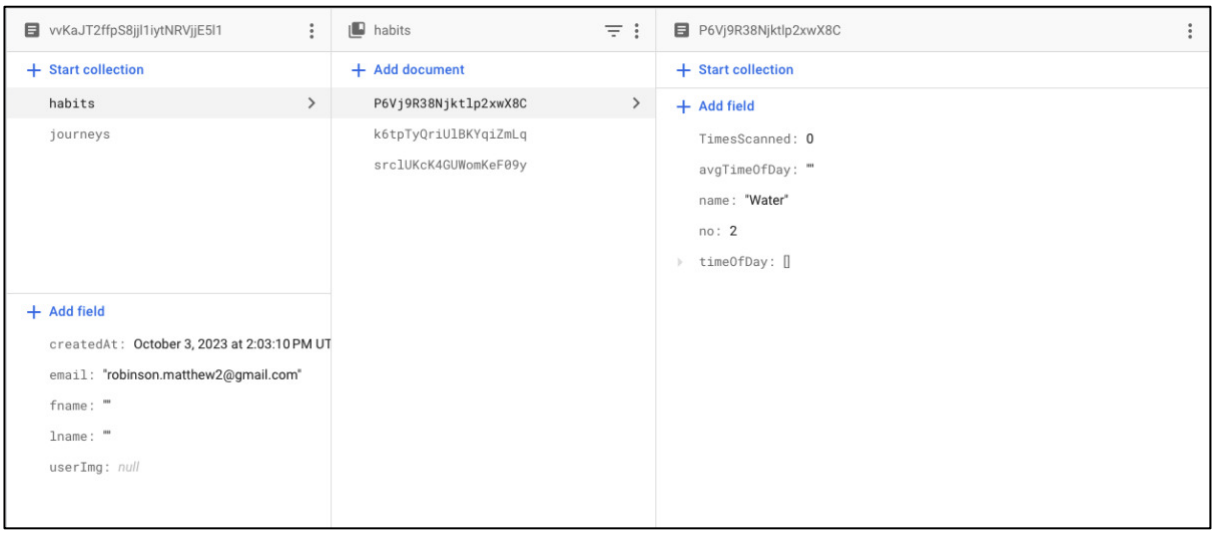


Figure 12: Structure of the habit documents stored by the application.

Sleep Journey – Prototype Application

Diving into the creation of the prototype application, this section aims to provide an overview of the application, the user centric design choices, technological implementations and highlight the iterative workflow employed. This chapter should provide a holistic showcase of the prototyping process and a comprehensive understanding of the journey from design to implementation.

Whilst function was the focus for the application it was also important to ensure the application was visually appealing and minimal in its design. The application has been

designed to provide a consistent and appealing experience for the user but not for them to spend time scrolling or unconsciously using the app.

The flow of the prototype is designed to allow the user to perform the tasks in the app quickly with minimal friction and so the environment of the app is clutter free. (Orbell and Verplanken 2010) showed how environmental distractions caused individuals to "habit slip", this prototype has made efforts to reduce the potential for slipping into unconscious scrolling on the device.

Navigation

As previously stated, navigation was key to the prototype's success, therefore a robust and effective solution needed to be created to allow the user to have confidence when navigating through the application both with and without NFC tags.

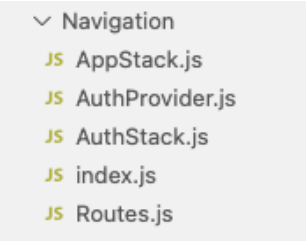


Figure 13: Navigation folder structure.

While the prototype is relatively small in scale the navigation has a large amount of complexity due to the NFC navigation, authentication, and tab navigator. This made it important to implement a modular design, clear flows for authentication and screen navigation, and loose coupling to help with scalability and iteration.

```
const Providers = () => {
  return (
    <AuthProvider>
      <Routes />
    </AuthProvider>
  );
}

export default Providers;
```

Figure 14: index.js file

As shown in Figure 14 the index.js file contains an auth context wrapper for the Routes component and nested child components. This allows the child components to access authentication data such as user and associated data.

```
const Routes = () => {
  const {user, setUser} = useContext(AuthContext);
  const [initialising, setInitialising] = useState(true);

  const onAuthStateChanged = (user) => {
    setUser(user);
    if (initialising) setInitialising(false);
  };

  useEffect(() => {
    const authSubscriber = auth().onAuthStateChanged(onAuthStateChanged);
    return authSubscriber;
  }, []);

  if (initialising) return null;

  return (
    <NavigationContainer>
      {user ? <AppStack /> : <AuthStack />}
    </NavigationContainer>
  );
};

export default Routes;
```

Figure 15: Routes.js file

Figure 15 shows the Routes file which listens for authentication state changes and conditionally renders either the authentication screens for non-authorised users or the application screens for an authorised user. This logic allows for the flow and entry points into the application shown in Figure 9.

```
const Stack = createStackNavigator();

function AppNavigator() {
    return (
        <Stack.Navigator>
            <Stack.Screen name="Home" component={HomeScreen} options={{options}} />
            <Stack.Screen name="Journey" component={JourneyScreen} options={{ options }} />
            <Stack.Screen name="TagDetails" component={TagDetailsScreen} options={{ options }} />
            <Stack.Screen name="CompletedJourney" component={CompletedJourneyScreen} options={{ options }} />
            <Stack.Screen name="Settings" component={SettingsScreen} options={{ options }} />
        </Stack.Navigator>
    );
}

const JourneysStack = createStackNavigator();

function JourneysNavigator() {
    return (
        <JourneysStack.Navigator>
            <JourneysStack.Screen name="Setup" component={SetupScreen} options={{ options }} />
            <JourneysStack.Screen name="WriteNdef" component={WriteNdefScreen} options={{ options }} />
        </JourneysStack.Navigator>
    );
}

const Tab = createBottomTabNavigator();

const AppStack = () => {
    return (
            <Tab.Navigator initialRouteName="Sleep Journey"
            screenOptions={{screenOptions}}>
                <Tab.Screen
                    name="Journey"
                    component={JourneysNavigator}
                    options={({ focused }) => ({options})}
                />
                <Tab.Screen
                    name="Sleep Journey"
                    component={AppNavigator}
                    options={({ navigation }) => ({options})}
                />
                <Tab.Screen
                    name="History"
                    component={HistoryScreen}
                    options={{options}}
                />
            </Tab.Navigator>
    );
            }

export default AppStack;
```

Figure 16: AppStack.js file containing the main navigator for the application.

Figure 16 shows the app stack that is displayed to an authorised user, it contains the bottom tab navigator which persists across all screens of the application and nested navigators for both the journey setup and main app navigator. Options have been removed in Figure 16 for brevity and to reduce the visual complexity.

Nested navigation especially using NFC tags was a real challenge to implement, and whilst this file has made every attempt to be as clear, modular, and scalable as possible, the complexity of the navigation has meant that function and user experience had to take the highest precedence in this instance. The way navigation has been used to enhance user experience will be explained later in this chapter.

Android NFC Prompt

A challenge encountered with choosing Android as the development platform is the lack of an NFC prompt feature within Android devices. Whilst IOS provides a software solution to inform the user to scan an NFC tag, Android doesn't have such a feature. This caused an issue when addressing a few of the user stories, as the idea of prompting the user to scan the tag was integral to the user's journey. There was also the NFC validation from the flow charts which would need to inform the user of a successful or non-successful NFC tag scan. This required a component to be created for the application to successfully integrate the NFC technology.

The NFCPrompt component shown in Figure 17 uses the React Native library to implement an animated prompt that displays to the user on the press of a button. useState properties are used to hold the value of the text displayed, this allows for custom text to be displayed depending on the tag scanned as well as validation messages to be passed and displayed within the prompt itself. The prompt contains a cancel button to allow the user to go back if the previous action was not intended.

```
const NFCPrompt = forwardRef((props, ref) => {
  const [visible, setVisible] = useState(false);
  const [hintText, setHintText] = useState('');
  const animValue = useRef(new Animated.Value(0)).current;

  useEffect(() => {
    if (ref) {
      ref.current = {
        setVisible,
        setHintText,
      };
    }
  }, [ref]);

  useEffect(() => {
    Animated.timing(animValue, {
      duration: 300,
      toValue: visible ? 1 : 0,
      useNativeDriver: true,
    }).start(() => {
      if (!visible) {
        setHintText('');
      }
    });
  }, [visible]);

  const backdropAnimStyle = {
    opacity: animValue,
  };

  const promptAnimStyle = {
    transform: [{
      translateY: animValue.interpolate({
        inputRange: [0, 1],
        outputRange: [500, 0],
      }),
    }],
  };

  return (
    <Modal visible={visible} transparent={true}>
      <View style={styles.content}>
        <Animated.View style={[styles.backdrop, backdropAnimStyle]} />
        <Animated.View style={[styles.prompt, promptAnimStyle]}>
          <Text style={styles.hint}>{hintText || 'Scan to start'}</Text>
          <TouchableOpacity onPress={() => setVisible(false)}>
            <View style={styles.btn}>
              <Text style={styles.btnText}>CANCEL</Text>
            </View>
          </TouchableOpacity>
        </Animated.View>
      </View>
    </Modal>
  );
});
```

Figure 17: NFCPrompt Component used to handle Android NFC interactions.

Onboarding screen

As shown in Figure 18 much of the design for this screen follows the design from the wireframe, though the screen has been made into a scrollable element which splits the information for easier viewing. The screens gradually get darker as the user navigates through, designed to be informative and visually appeal to introduce the user to the application. There is a skip button and a next button on each page, with a done button upon reaching the last page. The onboarding screen is only shown to a user the first time they download the application.

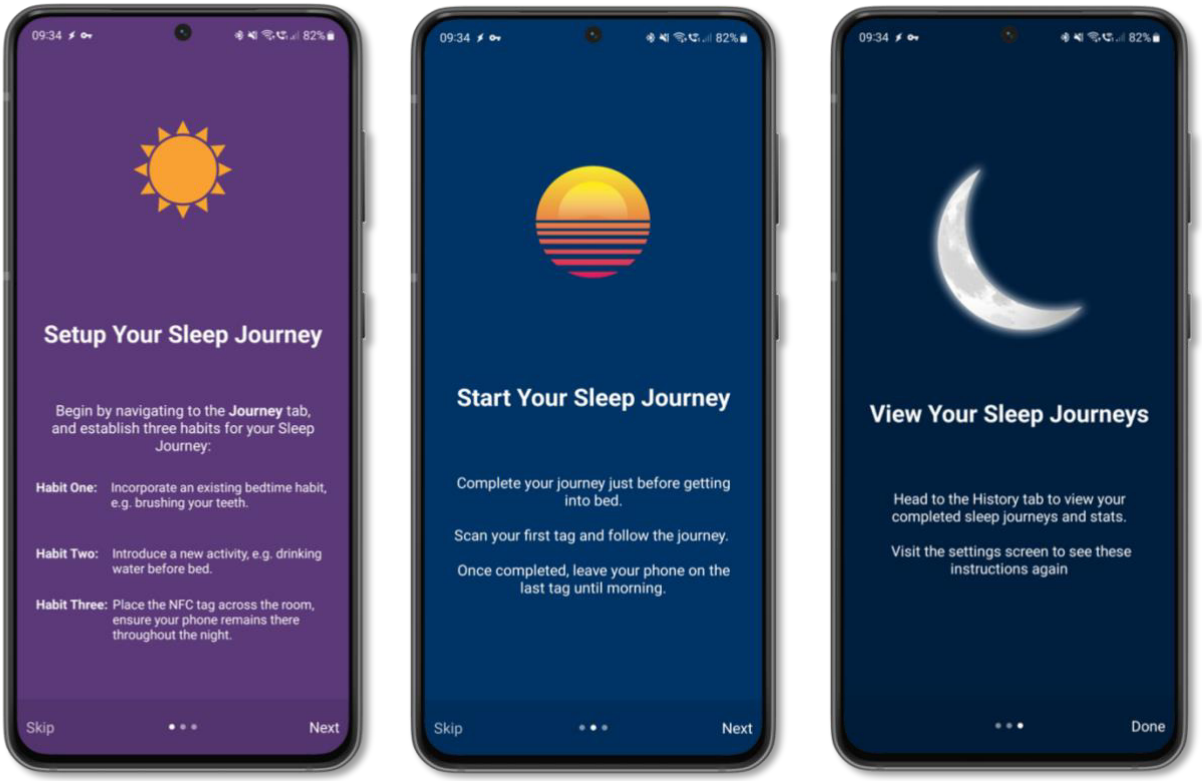


Figure 18: Onboarding Screen.

Sign In Screen/ Sign Up Screen

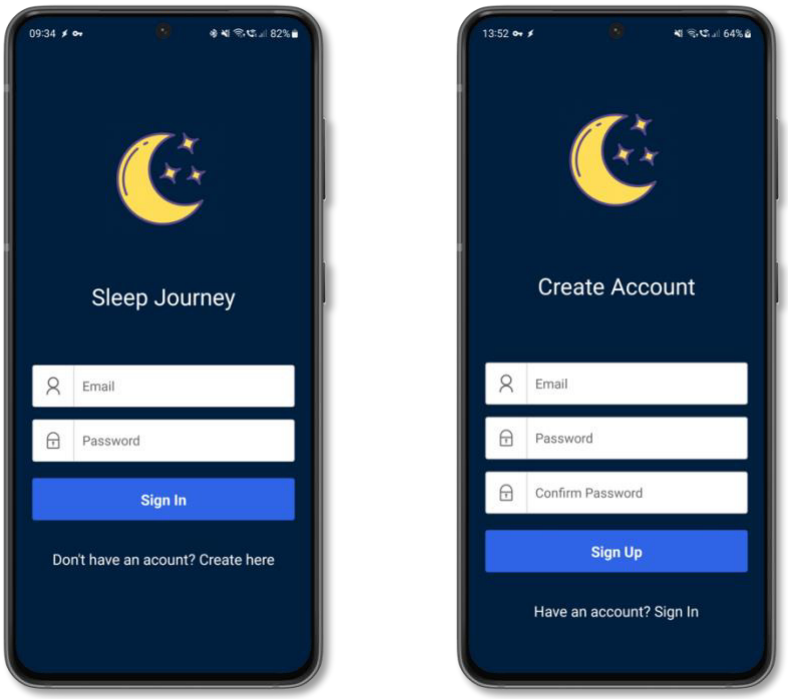


Figure 19: Sign In and Sign Up Screens.

Again, in Figure 19 much of the screens remain the same as in the wireframe design, with updates to the applications visual style and logo included, and validation checks included to satisfy user story 3. These checks are communicated to the user to enhance the user experience.

```
const handleSignUp = () => {
  setError('');
  if (!email || !password || !confirmPassword) {
    setError('All fields are required');
  } else if (!validateEmail(email)) {
    setError('Invalid email format');
  } else if (!validatePassword(password)) {
    setError('Password must be at least 6 characters long');
  } else if (password !== confirmPassword) {
    setError('Passwords do not match');
  } else {
    register(email, password);
  }
};
```

Figure 20: handleSignUp function.

Figure 20 shows the handleSignUp function used in validation, the function uses a state variable to store error messages, which gets reset each time the function is called. The function is called on the button press and if the function passes, the user is registered with the AuthContext.

Home Screen

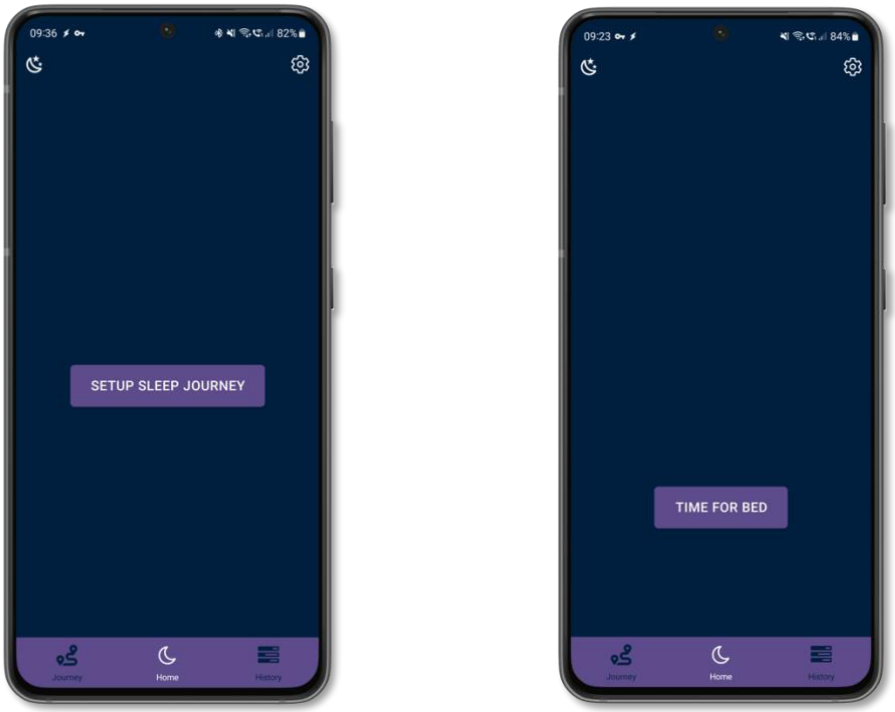


Figure 21: Home Screen with and without a created sleep journey.

The home screen is the anchor for most of the navigation in the application, however the main function of the screen is to launch the sleep journey. When an authorised user who previously created an account and is still signed in opens the app, they are taken straight to the home screen and the button to start the journey is present immediately, as shown on the right of Figure 21. If no sleep journey has been setup the button takes the user straight to the journey setup screen. Several other usability features were implemented to satisfy the personas of Mark and Emma and reduce the difficulty of starting the journey. Deep linking was used to allow the user to launch the application and start the sleep journey from scanning the NFC tag itself, with no other interaction needed. Deep linking is a unified protocol which enables IOT devices (in this instance an NFC tag) and applications (in this instance Sleep Journey) to interact without the need for user input (Al-Garadi et al. 2020).

```
React.useEffect(() => {
  function handleUrl(url) {
    const msg = url.split('://')[1];
    if (url && msg === habits[0]?.name) {
      navigation.navigate('Journey', {
        msg: msg,
      });
    }
  }

  Linking.getInitialURL().then((url) => {
    if (url) handleUrl(url);
  });

  const handleEventUrl = (event) => {
    handleUrl(event.url);
  };

  Linking.addEventListener('url', handleEventUrl);

  return () => {
    Linking.removeAllListeners('url');
  };
}, [navigation, habits]);
```

Figure 22: Deep Linking implementation.

When the NFC tags are written in the application, they are written with a Uniform Resource Identifier (URI) for the application (Google 2023b). The URI contains two parts, the package name in this case com.sleepjourney and the habit name, creating the URI com.sleepjourney://habit. On the app launch there is an event listener which checks the URI against the first habit in the sleep journey, if the habits match the user is taken straight to the sleep journey screen, otherwise they are taken to the home screen. The implementation of deep linking within the prototype application is shown in Figure 22.

Journey Setup Screen

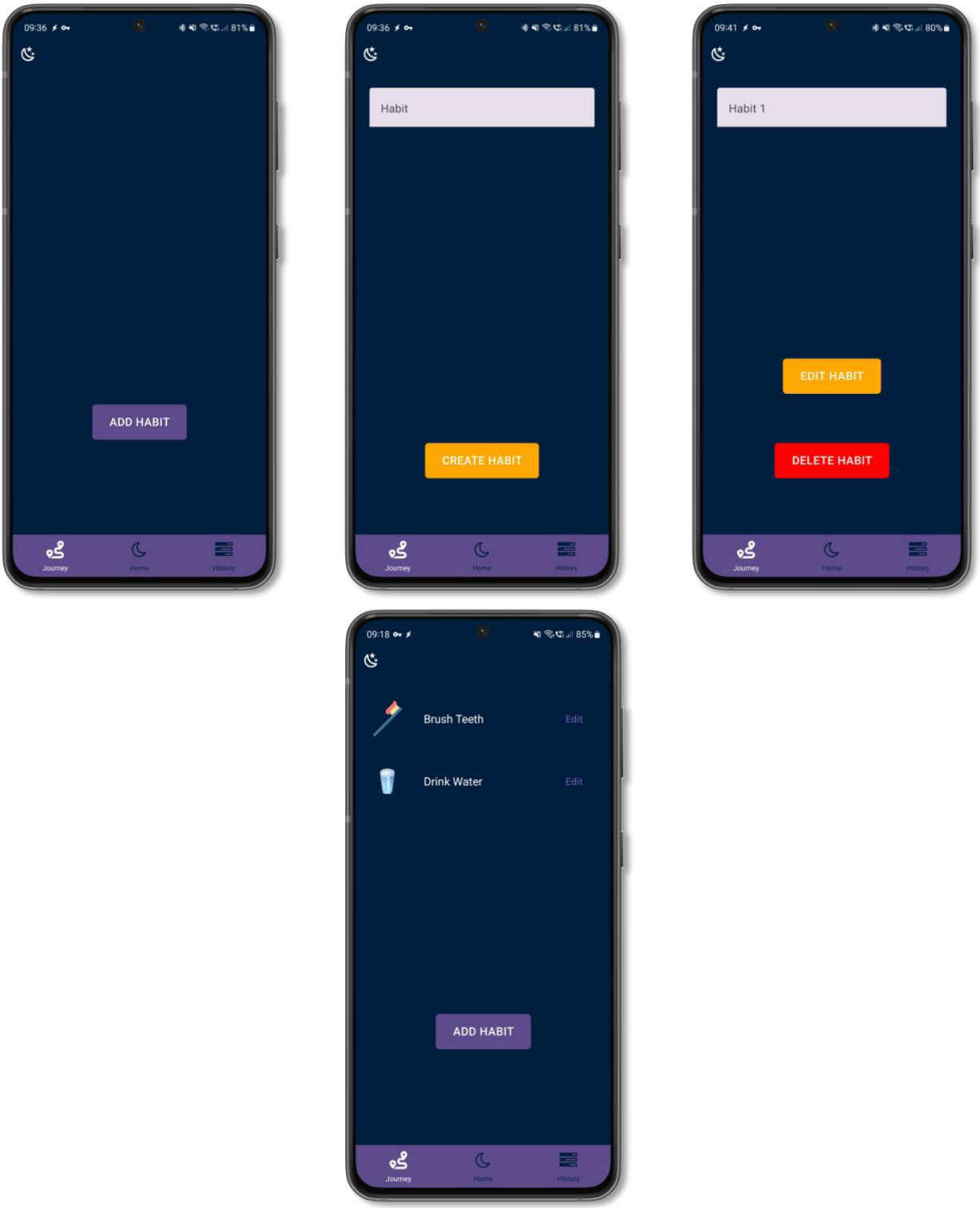


Figure 23: Setup Screen before and after adding a habit with intermediary screens shown.

Images have been incorporated into the screens in Figure 23 to improve the overall look of the application, these images are pulled from the database and shown to the user on a few different screens. To improve the user experience a loader component was implemented using the React Native activity indicator to communicate content loading on a page. This was important with images being rendered so the user was aware something was happening in the background.

```
async function writeNdef() {
  androidPromptRef.current.setVisible(true);
  androidPromptRef.current.setHintText('Now tap NFC');
  let scheme = 'com.sleepjourney://';

  const uriRecord = Ndef.uriRecord(`${scheme}${value}`);
  const bytes = Ndef.encodeMessage([uriRecord]);

  try {
      await NfcManager.requestTechnology(NfcTech.Ndef);
      await NfcManager.ndefHandler.writeNdefMessage(bytes);

      androidPromptRef.current.setHintText('Success');

      await addHabit(value, habitId);

      props.navigation.navigate('Setup');

    } catch (ex) {
      androidPromptRef.current.setHintText('Error');
      console.log(ex);
    } finally {
      NfcManager.cancelTechnologyRequest();
      setTimeout(() => {
          androidPromptRef.current.setVisible(false);
        }, 1500);
    }
}
```

Figure 24: async function used to write data to NFC tags.

The function shown in Figure 24 uses NDEF for data writing and has been modified from documentation by (Revteltech and Whitedogg13 2023). The URI described earlier is stored in the NFC tag using NDEF and uploaded to the database using a custom component. The function utilises the NFCPrompt from Figure 17 and provides clear feedback to the user if either the NFC or database writing fails.

Journey Screen

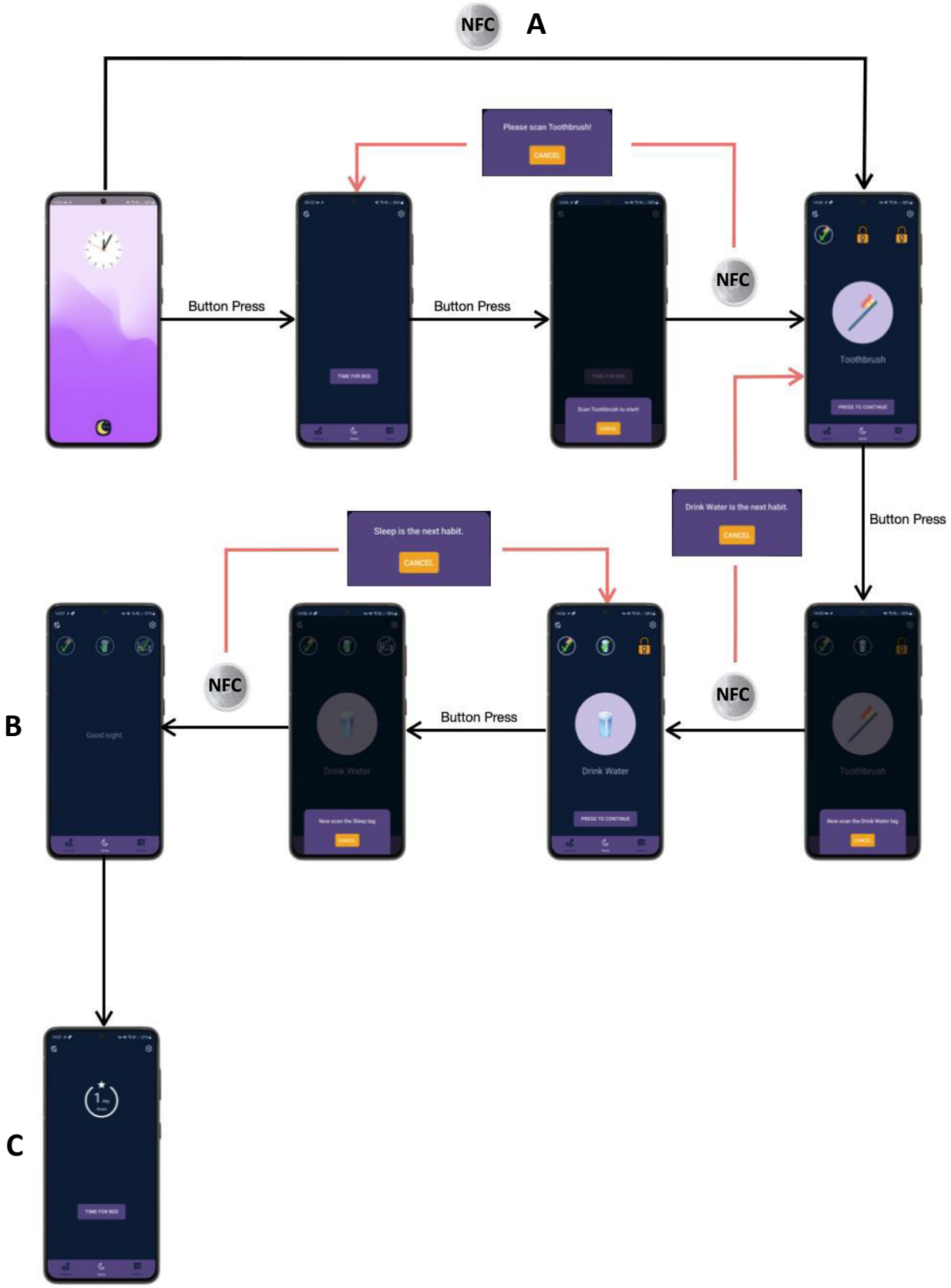


Figure 25: Flow chart illustrating the interactions via button press and NFC tag in the sleep journey. A) Deep Linking Route for starting sleep journey. B) Completed journey screen. C) Home screen at end of journey.

To explain the journey screen a flow chart is used to walk through the user journey including how validation is implemented. Figure 25 shows how a user can launch the sleep journey through deep linking (A), the user path taken through the sleep journey using button presses or tapping NFC tags, as well as the validation implemented (red routes) for incorrect NFC tag scans. The implementation of the validation used is shown in Figure 26:

```
if (scannedHabitName !== nextHabit.name) {
    androidPromptRef.current.setHintText(`${nextHabit.name} is the next habit.`);
    setTimeout(() => androidPromptRef.current.setVisible(false), 2000);
    return;
}
```

Figure 26: Validation logic for setting the android prompt in Figure 17.

Intention was the key part of implementing the journey screen shown in Figure 25, once a user scans the first tag or presses the time for bed button the journey starts and does not complete until the user is presented the “Good Night” text on the completed journey screen (B). The flow through these screens is one way and progresses as the user responds to the application prompts. To handle the Android NFC prompt a button (Press to Continue) was implemented for the user to communicate to the application that the previous habit had been complete and the user was ready to move on to the next. When the user reaches the completed journey screen the application redirects the user back to the home screen and notifies the user of the successful Journey (C).

History Screen

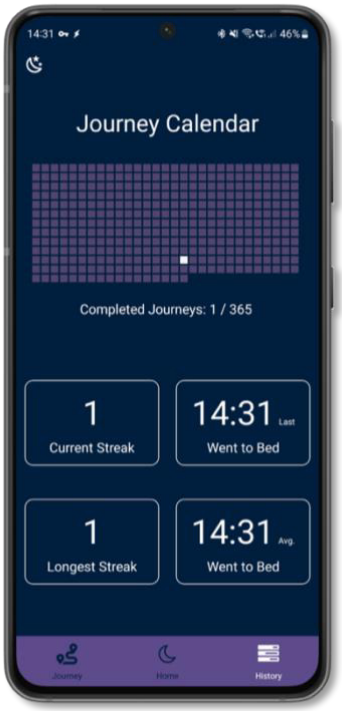


Figure 27: History Screen displaying information about previously completed Sleep Journeys.

The history screen retrieves information from the Firestore database about the sleep journeys a user has previously complete, the implementation of which is shown in Figure 28. As shown in Figure 27 the design is minimal with a limited amount of information displayed, intended so a user doesn't spend long periods of time accessing this data. As stated in the design chapter the history screen was implemented to satisfy the user personas of Sarah and David who both had a keen interest in improving sleep routines and integrating technology into existing routines.

```
export async function fetchScreenData() {
    try {
      const user = auth().currentUser;
      if (!user) throw new Error("User not authenticated");
      const docRef = firestore()
        .collection('users')
        .doc(user.uid)
        .collection('journeys')
        .doc('screenData');

      const doc = await docRef.get();
      if (!doc.exists) {
        return {
          visitCount: 0,
          averageVisitTime: 0,
          visitDates: [],
          streak: 0,
        };
      }
      return doc.data();
  } catch (error) {
    console.error("Error fetching screen data: ", error);
    return null;
  }
}
```

Figure 28: fetchScreenData function used to populate data on the History Screen.

Settings Screen

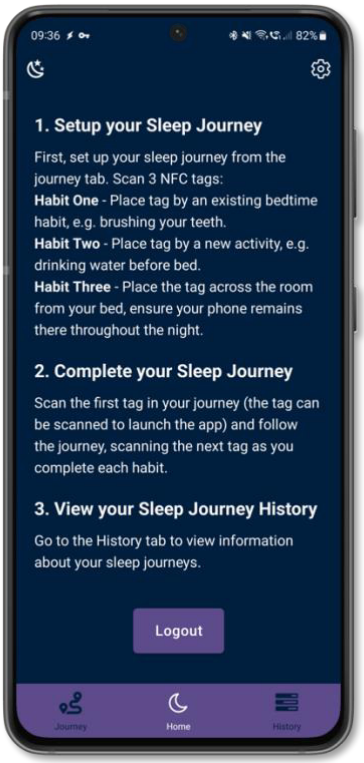


Figure 29: Settings Screen containing Sign Out functionality.

It was important for users to be able to see the information from the onboarding screen again but in a non-obtrusive way, as shown in Figure 29. The sign out button present on this screen is important in user trust and the handling of user data, as well as providing an opportunity for users to create multiple accounts.

Through this chapter the prototype created for the user testing has been explored and demonstrated. The reasoning behind the decisions have been understood and tie back to the previous chapter of both the design and user requirements. Next the testing that was performed using the application from this chapter will be explained and analysed.

User Testing and Analysis

As stated in the literature review habit formation takes on average 66 days to develop so a primary focus on the useability was taken across the requirement, design, and testing stages of this project. However, several important choices were made regarding the potential for this app to promote habit formation. This chapter will review the user features developed from the requirements chapter but will also explore the design choices made in developing a research driven application with the potential for promoting healthy sleep routines.

Methodology

Participants and Recruitment

Participants were recruited from those who completed the user requirements survey as well as through social media posts. In the end all 6 of the participants who agreed to participate were recruited from the previous pool of user testing participants. This was very useful as the user personas had been generated off those participants and as such the 6 participants covered the 4 different user personas. However, as will be discussed later there was a level of detail missing in the user personas which was highlighted by the user testing.

Materials

The user testing involved three different types of analysis:

- Mobile App Rating Scale (MARS)
- Thematic analysis
- Test cases

Section	Definition
A: Engagement	Fun, interesting, customizable, interactive (eg, sends alerts, messages, reminders, feedback, enables sharing), well-targeted to audience
B: Functionality	App functioning, easy to learn, navigation, flow logic, and gestural design of app
C: Esthetics	Graphic design, overall visual appeal, color scheme, and stylistic consistency
D: Information	Contains high-quality information (eg, text, feedback, measures, and references) from a credible source. Select N/A if the app component is irrelevant
App quality	Mean score of sections A, B, C, and D
E: App subjective quality	Personal interest in the app
F: App specific	Perceived impact of the app on the knowledge, attitudes, and intentions to change of the users, as well as the likelihood of actual change in the target health behavior

Figure 30: Definitions of the MARS sections taken from (Salazar et al. 2018).

The MARS useability assessment tool was selected for its specificity to the chosen subject of this research project. The MARS was designed to assess the useability of mobile applications and specifically mobile health applications. Whilst other general useability tools such as the System Usability Scale (SUS) or the Usability Testing Evaluation Questionnaire (UTEQ) have a broad applicability, the MARS is far more suited to this project. Figure 30 provides an

overview of the sections of the MARS, with the specific implementation used in this study shown in Appendix B.

Thematic analysis was performed on a set of interviews conducted at the end of the extended-use study. Transcripts and recordings were taken of the interviews, so that key themes could be understood.

Test cases were created from the user stories gathered through the user requirements analysis. The test cases were designed to assess the useability of the application through various scenarios, providing a pass or fail based on whether they satisfied the criteria of the test case.

Pilot Study

Prior to user testing the application was uploaded to the Google Play Store using the Google Developer Console (Google n.d.). The software allows a user to launch an application to testers as well as publicly publish the application. For the initial round of user testing internal testing was chosen to control and limit the usage of the application to just the selected users.

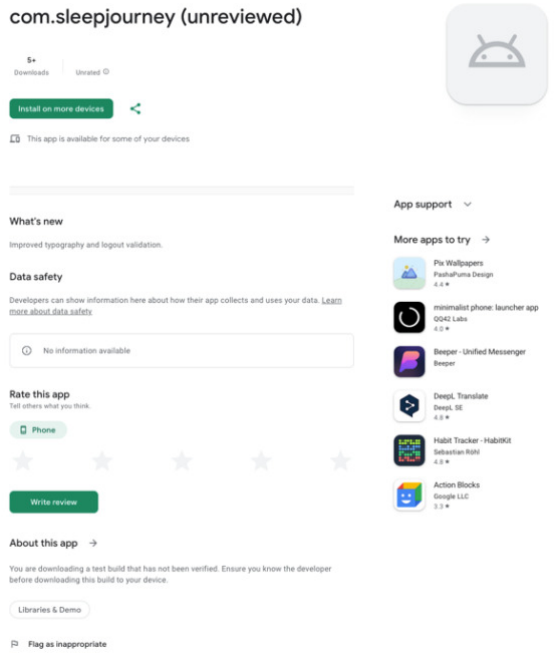


Figure 31: Google Play Store listing for the prototype application with the updated release changes after the pilot testing.

The Developer Console allows a developer to create releases and update the application with new versions. These app bundles are created through Android Studio (Google, 2022) and use Gradle (Gradle Inc., 2023) to bundle the source code for release. This was very useful as a pilot test was run with both the project supervisor and another selected user. The pilot test aimed to look at the downloading and initial setup of the application to ensure this provided no problems for the user testing. On the back of this initial testing a setup

instruction manual was created as there were several unusual behaviours when downloading an internal testing application through the Google Play Store. Whilst not a formal test case these instructions allowed the users to successfully use the Google testing platform to download and install the application.

The pilot testing also highlighted some readability problems as well as a lack of confirmation checks for the user when signing out. Changes were made to the typography as well as adding a confirmation prompt to the sign out button to improve the user experience.

Procedure

The user testing was split into two parts, participants were asked to meet and set up the application on day one of the testing, this allowed useability testing to be completed on the application setup. Test cases were used to verify the applications useability against the requirements, all test cases excluding 7, 8 and 9 were performed in person and participants were encouraged to think aloud during each test case. Results were captured and any changes required upon a failed test were documented. Test cases 7,8 and 9 were performed remotely at the end of the extended-use study. The individual test cases are shown in the results section of this chapter.

On day one participants were given Type 2 NFC tags for the duration of the study, and were asked to setup three habits for the sleep routine:

- A pre-existing habit (suggestion being brushing teeth)
- A new habit they wanted to incorporate.
- A final pre-defined habit of placing the phone away from the bed before sleep.

This routine allowed for a level of individuality whilst still following a set structure for the testing. Participants were then asked to use the application for five nights before bed, to better understand the impact of this application on a pre-sleep routine. Participants would go about their normal day and upon brushing their teeth, begin the sleep routine by scanning the first tag. Participants were encouraged to complete the sleep routine however they felt best and finish the routine by leaving the phone on the final tag. On the sixth day the participants were asked to meet virtually so a longer evaluation could be performed. The participants were given the Mobile App Rating Scale (MARS), the final test cases (7, 8 and 9) were completed, and an interview was conducted with the participants to evaluate their experience both qualitatively and quantitatively.

Analysis

Mobile App Rating Scale (MARS)

The MARS is divided into sections as shown in Figure 30 with each section given a mean score based on the results from the 6 individual participants. The app quality score is the mean score of sections A to D, the subjective app quality provides insight into the participants perceived interest in the application and the app specific score shows how much the participants felt the app prompted behaviour change. The full details of the MARS

implementation for this study are shown in Appendix B. To analyse the results of the MARS the results were compared to a comparative study performed by (Salazar et al. 2018). The study compared the MARS results of 18 health applications and ranked those applications from best to worst.

Thematic Analysis

(Braun and Clarke 2006) detail a step-by-step process for performing thematic analysis which was used as a blueprint to identify themes present within the data and to better understand and answer the key question of this research. Whilst some of the data aligned with previous expectations there were a few areas which emerged which were not anticipated.

Test Cases

Each test case has a set of expected results and the actual results which were observed. The test cases receive a pass or fail based on whether the actual results across all participants matches the expected results. Failed tests contain a proposed change intended to bring the test case up to the correct standard.

Results

Mobile App Rating Scale (MARS)

Table 1 shows the results of the MARS assessment given to the participants, the scores for each section are calculated on a scale of 1 (inadequate) to 5 (excellent). When comparing these mean scores displayed in Table 1 to a study on 18 health applications performed by (Salazar et al. 2018), we can see that best rated applications in that study had an app quality score of 4.0 and interestingly an app specific score of 3.51. The prototype created for this project falls in line with the highest rated apps from that study and shows some promising signs of promoting behaviour change through its features.

Table 1: Results of the MARS completed by the six participants.

Section	Mean Score
A: Engagement	3.4
B: Functionality	4.5
C: Aesthetics	4.6
D: Information	2.7
E: Subjective App Quality	3.7
F: App Specific	3.8
App Quality Score (A – D)	3.8

Thematic Analysis

Theme 1 – Engaging in Kinetic Routines through NFC interaction.

All participants talked about the benefit of physically scanning the tags as they completed the routine and how that provided motivation compared to previous apps they had used with similar function. NFC tags were chosen to provide a more tangible experience and take away from the purely digital aspect of using a mobile application, it is clear from the interviews that the participants enjoyed the active engagement this provided:

"*I really like the physical element, when I've used similar apps, they lack that, which is really nice and unique*". **Participant 2**

"*Somehow it adds extra gratification for completing the task*". **Participant 1**

However, some participants talked about placing the tag in a difficult to reach area or having the tags spaced around the house causing a level of friction. The ability to choose any habit and more importantly place the tag anywhere the participant wanted introduced an important consideration. The NFC tag placement can act as a valuable customisation for the user however, thoughtful placement of the tag should be encouraged as there is a balance to be found between engaging physical interaction and effortless interaction:

"*I couldn't scan the tag because of where I had stuck it so had to move the tag to another location*". **Participant 2**

"*I would walk downstairs to prepare my lunch and forget my phone having to walk back upstairs first before I could scan the tag, got my step count up at least*". **Participant 3**

Having to scan the tag whilst doing the habit was also seen as of benefit, providing a greater connection between the app and the habit itself. As described in earlier chapters visual cues play a significant role in habit formation (Khan et al. 2021). Having to scan the tag and mark it done in the same place increases the location context for that habit and improves the association of the cues given by the application:

"*I found it useful seeing my toothbrush and having to the scan the tag next to it, instead of marking something as done later on*". **Participant 2**

"*It's different to having an app where I just mark things as tick, tick, tick, done. Instead of having the physical aspect*." **Participant 4**

There was however still a learning curve involved for some participants with using the NFC tag, so lowering that difficulty threshold as much as possible is important. More detailed instructions and clear guidance around the use of NFC tags would have been of benefit, including as touched on earlier intuitive placement suggestions. These aspects would

increase the ease of use for the user and therefore ensure reliability and consistency in the use of the application:

"*I had a couple times where I couldn't get the tag to scan which I couldn't work out*". **Participant 6**

"*I hadn't seen NFC tags before so wasn't sure where best to place them or which habits to choose*". **Participant 5**

One participant had previously used NFC technology for a diabetes monitor and commented on how seamless it was to use having used the technology before and other participants also didn't find the technology challenging. It is important to remember and design for those with the least knowledge of a technology, however, as NFC technology continues to be more readily used, knowledge in this area will increase:

"*I use one to scan for my diabetes monitor, so it worked just the same*". **Participant 3**

Theme 2 – The balance between customisation and simplicity.

Participants made several comments about the ease of setting up the application as well as the simplicity of starting the routine each night. These comments highlight the importance and desire for simplicity and ease of setup in an application aimed at behaviour change. Effortless interaction was a key design feature, and the participants reinforced the success of this within the application:

"*It's so easy and sleek, it's really simple to use, so you know when you first use it, it really isn't that complicated*". **Participant 1**

"*Being able to see the tag and just tap my phone and it would just pop up, it's pretty cool how you don't have to go looking for the app*". **Participant 6**

However, nearly all participants wanted more customisation features within the application whilst also previously commenting on how they liked the clean and minimal approach. Finding a way to test and incrementally introduce features for those who desire more complexed features would likely be an ongoing challenge in the application design. The priority would be maintaining the minimal interface and core science based features whilst providing discoverable optional features that enhance the user experience:

"*I would like an option to input my shift patterns*." **Participant 3**

"*It would be cool to add a timer option to the tasks to track how long we did them*." **Participant 5**

"*I want to set new habits and have a longer journey*". **Participant 1**

Participants were encouraged to create a unique sleep routine for them to bring individuality to their habits, however allowing that customisation created issues for some. This is the key point with customisation and a problem with developing a feature rich application. The individuality being sought to improve habit formation can lead to a potential risk of discouragement from using the application:

"*I put one of my habits as packing lunch for the next day, I realised I should have done something more sleep routine as I ended up and down the stairs a lot*". **Participant 2**

"*I wanted to change my habit after the first day but thought that would mess things up*" **Participant 6**

Theme 3 – Finding consistency in the irregular.

When designing the application, the user personas were referenced to ensure the user needs were met, the two personas Emma and Mark who were reluctant to change informed a minimal and simplified app design. However, Participant 3 who at first glance fit into the persona of Mark, was a night shift worker which hadn't been accounted for and so found challenges with integrating their routine with the application:

"*The history screen didn't work for me; it's not adjusted for the fact I do night shifts*". **Participant 3**

They managed to complete the sleep journey after every shift, but the inaccuracy of the data caused a negative association with the app. This was a significant discovery, if the participant felt the application wasn't intended for their use there is a significant chance of quick abandonment or lack of adoption:

"*I've done it every day, but I have a day missing which is really frustrating*." **Participant 3**

Other participants commented on how it worked well during their normal working week but on the weekend didn't fit into what they were doing, this was also when frustrations around the data the app showed started to appear. Again showing how if the design doesn't feel like it caters to the participants lifestyle or introduces complexity and inaccuracy there is a negative association created:

"*Monday to Thursday it worked great but when it got to the weekend, and I was out later it became hard to still do the routine*". **Participant 2**

"*It was 2am and I had forgotten to do it that night but was tired so just went to bed*". **Participant 4**

"*It was after midnight so even though I did it the app didn't count it*". **Participant 1**

However, all 6 participants used their phone in bed prior to the study and most commented on how after the first couple of days they slept better and kept their phone away from the

bed, even on days they struggled with the journey. This discovery highlights that the frustrations were more around the feeling of the application design not matching their lifestyle:

"*Normally I'm sat there on my phone scrolling, and I was like, no, no, no*" **Participant 4**

"*100% I avoided lying in bed and scrolling*." **Participant 5**

"*It was late, but I had to make sure my phone was on the other side of the room*." **Participant 2**

This final point is key and an area for further research. The application design needs to be able to handle the complexity and individuality of different sleep schedules, especially for individuals who don't have standard working patterns. However, as highlighted in Theme 2 that amount of customisation needs to not come at the expense of the rest of the applications purpose. Solutions to this problem are explored further in the Future research section of this project.

Test cases

Test Case 1	**Related User Story 1**
Title	Verify Onboarding Screen Functionality
Description	User is shown the onboarding screen on first launch of the application.
Expected Results	• Onboarding screen shown on application download. • Users can navigate through onboarding screen using swipe or buttons. • Users are taken to login screen on pressing done button. • Users are not shown onboarding on subsequent app launches.
Actual Result	• Onboarding appeared as expected on first launch. • Users were able to navigate using swipe and buttons effectively. • Pressing done took the users to the sign in screen. • On subsequent relaunches users bypassed the onboarding screen to the application content.
Status	**Pass**
Proposed changes	N/A

Test Case 2	Related User Story 2
Title	Verify Account Creation
Description	Verify that a user can create an account to login to the application.
Expected Results	• Users should be able to navigate to the sign-up screen from the sign in screen. • Users should be able to input email and password to create an account. • Users should receive feedback if email or password do not meet validation and should be able to try again. • Users should be able to press the sign up button to create an account. • Users are taken to the home screen upon successful account creation.
Actual Result	• Users were able to press the button on screen to navigate to the sign up screen. • Users were able to input both email and password. • Users were provided on screen feedback of failed validation and could input details again. • Users were able to press the sign up button and create an account. • Upon successful account creation users were taken to the home screen.
Status	Pass
Proposed changes	N/A

Test Case 3	Related User Story 3
Title	Verify Sign in
Description	Verify users can sign into the application and remain signed in until user explicitly signs out.
Expected Results	• Users should be able to input email and password. • Users should receive feedback if email and password do not meet validation requirements and should be able to try again. • Users should be able to press the sign in button and be redirected to the home screen. • Users should remain signed in until the sign out button is pressed.
Actual Result	• Users were able to input both email and password. • Users were provided on screen feedback if either email or password failed to meet validation. • Users were able to try again to input email and password. • Users were able to press the sign in button and were redirected to the home screen. • Users remained signed in until the sign out button was pressed including on app close.
Status	Pass

Test Case 4	Related User Story 4
Title	Verify Sleep Journey creation.
Description	Verify users can create a sleep journey by adding three habits, each associated to an NFC tag.
Expected Results	• Users should be able to press the create habit button. • Users should be redirected to the habit creation screen. • Users should be able to input a habit name. • Users should be able to press the add habit button. • Users should be shown the NFC prompt and able to write to an NFC tag. • Users should be notified if any errors occur and should be able to try again. • Users should be redirected to the sleep journey setup screen with the added habit displayed along with an associated image. • Users should be able to repeat these steps twice more to complete the journey setup.
Actual Result	• Users were able to press the habit creation button. • Users were redirected to the habit creation screen. • Users were able to input a habit name. • Users were able to press the add habit button and received the NFC prompt. • A User was not able to scan the NFC tag due to NFC not being enabled on mobile device. • Users were notified of errors in scanning but the user with NFC disabled received no feedback. • Upon turning on NFC all users were able to Scan and be redirected to the Journey setup screen with habit and image displayed. • Users were able to repeat twice more and complete the journey setup.
Status	**Fail**
Proposed changes	Add a function to check if NFC features are available and enabled on device. Direct user to enable NFC or provide feedback if NFC is not available on device.
Proposed changes	N/A

Test Case 5	Related User Story 5
Title	Verify Editing a habit.
Description	Verify users can edit an individual habit to update a sleep journey.
Expected Results	• Users should be able to press the edit button associated to a habit. • Users should be redirected to the habit update screen. • The current habit name should be displayed to the user, which can be updated through the input field. • Users should be able to press the edit habit button.

	• Users should be shown the NFC prompt and able to write to an NFC tag. • Users should be notified if any errors occur and should be able to try again. • Users should be redirected to the sleep journey setup screen with the updated habit displayed along with an associated image.
Actual Result	• Users were able to press the edit button. • Users were redirected to the habit update screen. • The current habit was displayed to the users. • Users were able to input a new habit name. • Users were able to press the edit habit button and the NFC prompt was displayed. • Users were able to update the habit but there was no check to make sure the tag they scanned was the correct one. • Users were redirected to the journey setup screen with the updated habit name showing
Status	**Fail**
Proposed changes	A validation check needs to be performed on writing to the NFC tag to ensure the habit being updated is the one stored in the tag. If not, the user should be notified.

Test Case 6	**Related User Story 6**
Title	Verify Deleting a habit.
Description	Verify users can delete an individual habit to update a sleep journey.
Expected Results	• Users should be able to press the edit button associated to a habit. • Users should be redirected to the habit update screen. • Users should be able to press the delete habit button. • Users should be asked to confirm deletion. • On confirm users should be redirected to the sleep journey setup screen with the deleted habit no longer displaying in the list. • On cancel users should be shown the habit update screen.
Actual Result	• Users were able to press the edit button. • Users were redirected to the habit update screen. • Users were able to press the delete habit button. • Users were shown a confirmation notification. • Users could confirm and be redirected with the habit removed from the database and no longer displaying in the list. • Users could cancel and remain on the habit update screen.
Status	**PASS**
Proposed changes	N/A

Test Case # - 7	Related User Story # - 7
Title	Verify sleep journey start
Description	Verify users can scan an NFC tag associated with the first habit in the sleep journey.
Expected Results	• Users should be able to press the Time For Bed button. • Users should be shown the NFC prompt with the first habit shown. • Users should be able to scan the NFC tag. • Users should be notified if the tag scanned is not the first habit and able to try again. • Users should be redirect to the sleep journey screen with the first habit completed. • Users should also be able to launch the application and start the sleep journey by scanning the first tag in the journey.
Actual Result	• Users were able to press the Time For Bed button. • Users were shown the NFC prompt with the correct habit shown. • Users were able to scan the NFC tag. • Users were provided feedback if the tag was not the first habit in the journey. • Users were taken to the journey screen with the first habit checked if correct tag scanned. • User were able to launch the application and start the sleep journey by scanning the first habit tag.
Status	**PASS**
Proposed changes	N/A

Test Case # - 8	Related User Story # - 8
Title	Verify sleep journey completion.
Description	Verify users can complete the sleep journey by scanning NFC tags associated with habits and returning to the home screen.
Expected Results	• Users should be able to press the Press to Continue button. • Users should be shown the NFC prompt with the next habit displayed. • Users should be able to scan the NFC tag. • Users should be notified if the tag scanned is not the next habit in the sleep journey. • Users should receive on screen feedback upon scanning the final habit in the journey. • Users should not need to interact with the application upon final tag being scanned and should be returned to the home screen.
Actual Result	• Users were able to press the Press to continue button.

	• Users were shown the NFC prompt with the correct habit shown. • Users were able to scan the NFC tag. • Users were provided feedback if the tag was not the next habit in the journey. • Users were shown the good night text feedback upon scanning the final tag. • User were redirected to the home screen upon seeing the feedback text.
Status	**PASS**
Proposed changes	N/A

Test Case # - 9	**Related User Story # - 9**
Title	Verify history functionality
Description	Verify users can navigate to the history screen and view accurate data from completed sleep journeys.
Expected Results	• Users should be able to press the history icon in the bottom tab navigator. • Users should be redirected to the history screen. • Users should be shown a calendar representation of completed sleep journeys. • Users should be shown current and longest streak. • Users should be shown current and average time to bed.
Actual Result	• Users were able to navigate to the history screen using the bottom tab navigator. • Users were not shown an accurate representation of completed sleep journeys. • Users were not shown an accurate current and longest streak. • Users were shown current and average time to bed.
Status	**FAIL**
Proposed changes	Due to two participants working night shifts and shift work the data collected was not accurate enough to provide valuable data. Introduce a more accurate representation for users with abnormal sleep patterns.

Test Case # - 10	**Related User Story # - 10**
Title	Verify sign out functionality.
Description	Verify users can navigate to the settings screen from the home screen and sign out of the application.
Expected Results	• Users should be able to press the settings icon in the header of the home screen. • Users should be redirected to the settings screen. • Users should be shown information about the application as well as a sign out button.

	• Users should be able to press the sign out button. • Users should be shown a confirmation prompt. • Users should be able to confirm to sign out and cancel to return to the settings screen.
Actual Result	• Users were able to navigate to the settings screen from the home screen. • Users were shown information about the application as well as a sign out button. • Users were able to press the sign out button and received a confirmation prompt. • Users were able to confirm and be signed out of the application or cancel and remain on the settings screen.
Status	**PASS**
Proposed changes	N/A

The results from the tests cases show a need to address a few areas to ensure the application is fit for purpose and provides the right user experience to be effective. Whilst some of the test cases highlight useability improvements which can be addressed using improved UI/UX design, Test Case 9 highlights a wider issue which needs to be explored further to properly understand and improve the implementation.

Application updates

Following on from the user testing a set of updates were made to the application to reflect the improvements needed to fulfil the test cases and better enhance the experience the participants had testing the application.

Test Case 4

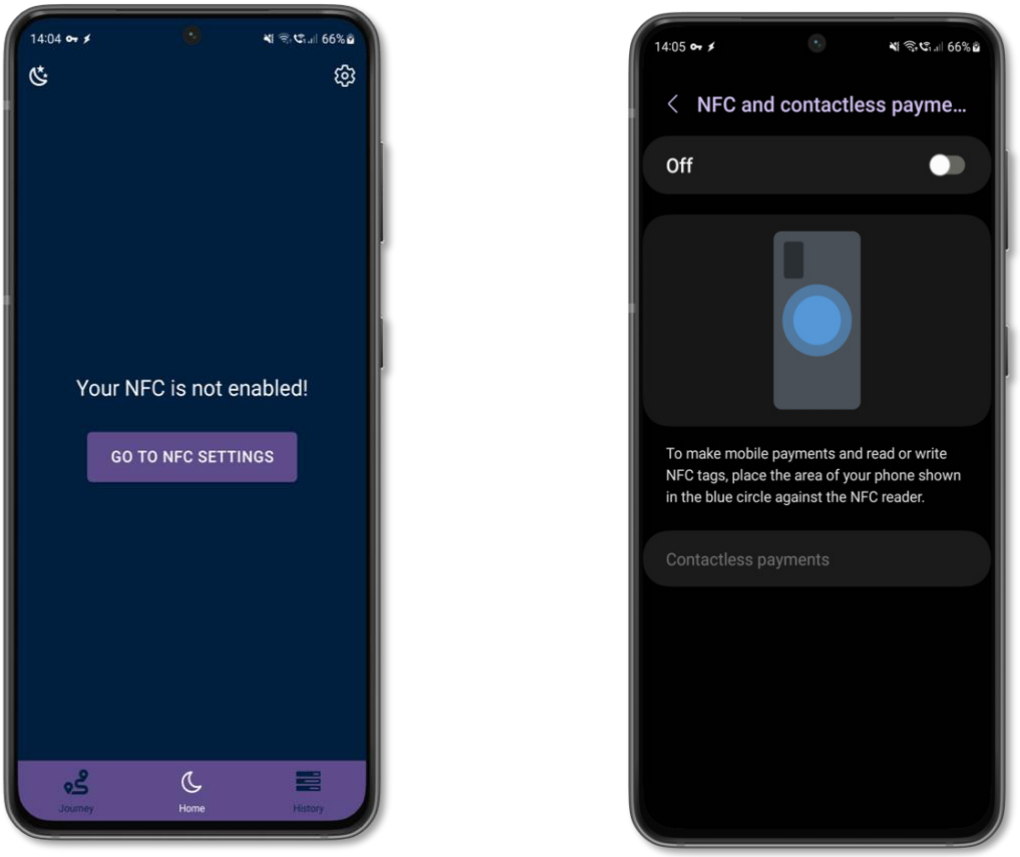


Figure 32: Home Screen when NFC is not enabled and destination of button press.

Figures 32 shows the updated home screen for a user with NFC not enabled on their device. The user can press the button on the home screen and is taken to the NFC section of the settings for the device, introducing a quick and efficient solution to the results found in test case 4. Figure 33 shows the implementation of this solution. A useEffect hook checks the NFC status on screen mount through the checkNFC async function and when the screen comes into focus with the NFCFocusListener. The button displayed to the user makes use of the NfcManager.goToNfcSetting() method which takes the user directly to the correct settings screen.

```
React.useEffect(() => {
  const checkNfcStatus = async () => {
    const supported = await NfcManager.isSupported();
    if (supported) {
      const enabled = await NfcManager.isEnabled();
      setEnabled(enabled);
    }
    setHasNfc(supported);
  };

  checkNfcStatus();

  const NFCFocusListener = navigation.addListener('focus', checkNfcStatus);

  return () => NFCFocusListener();
}, [navigation]);
```

Figure 33: Async function to check mobile device NFC status.

These updates ensure that Test Case 4 satisfies the pass criteria and improves the user experience for the failed test case by providing a quick and efficient solution for the user to not only identify that they have NFC disabled but to take them directly to the location to be able to enable it.

Test Case 5

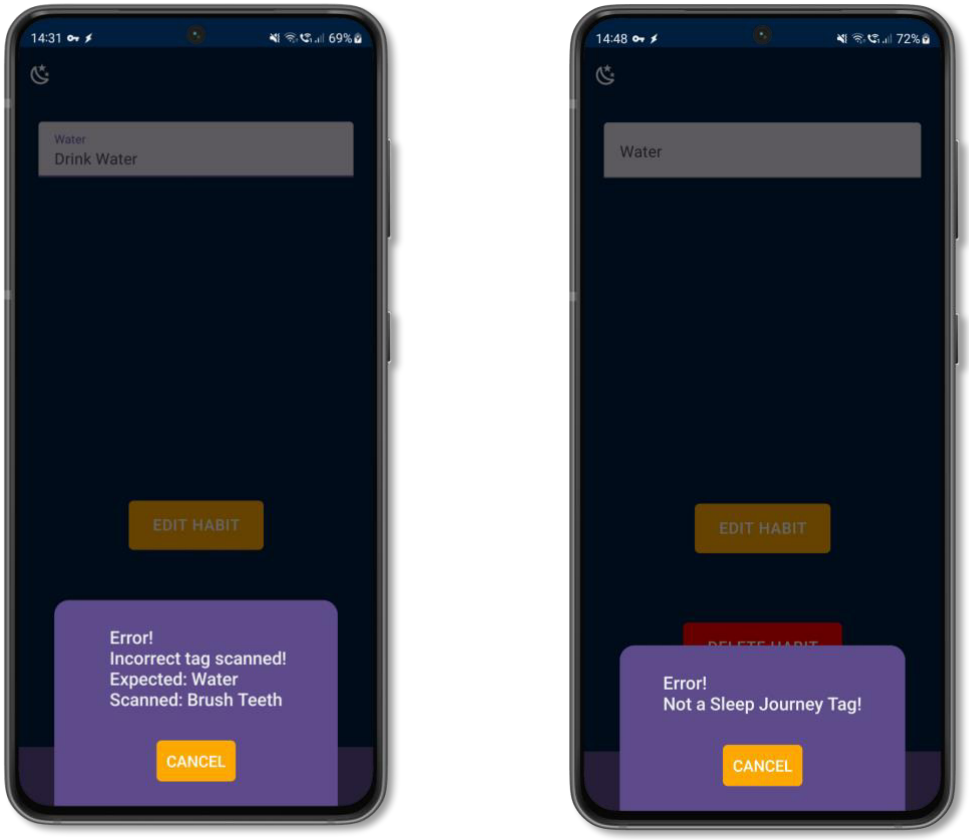


Figure 34: NFC Prompt error messages when incorrect NFC tag is scanned.

Figure 34 shows the error messages provided to the user when an incorrect habit is scanned as well as when an NFC tag is scanned which doesn't match the URI for Sleep Journey. When using NFC tags it was important the user doesn't get confused between the tags they are using. Providing detailed feedback to the user prevents confusion and allows them to quickly understand and correct any mistakes made when editing a habit. Figure 35 shows the logic involved for handling the error messages and ensuring the edit habit function works correctly, ensuring Test Case 5 passes on a subsequent testing.

```
if (!uri || uri.split('://')[0] !== scheme.slice(0, -3)) {
  androidPromptRef.current.setHintText(`Error!\nNot a Sleep Journey Tag!`);
  return;
}
let scannedHabitName = uri.split('://')[1];

if (scannedHabitName.toLowerCase() !== habitName.toLowerCase()) {
  androidPromptRef.current.setHintText(
    `Error!\n Incorrect tag scanned!\n Expected: ${habitName}\n Scanned: ${scannedHabitName}`
  );
  return;
};
```

Figure 35: Validation logic on an edited tag.

The user testing involved the gathering of significant amount of data, some of which aligned with expectations and some which came as a surprised during the process. Following the updates made to the application which satisfied the test cases it was important to better understand the results to be able to draw clear and accurate conclusions.

Discussion

Upon revisiting the aim of this project to build an application to better promote sleep routines, this research highlights the potential of NFC technology as a novel intervention. The user-centric design choices and science-based features have shown to be effective in not just addressing a diverse range of user needs but also in developing potential behavioural changes. However, the limitations uncovered with users who have non-standard sleep patterns shows the need for development of further adaptive and individualised systems. These findings echo (Pinder et al. 2018), who highlighted the need for flexibility and individuality in health based behavioural interventions. Further iterations of the prototype will need to address these challenges to ensure effectiveness for all users of the application.

As stated earlier it was important that this project focussed on the real word applicability of the prototype application, hence this was the reasoning behind a user-centric approach and extended-use study. The results of the test cases and subsequent changes show an overall success in the outcome of that objective. (Stawarz et al. 2023) showed that the design of an application can negatively influence the desire of an individual to engage with it, even if the function is of benefit to the individual. To properly assess the effectiveness of the prototype in its potential for behaviour change, the approach needed to ensure that the design and aesthetics of the application didn't hinder that in any way, even during these early stages of development. The continued reinforcement from the participants through the MARS and interviews around the overall appeal of the application proves this as a success. It also underscores the importance of visually appealing and robust application design.

The test cases showcase a functional and useable application that achieves what was set out in the planning and design, however it also highlighted a crucial insight around the design of applications promoting sleep hygiene. Test case 9 which focussed on the data stored about the users sleep journeys reveals the importance of accuracy and flexibility within the application. The inability of the application to effectively track and display information about sleep journeys for users with non-standard sleep patterns (e.g. shift workers) is a critical discovery. The limitation in the design is significant as it has the potential to alienate and discourage a large portion of potential users. Alongside this point the fact that even those on more typical sleep patterns found challenges when those patterns were disrupted increases the need for a specific and individualised solution, especially when a mobile application records data and presents that back to the user.

(Pinder et al. 2018) stressed the importance of seeking to individualise any solution looking to affect behaviour change. Through the customisation offered to the user in a sleep journey and by allowing the user to select their own habit triggers and cues the application aimed to employ a "pick and mix" style approach and increase that individuality. As well as the attempt to foster both unconscious (the initial trigger) and conscious (the subsequent journey) processes when using the application.

(Verplanken and Orbell 2022) described how 'piggybacking' off existing routines maybe a way to overcome the problem of context in relation to habit formation which this application has implemented to early success. The participants descriptions as well as the high app

specific score on the MARS shows promise that this approach does have the potential for improving an individual's sleep routine and reinforces the potential effectiveness of chaining together habits (Judah et al. 2013).

An area related to the inaccuracy of data was the implementation of streaks within the application. (Renfree et al. 2016) identified that many users perceived reminders and streaks as the most useful features for supporting repetition. Reminders were excluded as an option from this application due to the potential for technological dependency, however, streaks were implemented in a minimal way to increase gamification whilst attempting to maintain the non-conscious aspects of habit formation. During the interviews streaks were a popular subject and the fear of losing a streak was mentioned by several participants. However, of greater interest was the frustration with the lack of accuracy in the streak for those users with non-standard sleep patterns. The inclusion of streaks generated several negative responses about the application from those participants and reinforces the need for applications to implement these features in a more effective way. The inclusion of the feature for those users made them feel as if the application was not designed for them.

Simplicity and low friction were key throughout the development of the application, which was commented on highly and scored well across the MARS sections, with both functionality and aesthetics scoring extremely high. However, the lower scores in engagement and information are also a reflection of this more minimal approach. The participants provided several suggestions of ways to improve the application when prompted, including adding a bedtime reminder, more detailed data around the sleep habits as well as allowing for longer and more customisable sleep routines. Whilst they continually praised the simple and easy to use approach the participants also wanted features to make the application more engaging and exciting to use.

The use of NFC technology in the application was overall very successful. The immediate feedback the user receives upon scanning the tag combined with the physical act itself provided the participants with motivation and introduced a unique element most hadn't seen before. Whilst there are some challenges introduced due to location and placement of NFC tags, better information and direction in the app could help to significantly mitigate those problems encountered. Particularly interesting was the greater association with the habit itself when scanning. The interaction of scanning the tag and using the previous habit as a cue for the next shows promising potential and falls in line with the findings of (Khan et al. 2021), who identified the strength of visual cues in habit formation.

Future Research

There are several promising directions for future research that the findings from this study have revealed. With the increase of sleep related disorders such as obstructive sleep apnoea (Lyons et al. 2020) and the high global levels of sleep disruption (ResMed Inc. 2023) it is important that research continues to find effective interventions for these issues.

Longitudinal studies

Whilst important information was gathered from the studies performed in this research to fully understand the extent with which the application can affect habit formation and long-term behaviour change, longer more in-depth studies need to be performed. Future studies should look to include a larger sample size and more diverse participants. The inclusion of shift workers revealed valuable insights in this study, continuing to broaden the participation in future studies will help to deepen the understanding of the complex challenge of behaviour change involving sleep. This includes involving participants with varied sleep patterns and diverse sleep problems to better understand how those with existing sleep problems are affected. The studies should then be performed over a significant period to critically evaluate the strengths and weaknesses of the intervention.

Technological advancements

NFC technology is continuing to evolve, and new potential use cases are emerging from those advancements, two areas of prominent research are NFC biosensors (Lazaro et al. 2023) and battery-free NFC sensor systems (Escobedo et al. 2021). As the technology grows and comparative technologies grow along side, this should be evaluated and contrasted to reveal the continued efficacy of such solutions.

As discussed, one of the important challenges in habit formation is that of context and behavioural understanding, with the advancements in machine learning (ML) this is a key area with which models could be employed to better understand and deliver individualised solutions to these problems. (Singh et al. 2017) proposed a ML model that analyses a person's mood and suggests activities the user would prefer in that current mood, exploring options such as this could enhance the adaptability and specificity of the application.

Iterative design components

The process of design and development for the application was iterative and as such there were design elements which were not included to focus the research as well as due to time constraints. A potential expansion of the current application would be to include a morning routine option to allow the user to perform a sleep journey in reverse upon waking up. This could allow the individual to further enhance their sleep hygiene and create more intentional use of the mobile device around sleep. Alongside having the smartphone in bed prior to sleep another key time for overuse of the mobile phone has been identified just after waking up (Oulasvirta et al. 2012).

This project has touched on a wide range of topics from behavioural psychology, mobile health technology, sleep-related issues and application design, the findings not only contribute to the existing research in such areas but provide directions for new innovations in health technology.

Conclusion

This project has explored the important topics of sleep, technology usage and behaviour, in particular the potential of NFC technology to promote better sleep routines. The findings in this study have practical implications for both developers and healthcare professionals, as well as confirming and expanding upon the current literature in these fields.

The results gathered through this project show a potential for NFC technology to promote better sleep routines and explores an implementation which aims to improve rather than disrupt the users sleep hygiene. The results highlight how technology can be used as an effective tool in promoting better sleep habits.

The approach taken in this project also demonstrates how a user centric approach to design can effectively provide the end user with the correct preferences and needs in a prototype application. The methodology and documentation throughout ensures that the final iteration of this project not only achieves the intended aim but does so in a way that will be effective and appealing to those in the intended audience group.

A key insight uncovered during this project was the challenges faced when designing sleep routine interventions for individuals with non-standard sleep patterns. This discovery presents an interesting direction for future research and one which could help to design more effective and more inclusive sleep hygiene tools. The significance of individualised solutions for both sleep problems and in habit formation has been emphasised in this project and the continued research in this direction could lead to significant advancements in both areas.

In conclusion, this project not only achieves it stated aim of developing a mobile application to promote the formation of better sleep routines but also provides valuable insights for future research.

Reflection on Learning

Following the conclusion of this research I will now use this next chapter to critically assess the learning I have taken away from both the research process itself and my personal development through this period of study.

Learning Outcomes

As with any endeavour it is important to have a set of defined learning outcomes, I have continually used those set out in the project handbook of this course to assess and update my approach.

Undertaking a literature review was a vital part of this project and the evaluation of current research helped steer the direction of many of the decision made in developing the prototype application. Whilst I had previous experience analysing literature, doing so in the field of computing was new to me. Given the broad range of subjects addressed in this project, from psychology, health, sleep, behaviour, and mobile technology, I did at times find it challenging to refine and concentrate my evaluation. Whilst it was important to explore all these subjects to understand the fullest picture of the dissertation title, in future I would look to be more selective and focussed on how I approach this area of the project to avoid any potential for missing information, or not being able to go deep enough Into a topic due to the breadth of research.

Many of the modules I worked through on this course provided me with opportunities to refine my ability to communicate ideas, as well as the time I spent on placement which was invaluable in developing not only my programming skills but a whole range of other skills. This was instrumental in both the writing of the dissertation and in the information given to the participants of the studies, including the information present within the application. Using diagrams such as use cases, tables for the conveying of results and structured writing for the delivery of conclusions allowed me to express the research in a clear and detailed way. The time I spent on placement also allowed me to understand communication through UX/UI in a practical way which was key to the success of the application I built.

Whilst the support and guidance from my supervisor was invaluable in this process, the skills I obtained throughout my time as a master's student enabled me to drive and plan this project from start to finish. Having worked in a team which used a Scrum approach in a course module and within a team which used a Scrumban approach during my time on placement I was able to map out and divide my time effectively using the lessons I learnt from both approaches, this was particularly effective in the development stages of the project (Nikitina et al. 2012). Dividing my time into weeklong sprints each with a target workload to achieve and having knowledge of potential technological challenges such as preparing a production environment was crucial in effective time management. Utilising Jira boards (Atlassian 2023), wireframe designing, and iterative workflows all skills I had developed over my student journey allowed for a successful but more importantly time mapped prototype to be developed.

Whilst the technologies and tools I chose to use for this project were successful in achieving the aims and objectives set out, I would make several changes from the lessons learned through this process. In designing and developing the prototype, a considerable amount of time was taken in the planning and pre-design phases of the project. Having the overall planned structure of the project allowed me not to feel pressured to start coding and developing too soon. Trusting in my planning was key to having a well thought out and achievable design. In hindsight though, I was almost too rigid in my sprints as it meant that certain features which would have been interesting to explore were left out of the prototype, and the scope of the project was slightly restricted by this approach. Also to leave the door open for IOS development I chose React Native as the technology for development, however, due to time restrictions IOS development never really became a viable option. This decision restricted my potential participant pool but more importantly closed the door on other technologies which could have been used for this project. I found several challenges with React Native, not least with a rather slow development process. In the future I would think even more critically about the development tools I use and not be afraid to focus my development to a specific area. The plan to initially build an MVP mobile application through to production was invaluable. Knowing I had the facility to introduce releases to my production application and utilising pseudocode designs and atomic features allowed me to effectively iterate on a production ready application. The Google Play Store Console has an evaluation period before allowing an application to be released, had I not planned this out early in the process I would not have been able to successfully release my application to the Play Store, and subsequently not allowed my participants to use the application for an extended-use study. Having a map and timeline spanning the entirety of the project allowed for these kinds of decisions to be made and meant I wasn't restricted due to not acting early enough of tasks.

Project Objectives

Along with the learning outcomes I also set several objectives at the start of this project, they formed the blueprint by which this project evolved. Some have already been touched upon through the learning outcomes the rest will be explored below.

One area which hindered the project somewhat was that of the initial user requirement analysis. I understood the importance of conducting effective and thorough user requirements however, due to time constraints and attempting to produce an effective survey I lacked some detail in the data gathered from the initial user survey. Whilst I had a good amount of participation in the survey there were several questions which had I asked may have provided valuable insights, most notably the discovery around shift workers and sleep habits. In future I would look to strike more of a balance between creating an effective survey and getting the information I require out of it. The decision to allow the longer answers to be optional in the survey also contributed to this, while it was effective in getting users to complete the survey evidenced by the fact no one stopped before the final question, I potentially missed out on valuable insights due to the reduced data on those questions.

Upon completion of the prototype application user testing was conducted. As already stated, this was an extended-use study and one of the reasons this project was successful was the decision to make the final study extended-use. The decision did bring challenges and reduced the overall time of the project; however, It was undoubtably the reason several of the discoveries were made during the testing. The choice to also evaluate the study across useability test cases, MARS, and thematic analysis, provided a breadth of data and allowed for a thorough investigation and understanding of the research question to be performed. These decisions along with updates and improvement to the application, documentation, changing the order of approach and structure allowed for a detailed and robust analysis to be implemented.

Finally looking back across the entire project there were challenges and many strengths and weaknesses I discovered about myself throughout the process. However, zooming out and looking at the overall aim of the project, this study delivers a prototype mobile application which helps promote the formation of better sleep routines using NFC technology. As with the other parts of my time as a master's student I will look to build on and continually grow from the challenging yet fulfilling process it has offered.

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Appendix

Appendix A – User Requirements Survey Results

MSc Computing: Sleep Routine Survey

33	02:19	Active
Responses	Average time to complete	Status

1. I confirm that I have read the information sheet dated 22/07/22 version 1.0 for the above research project.

Yes	33

2. I confirm that I have understood the information sheet dated 22/07/22 version 1.0 for the above research project and that I have had the opportunity to ask questions and that these have been answered satisfactorily

Yes	33

3. I understand that my participation is voluntary and I am free to withdraw at any time without giving a reason and without any adverse consequences (e.g. to medical care or legal rights, if relevant). I understand that if I withdraw, information
about me that has already been obtained may be kept by Cardiff University.

Yes 33

4. I understand that data collected during the research project may be looked at by individuals from Cardiff University or from regulatory authorities, where it is relevant to my taking part in the research project. I give permission for these individuals to have access to my data.

Yes 33

5. I consent to the processing of my personal information; name, email address. For the purposes explained to me. I understand that such information will be held in accordance with all applicable data protection legislation and in strict confidence,unless disclosure is required by law or professional obligation.

Yes 33

6. I understand who will have access to personal information provided, how the data will be stored and what will happen to the data at the end of the research project.

Yes 33

7. I understand that anonymised excerpts and/or verbatim quotes from my QUESTIONNAIRE may be used as part of the research publication.

Yes 33

8. I understand how the findings and results of the research project will be written up and published.

Yes 33

9. I understand that I must be above the age of 18 to participate in this study

Yes 33

10. I agree to take part in this research project.

yes	33

11. Do you have a consistent pre-sleep routine that you follow before going to bed? (This could be anything from drinking a glass of water before bed, reading a book or journalling).

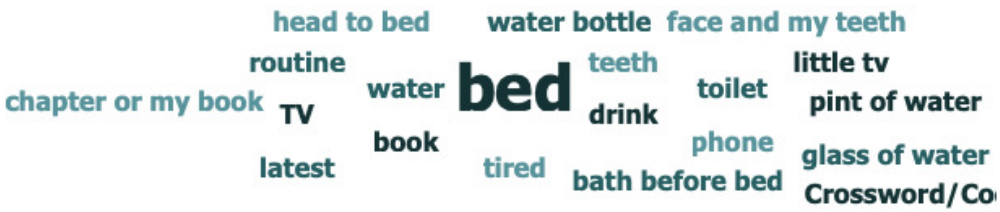
Yes	23
No	10

12. Please provide details for your answer to Question 11

24
Responses

Latest Responses
"Read in bed before going to sleep"

11 respondents (**46**%) answered **bed** for this question.



13. Do you keep your phone in or next to your bed (e.g. beside table) whilst sleeping?

Yes	23
No	10

14. Do you currently use any mobile apps to either monitor your sleep or help with any pre-sleep routines?

Yes	4
No	28

15. Please provide details for your answer to Question 14

9
Responses

Latest Responses
"I use my garmin watch to monitor sleep, this links to Garmin conn...

4 respondents (**44**%) answered **sleeping** for this question.

16. Are you interested in improving your pre-sleep routine?

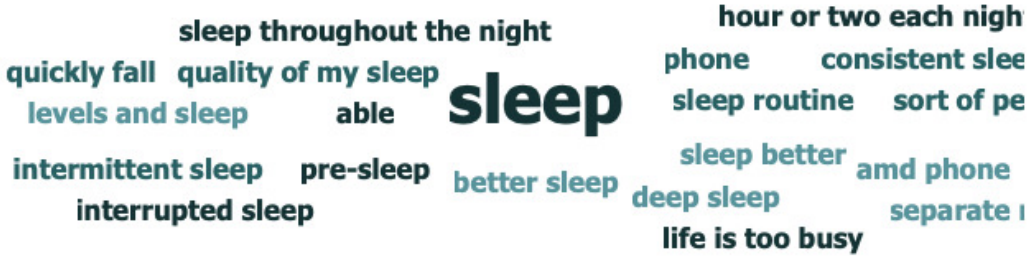
Yes	18
No	15

17. Please provide details for your answer to Question 16

17
Responses

Latest Responses

10 respondents (**59**%) answered **sleep** for this question.



Appendix B- MARS Useability Results

MARS User Testing Form

6	10:57	Active
Responses	Average time to complete	Status

1. Is the app fun/entertaining to use? Does it use any strategies to increase engagement through entertainment (e.g. through gamification)?

   1 Dull, not fun or entertaining at all

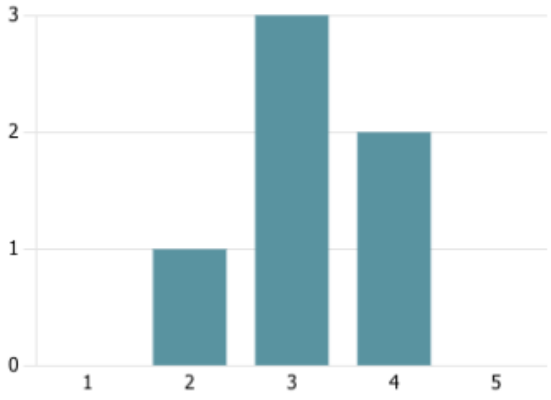
   2 Mostly boring

   3 OK, fun enough to entertain user for a brief time (< 5 minutes)

   4 Moderately fun and entertaining, would entertain user for some time (5-10 minutes total)

   5 Highly entertaining and fun, would stimulate repeat use

3.17
Average Rating



2. Is the app interesting to use? Does it use any strategies to increase engagement by presenting its content in an interesting way?

   1 Not interesting at all

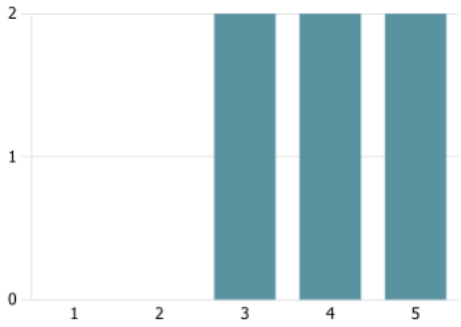
   2 Mostly uninteresting

   3 OK, neither interesting nor uninteresting; would engage user for a brief time (< 5 minutes)

   4 Moderately interesting; would engage user for some time (5-10 minutes total)

   5 Very interesting, would engage user in repeat use

4.00
Average Rating



3. Does it provide/retain all necessary settings/preferences for apps features (e.g. sound, content, notifications, etc.)?

   1 Does not allow any customisation or requires setting to be input every time

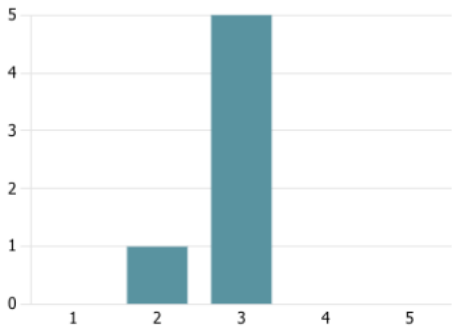
   2 Allows insufficient customisation limiting functions

   3 Allows basic customisation to function adequately

   4 Allows numerous options for customisation

   5 Allows complete tailoring to the individual's characteristics/preferences, retains all settings

2.83
Average Rating



4. Does it allow user input, provide feedback, contain prompts (reminders, sharing options, notifications, etc.)? Note: these functions need to be customisable and not overwhelming in order to be perfect.

1 No interactive features and/or no response to user interaction

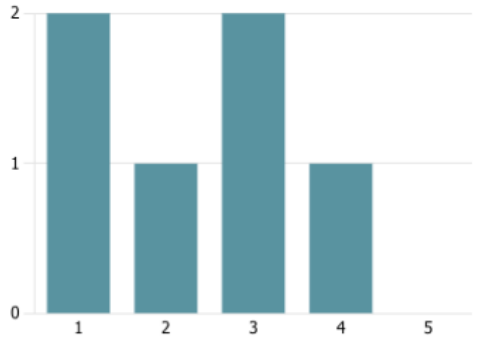
2 Insufficient interactivity, or feedback, or user input options, limiting functions

3 Basic interactive features to function adequately

4 Offers a variety of interactive features/feedback/user input options

5 Very high level of responsiveness through interactive features/feedback/user input options

2.33
Average Rating



5. Is the app content (visual information, language, design) appropriate for the target audience?

1 Completely inappropriate/unclear/confusing

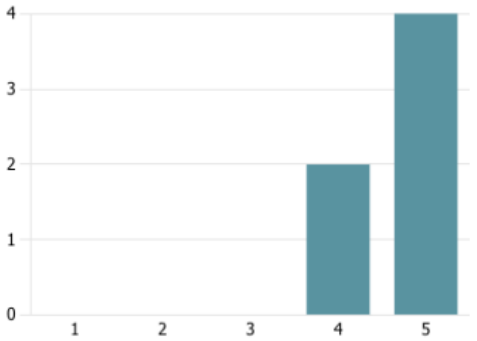
2 Mostly inappropriate/unclear/confusing

3 Acceptable but not targeted. May be inappropriate/unclear/confusing

4 Well-targeted, with negligible issues

5 Perfectly targeted, no issues found

4.67
Average Rating



6. How accurately/fast do the app features (functions) and components (buttons/menus) work?

   1 App is broken; no/insufficient/inaccurate response (e.g. crashes/bugs/broken features, etc.)

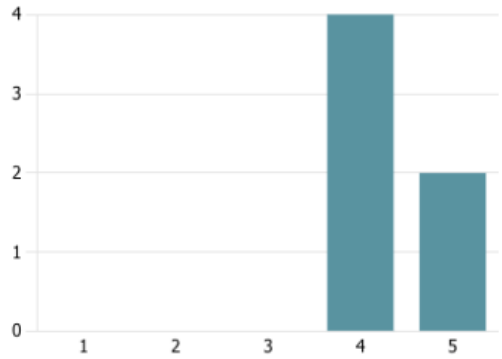
   2 Some functions work, but lagging or contains major technical problems

   3 App works overall. Some technical problems need fixing/Slow at times

   4 Mostly functional with minor/negligible problems

   5 Perfect/timely response; no technical bugs found/contains a 'loading time left' indicator

4.33
Average Rating



7. How easy is it to learn how to use the app; how clear are the menu labels/icons and instructions?

   1 No/limited instructions; menu labels/icons are confusing; complicated

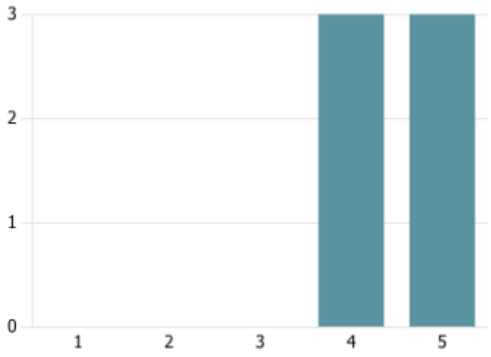
   2 Useable after a lot of time/effort

   3 Useable after some time/effort

   4 Easy to learn how to use the app (or has clear instructions)

   5 Able to use app immediately; intuitive; simple

4.50
Average Rating



8. Is moving between screens logical/accurate/appropriate/ uninterrupted; are all necessary screen links present?

1 Different sections within the app seem disconnected and random/confusing/navigation is difficult

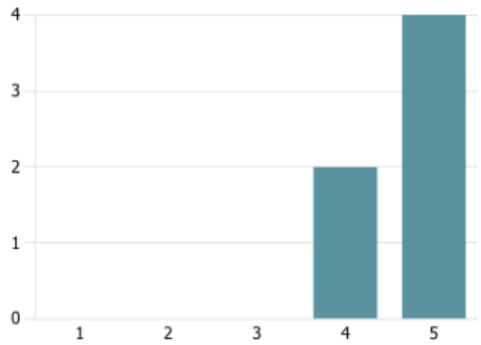
2 Usable after a lot of time/effort

3 Usable after some time/effort

4 Easy to use or missing a negligible link

5 Perfectly logical, easy, clear and intuitive screen flow throughout, or offers shortcuts

4.67
Average Rating



9. Are interactions (taps/swipes/pinches/scrolls) consistent and intuitive across all components/screens?

1 Completely inconsistent/confusing

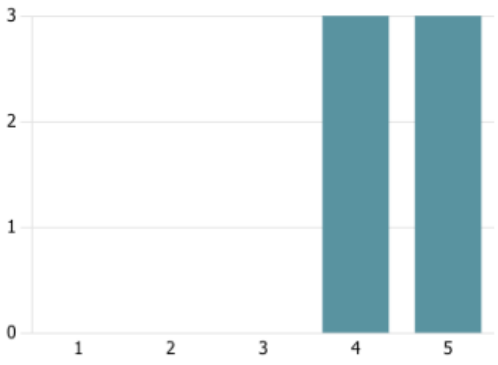
2 Often inconsistent/confusing

3 OK with some inconsistencies/confusing elements

4 Mostly consistent/intuitive with negligible problems

5 Perfectly consistent and intuitive

4.50
Average Rating



10. Is arrangement and size of buttons/icons/menus/content on the screen appropriate or zoomable if needed?

    1 Very bad design, cluttered, some options impossible to select/locate/see/read device display not optimised

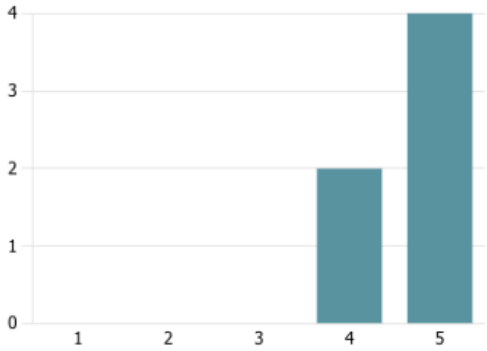
    2 Bad design, random, unclear, some options difficult to select/locate/see/read

    3 Satisfactory, few problems with selecting/locating/seeing/reading items or with minor screen-size problems

    4 Mostly clear, able to select/locate/see/read items

    5 Professional, simple, clear, orderly, logically organised, device display optimised. Every design component has a purpose

4.67
Average Rating



11. How high is the quality/resolution of graphics used for buttons/icons/menus/content?

    1 Graphics appear amateur, very poor visual design - disproportionate, completely stylistically inconsistent

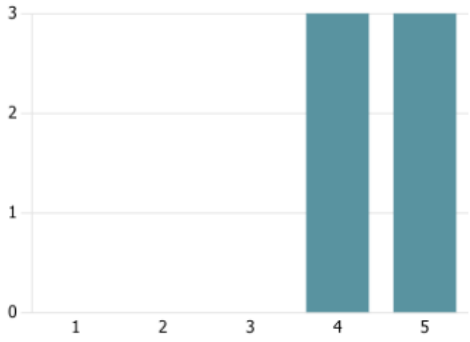
    2 Low quality/low resolution graphics; low quality visual design – disproportionate, stylistically inconsistent

    3 Moderate quality graphics and visual design (generally consistent in style)

    4 High quality/resolution graphics and visual design – mostly proportionate, stylistically consistent

    5 Very high quality/resolution graphics and visual design - proportionate, stylistically consistent throughout

4.50
Average Rating



12. How good does the app look?

1 No visual appeal, unpleasant to look at, poorly designed, clashing/mismatched colours

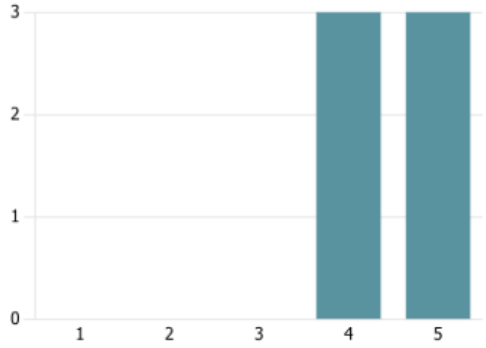
2 Little visual appeal – poorly designed, bad use of colour, visually boring

3 Some visual appeal – average, neither pleasant, nor unpleasant

4 High level of visual appeal – seamless graphics – consistent and professionally designed

5 As above + very attractive, memorable, stands out; use of colour enhances app features/menus

4.50
Average Rating



13. Does app contain what is described in App store listing?

1 Misleading. App does not contain the described components/functions. Or has no description

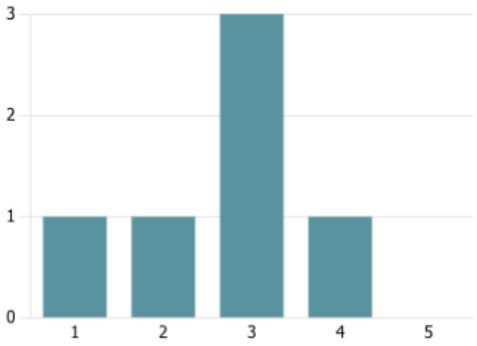
2 Inaccurate. App contains very few of the described components/functions

3 OK. App contains some of the described components/functions

4 Accurate. App contains most of the described components/functions

5 Highly accurate description of the app components/functions

2.67
Average Rating



14. Is app content correct, well written, and relevant to the goal/topic of the app?

1 Irrelevant/inappropriate/incoherent/incorrect

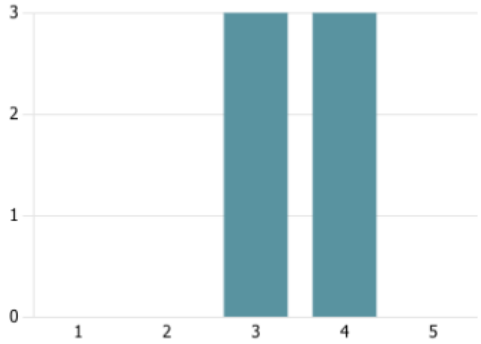
2 Poor. Barely relevant/appropriate/coherent/may be incorrect

3 Moderately relevant/appropriate/coherent/and appears correct

4 Relevant/appropriate/coherent/correct

5 Highly relevant, appropriate, coherent, and correct

3.50
Average Rating



15. Does the app come from a legitimate source (specified in app store description or within the app itself)?

1 Source identified but legitimacy/trustworthiness of source is questionable (e.g. commercial business with vested interest)

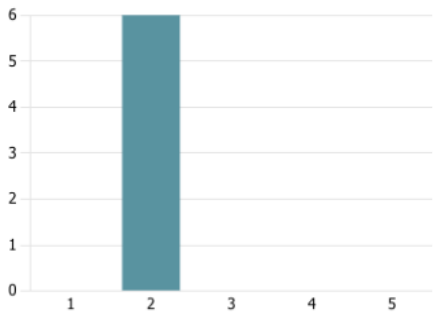
2 Appears to come from a legitimate source, but it cannot be verified (e.g. has no webpage)

3 Developed by small NGO/institution (hospital/centre, etc.) /specialised commercial business, funding body

4 Developed by government, university or as above but larger in scale

5 Developed using nationally competitive government or research funding

2.00
Average Rating



16. Would you recommend this app to people who might benefit from it?

1 Not at all I would not recommend this app to anyone

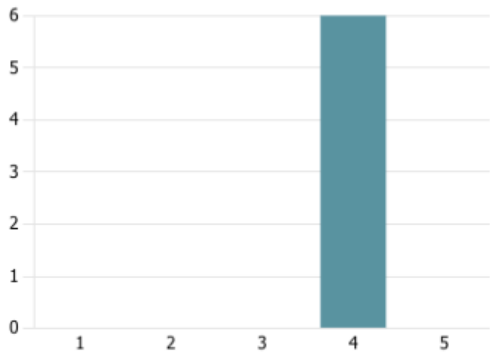
2 There are very few people I would recommend this app to

3 Maybe. There are several people whom I would recommend it to

4 There are many people I would recommend this app to

5 Definitely I would recommend this app to everyone

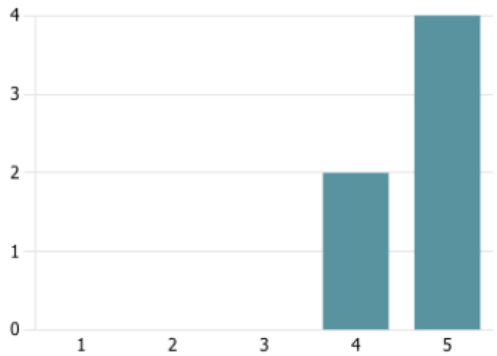
4.00
Average Rating



17. How many times do you think you would use this app in the next 12 months if it was relevant to
you?

1 None
2 1-2
3 3-10
4 10-50
5 >50

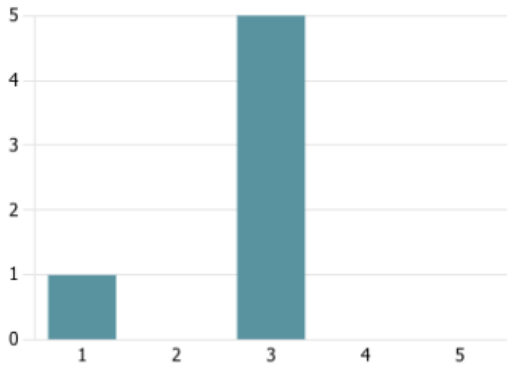
4.67
Average Rating



18. Would you pay for this app?

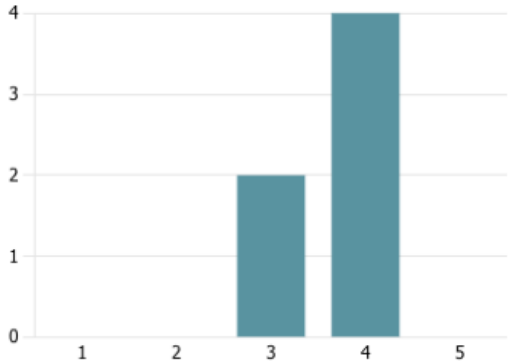
1 No
3 Maybe
5 Yes

2.67
Average Rating



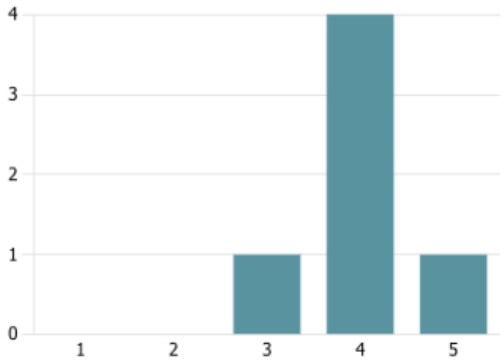
19. What is your overall star rating of the app?

3.67
Average Rating



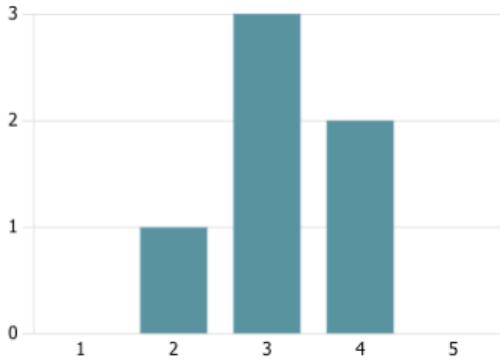
20. Use of this app is likely to increase the development of a healthy bedtime routine.
    1 - Strongly disagree
    5 - Strongly Agree

4.00
Average Rating



21. This app is likely to change attitudes towards improving a healthy bedtime routine.
    1 - Strongly disagree
    5 - Strongly Agree

3.17
Average Rating



22. This app is likely to increase motivation to improve a bedtime routine.
    1 - Strongly disagree
    5 - Strongly Agree

4.17
Average Rating