How can machine learning with phone sensors and recommender systems be used to manage mood and promote positive mental health?

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A dissertation submitted in fulfilment of the requirements for the degree of Master in Computer Science.

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Declaration

I declare that this dissertation has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

Signed:  

Date:
Acknowledgements

I would like to express my gratitude to

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Divine
Abstract

This research aims to investigate how phone sensor data using machine learning and recommender systems could be incorporated into a mood management app and promote positive mental health. Theoretical information from relevant literature was analysed resulting in the design of a system and high fidelity prototype app to simulate the functionality of the system. In line with a user centred approach, two design phases paired with two data collection stages were planned. The data collection consisted of a prototype app evaluation by a sample space of target end-users through an app demo video. The feedback gathered from the evaluation combined with relevant literature contributed to the development of the refined high fidelity prototype app.

The findings of this research indicated that participants liked the idea of mood detection and activity recommendation and felt that they are useful features. Overall participants had positive responses regarding the usefulness and engagement of the app. Majority of the participants felt that the app would help them manage their mood and promote positive mental health. Finally, suggestions for future work were provided including recommendations to incorporate gamification to encourage continued use of the app.

The key finding from this study is that mood detection through the use of machine learning with phone sensor data and activity recommendation can be incorporated into a mood management app. From the final evaluation it was found that such an app could have the potential to help users manage their mood while reducing the data capture burden and promote positive mental health. Further end-user testing and evaluation is recommended for those who are interested in pursuing this approach to develop a mood management app.
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Chapter 1: Introduction
1.1 Introduction

This dissertation explores how machine learning using phone sensor data and recommender systems can be incorporated into a mood management app and promote positive mental health. The application simulates the designed mood detection and activity recommendation functions. The overall usefulness of the application was then evaluated with a group of participants over two data collection phases.

1.2 Motivation

The motivation for this project was influenced by a module the author undertook. In the Urban Computing module, I, the author, learned how phone sensors could be used to build applications that could benefit an urban area. I was intrigued by this topic and wanted to incorporate phone sensor data into their dissertation. The author is passionate about mood management and the maintenance of positive mental health and decided to incorporate this passion into their dissertation also. After conducting some research I found that phone sensor data could potentially be used to detect mood with machine learning. From this I wanted to explore how machine learning using phone sensor data and recommender systems can be incorporated into a mood management app to help users manage their mood and promote positive mental health.

1.3 Scope

Through conducting a literature review, the author developed a basis for potential solutions for this research. In order to ensure the design solutions would be beneficial to target end users, it was necessary to involve participants who are interested in mood management in the design phases (Norman, 2013). To gather this feedback, two phases of data collection were conducted. This allowed the author to design an appropriate solution that could potentially be useful to users. The developed application was a functioning prototype mood management app that simulated mood detection and activity recommendation. Though neither mood detection nor activity recommendation was implemented into the prototype app they were still designed by the author. The scope of this research focused on the design and implementation of a mood management app that simulates the designed mood detection and activity recommendation functions. The development of these functions, and deployment of a fully functioning app was outside the scope of this research.

1.4 Research Objectives

The primary aim of this research was to investigate how machine learning using phone sensor data and recommender systems can be incorporated into a mood management app to help users manage their mood and promote positive mental health. In order to find appropriate solutions to achieve this aim the following objectives were set out:

▸ To conduct a literature review. This research would validate the need of addressing the research question and influence the choices made throughout the research.
Based on the theoretical information gathered from the literature review, to design a system and a high fidelity mood management prototype app that incorporates mood detection and activity recommendation.

To implement the designed high fidelity prototype app using Android Studio and create an app demo video to demonstrate the functionality of the app.

To follow a user centred design approach by conducting two data collection phases with participants who are interested in mood management.

To redesign the prototype app to create a design for the refined high fidelity prototype app based on an analysis of the findings gathered through the first data collection phase.

To implement the refined high fidelity prototype app and create an app demo video for the refined application.

To conduct a final round of evaluation with participants in order to gather final target end-user feedback regarding the function design and ultimately uncover whether the research aim has been achieved.

1.5 Research Overview

The research objectives were achieved and are included in the dissertation as follows:

Chapter 2: Literature Review

Describes the information gathered from the literature review conducted by the author throughout this research. The chapter details how mood can affect mental health and why tracking mood can help, tracking mood on paper versus digital tracking, mood detection using phone sensors and recommender systems. An analysis of various mood apps was also carried out and discussed in this chapter. This chapter also explores literature that influenced some design choices in this research.

Chapter 3: Methodology

Provides an insight into the reasoning behind the choices made and methods implemented throughout this research in order to achieve the research objectives. The data collection and design phases described were designed to involve target end users. Information on ethics approval, evaluations, implementation and limitations are discussed in this chapter.

Chapter 4: Design & Data Collection

Discusses the user interface (UI) design choices made in each design phase. It also explains the findings from the first data collection phase which influenced the design choices for the second round of design.
Chapter 5: Implementation

Details the implementation process of the developed application and app demo video that was created for the data collection phases.

Chapter 6: Evaluation & Discussion

Examines the findings from the final phase of evaluation. This chapter also discusses the significance that these findings and the developed application had on the research.

Chapter 7: Conclusion

This chapter includes a reflection on the outcomes of this dissertation. The limitations and potential future work are also discussed in this chapter.
Chapter 2: *Literature Review*
2.1 Introduction

This chapter discusses the preliminary research conducted to satisfy the research question. By reviewing the literature the author was able to devise manners in which the research question can be achieved. To achieve this, the research conducted started on how mood can affect mental health, why tracking mood can help and discussed mood tracking for clinical use. Within this research, the contrast between tracking mood on paper versus a mobile app was outlined. Next, research behind mood detection was explored; how phone sensors can detect and derive mood. Following this is a discussion on the research undertaken on how activities can be recommended to improve mood. The author looked into recommender systems and what activities can improve an individual's mood. Finally, the author ran a systematic search on popular mood apps and looked into the best mood apps for mood disorders to conduct an analysis on mood apps and investigated the features that users desire in a mood app through looking at app reviews. As a result, this chapter identifies the gap in literature in regards to the research question, and provides an understanding of the motives behind the decisions made after literature has been reviewed.

2.2 How Mood Can Affect Mental Health & Why Tracking Mood Can Help

2.2.1 Introduction

Mood and mental health is a key concept in this research. This section provides an overview on how mood can affect mental health, why tracking mood can benefit an individual and how it can be used to help patients self-manage their mental health conditions.

2.2.2 How Mood Can Affect Mental Health

Triggers, duration, intensity, frequency and recovery are apative factors of mood. Any one of these factors can cause problems and be detrimental to one's mental health as many mental problems are linked to the regulation of mood (Scherer, 2015). Negative mental health has been a concern in recent years with the increase in stress and unhealthy lifestyles in everyday life. Mood disorders such as depression, anxiety and bipolar disorder are especially having a serious impact on an individual's quality of life due to the unstableness of mood (Ma et al, 2012). Maintaining a positive mood is associated with the prevention of going into depressive states (Ciarrochi et al, 2000).

2.2.3 Why Tracking Mood Can Help

Effective prevention, early intervention and self-management are key aspects to promoting positive mental health. Self-management through tracking can bring improvements to mood and habits (Bennett-Levy et al, 2010). According to a research conducted in 2021, mood is a frequent transdiagnostic factor in mental health and mood tracking is available in over half of mental health apps, and is one of most popular and relevant features of these apps (Lagan et al, 2021). According to Hollis et al (2015) tracking mood leads to deeper insights into mental health issues and encourages individuals to look into the causes of negative mental health
motivating them to change and enforce better habits to promote positive mental health in their life. Rivera-Pelayo et al (2017) has proven that tracking mood in a workplace promotes positive mental health and improves work performance when managers react proactively to the mood states of employees and make effort to put in place measures for improvement. Schueller et al (2021) found that participants felt that mood tracking contributed to the improvement of self-awareness, promoted self-reflection, and overall helped them to intervene or change their mood. Most participants started tracking their mood while going through a tough time in relation to their mental health in hopes to improve it.

2.2.4 Mood Tracking For Clinical Use

Mental health apps are being progressively prescribed to widen treatment and help patients self-manage their mental health conditions (Chandrashekar, 2018). According to Van Ameringen et al (2017) mental health apps have the potential to provide mental healthcare beyond a clinic by providing a means of tracking, assessment and treatment from a mobile device and could potentially overcome treatment barriers like financial or location barriers. Lee et al (2016) conducted a systematic review on apps for the treatment and prevention of mood disorders during the perinatal period for women. It was found that studies associated with the selected apps reported significant improvements in maternal mood and depressive symptoms. The UK’s National Health Service (NHS) and US National Institute of Mental Health (NIMH) consider mental health apps to be scalable and cost effective solutions to tackle treatment barriers (Tweed, 2017). The NIMH groups mental health apps by functionality including symptom tracking and passive data collection (National Institute of Mental Health, 2019). Price et al (2014) states that apps for mental health cover all stages of clinical care including handling crisis, prevention, diagnosis, treatment, therapy sessions and post-treatment. Self-monitoring mood app features can increase emotional self-awareness (Bakker et al, 2016) which has been shown to reduce symptoms of mood disorders and mental illness (Kauer et al, 2012; Heron & Smyth, 2010).

2.2.5 Conclusion

This section validated the research question on how the management of mood by tracking mood states can help by encouraging self-awareness and self-reflection in the hopes that individuals will be prompted to improve their mood and mental health and how mood tracking can be used for clinical use as a means of overcoming treatment barriers.

2.3 Tracking Mood On Paper Versus A Mobile App

2.3.1 Introduction

To validate the development of a mobile app to track and manage mood for this research, different methods of tracking mood are explored and discussed below.
2.3.2 Tracking Mood On Paper Versus A Mobile App

Murnane et al (2016) conducted a study on self-monitoring practices of participants with bipolar disorder for reference to future designs of technologies to aid in the management of mental health. According to this study 45% of participants recorded mood as part of their self-monitoring practices and out of that 36.2% tracked mood on paper while 35.6% tracked their mood digitally. The forms of paper manual tracking included sticky notes, diaries and calendars and for digital mood tracking participants used spreadsheets, and various mood apps like iMoodJournal, eMoods and MoodTracker.com. The 36.2% of participants claimed that they preferred to use paper tracking methods due to the fact that technology can sometimes trigger them or affect them negatively and prefer not to be on their phones often and said that some mood apps are overwhelming, overly complex and that some are not very engaging. On the other hand the participants that preferred digital tracking methods stated that recording mood can be tedious and having support from technology is very beneficial and helpful.

Malhi et al (2017) argues that tracking mood on paper can be inaccurate with potential recall bias and the limitations of capacity; it has to collect and process data over prolonged periods of time while digital tracking with wearable and portable devices like Apple watches and smartphones can monitor behavioural patterns and levels of activity, and can collect data on mood instantly multiple times a day. With digital tracking methods being affordable it can also benefit for long term tracking and assessing the effects of mood. Mobile applications that remind users to submit their mood are more convenient than paper tracking as they are consistent and do not produce data with ambiguity (Depp et al, 2012). In a study Lieberman et al (2010) saw that participants using digital tracking tracked their mood twice as much as the participants tracking mood on paper.

Constant reminders to fill in mood can be intrusive. Passive sensing allows for the collection of data automatically with little human effort. Passive sensing is not just less intrusive and bothersome but can be collected in real-time and adaptively (Ebner-Priemer and Trull, 2009). This enables for the collection of data while reducing the burden on individuals’ awareness or behaviour. These advantages are particularly relevant in mental health, especially mood disorders, where data might be sensitive and potentially distorted (Spruijt-Metz and Nilsen, 2014). In a study Morton et al (2021) discovered that 50% of participants with bipolar disorder preferred apps that collected activity data passively. However, Pratap et al (2019) states that passive digital tracking, where a device uses sensor data to detect a user’s mood, while seeming promising are not suited for detecting mood at population level due to the variation in phone usage patterns and mood.

With the limitations of manual paper mood tracking being tedious and passive digital tracking being potentially not suited for detecting mood at population level, Choe et al (2017) propose using digital tracking with semi-automated tracking as a means of tracking mood as it balances out both the limitations of manual and complete automatic tracking. Data is collected periodically digitally and automatically and the user can manually change or add
data to the app. This will allow users to be engaged and involved in tracking their mood while being able to see their moods over a period of time helping them to identify patterns and be able to make measures to improve their mental health. Kim et al (2017) agreed and developed OmniTrack, an Android self-tracker application that uses semi-automated methods by combining automated and manual tracking to enhance self-awareness while reducing the data capture burden. Results from the usability study on the OmniTrack app showed that overall participants liked the app and found that the semi-automated tracking lowered the burden of having to constantly log data allowing the users to gain the benefits of trackers.

2.3.3 Conclusion

Different methods of tracking mood were explored in this section. The advantages and disadvantages of tracking mood on paper and digitally were detailed. Finally, distinct methods of digital mood tracking were detailed including their benefits. This further confirmed the necessity of developing a mobile application for this research. The next section will provide some detail of how phone sensors are being used to detect mood.

2.4 Mood Detection With Phone Sensors

2.4.1 Introduction

Throughout this section mood detection with phone sensors is investigated. This is achieved first through a brief discussion on what phone sensors have the potential to detect the mood of an individual. Next, a framework for deriving mood from phone sensor data is detailed. Finally, what classifiers are and an overview of the types of classifiers are discussed.

2.4.2 Phone Sensors That Can Detect Mood

Sensing technologies have over the years become a popular feature in modern mobile applications (Andrejevic and Burdon, 2015). Ma et al (2012) describes using a physical sensor like phone accelerometer to retrieve data on user behaviour such as picking up the phone and doing nothing useful and data on the user activity including sitting, standing, walking and running. By collecting data from sensors that provide and derive information through a phone’s operating system, the communication frequency of the user for example, can be calculated considering text messages and call logs which can be used to detect mood. Pratap et al (2019) conducted a study on the accuracy of mood detection using phone sensors with physical GPS sensors to collect data on mobility distance and mobility radius and phone operating systems to retrieve information on call duration, text messages count and length, rate of communication, interaction diversity, missed interactions and unreturned calls to detect mood. Saeb et al (2016) found that using GPS sensor data was an important and reliable way of detecting depressive symptoms which can potentially provide early warning signs of depression.

Funf is a mobile application that uses Bluetooth proximity sensing to track face-to-face social interactions and other behavioural patterns to determine mood (Moturu et al, 2011). Spathis et
al (2019) designed an application to predict mood by collecting information on noise levels through a phone's microphone and accelerometer data for movement. This application was designed to be used to detect mood for individuals whose mood is heavily affected by noise. Jacobson and Chung (2020) predicted depression, a mood based disorder, through a combination of hourly ecological momentary assessments and the collection of passive phone sensor data from a variety of sensors including location based weather, and heart condition information.

### 2.4.3 Deriving Mood From Sensor Data

Ma et al (2012) proposed a framework to detect mood from phone sensors. The framework collects sensor data on a mobile phone, this data is then combined to model an individual's daily behaviour patterns from physical movements to location trace and communication. These features are used as inputs to model the individuals real-time mood built based on a factor graph to do the assessment and analysis. Mood is represented by three dimensions adopted from Thayer's (1996) theory being displeasure, tiredness and tensity. From this the overall mood an individual is represented as \( \text{mood} = (\text{displeasure}, \text{tiredness}, \text{tensity}) \). The phone sensor data is known as features and are inputs to the model. With the feature phone sensor dataset and the previous mood state, the classification problem can be defined as \( f(\text{feature inputs, previous mood state}) \rightarrow \text{mood} \). The model assumes that an individual's mood and the feature inputs have a Markov property meaning that each mood state is conditionally independent of each other, the same applies for the phone sensor data. The proposed framework uses Naive Bayes algorithm to model the correlation between mood and behaviour derived from phone sensor data and is used to model the persistence of mood states.

### 2.4.4 Classifiers In Machine Learning

In the previous section a classifier problem was derived. This section will discuss what classifiers are and describe different types of classifiers that could be used to solve a classifier problem. A classifier is a supervised machine learning function that uses values from features and predicts the label (class) that the variable belongs to. The classifier has a number of parameters that it will need to learn from training data, a set of example data prepared for training purposes, to be able to predict the label (\( y \)) for other variables. The classifier is a function \( f \) that predicts the label \( \hat{y} = f(x) \) (Pereira et al, 2009).
Nearest-Neighbour Classifiers

The most simple classifier is the Nearest-Neighbour. The classification of a test example variable is done by finding the training data set that is most similar to the test example by some measure and assigning the label of the ‘nearest neighbour’ to that test example. This classifier is very good when there is a small number of features and tends to fail when there are many features with little information (Pereira et al, 2009).

Support Vector Machine (SVM)

SVM performs classification by building a $N$-dimensional plane that separates data into two categories. The goal of the SVM model is to find the most optimal plane that separates the groups of data in a way that variables with one category of the label are on one side of the plane and the variable with the other category are on the other side of the plane (Ayodele, 2010).

Decision Trees

Decision trees use a graph to simulate the choices that lead to a result in the form of a tree. The nodes of the graph represent an event or choice and the edge of the graph represents
the decision rules. The training data is used to form the tree structure so test data can be used against it to validate the decisions made that lead to a result.

Naive Bayes

Naive Bayes is a classifier based on Bayes Theorem, assuming that all predictors have a Markov property meaning this classifier assumes that the presence of a feature within a class is not related to any other feature in the classifier. The classifier classifies based on the conditional probability of something happening, by calculating the likelihood of the variable for each class and labelling the variable to the class with the highest likelihood (Mahesh, 2020).

![Figure 2.2: Categories of Classifiers (Ghori et al, 2019)](image)

2.4.5 Conclusion

Phone sensors that can potentially detect mood were discussed in this section. Furthermore a framework proposed to calculate mood from phone sensor data by modelling an individual’s daily behaviour patterns with a factor graph was also detailed. Finally, classifiers are defined and different supervised machine learning classifiers are detailed.
2.5 Recommending Activities To Improve Mood

2.5.1 Introduction

In order to promote positive mental health, it is essential that users are presented with ways to improve their mood (Alqahtani & Orji, 2020). In this section recommender systems are explored as an option to suggest activities that a user can do to improve their mood. Furthermore, activities that could be initially suggested to improve mood are discussed below.

2.5.2 Recommendation Systems

Recommender systems transform data on users and their preferences into predictions of users' potential future interests (Lü et al, 2012). Whenever there is an abundance of diverse products and unique customers, personalised recommendations help to deliver the right content to the right individual (Anderson, 2006). Not only does recommender systems help deliver the right personalised content to customers but it also improves customer loyalty as they tend to return to companies that best serve their needs (Schafer et al, 2001).

Challenges

Several challenges are encountered when developing a recommender algorithm, the major ones according to Lü et al (2012) are detailed below:

1. Diversity vs. Accuracy: It is important to not only recommend items likely to satisfy the user but to also incorporate the recommendations of popular or new items in order to allow the user to explore, try new things and potentially discover new preferences. However this is not always the case. There is a trade-off between how diverse a recommendation should be versus how accurate the recommendation system could be.

2. Cold Start: Cold start refers to the lack of information being made available to make a recommendation as a result of data being sparse. This can happen when new users enter the system.

3. Transparency: Users like to know why a specific item has been recommended to them in a clear and concise manner to accept the suggestion and value it, otherwise they assume the recommendation was random with no effort made to tailor the suggestion to the user.

4. Time Length: A lot of recommendation algorithms disregard the timestamps of preferences when old interests should fade with time and temporary preferences should be identified and considered in the evaluation of item relevance.
Collaborative Filtering Recommender Systems

These recommender systems use an information filtering technique based on the user's history or users with similar preferences, likes and with that information suggests items to the user (Claypool et al., 1999; Sarwar et al., 2000).

![Table 2.1: Advantages & Disadvantages of Collaborative Filtering (Ricci et al, 2011).]

Collaborative filtering recommender systems are the most widely implemented type of recommender system (Ricci et al., 2011).

Content-Based Filtering Recommender Systems

In contrast content-based filtering analyses a set of the users preferences from the past and uses that information as well as attributes associated with the items the user liked to provide recommendations (Basu et al, 1998).

![Table 2.2: Advantages & Disadvantages of Content-Based Filtering (Lops et al, 2011).]
Details on how activity recommendation could be implemented with recommender systems will be discussed in the design chapter found in section 4.4.

### 2.5.3 Activities To Improve Mood

According to Cooney et al (2013), antidepressants can have adverse side effects and there is a time lag between prescription and elevation of mood. Research suggests that patients experiencing mental health problems often accept exercise as a treatment option for depression and state it as a valuable form of treatment (Richardson et al, 2005). Contact with green space and nature is often elevating, restorative and helps to improve mood (Barton and Pretty, 2010). Pretty et al (2005) conducted a study on whether there was a benefit in exercising while being exposed to nature, ‘green exercise’. Green exercise in pleasant rural or urban areas was proved to have a positive impact on mood; by contrast green exercise in unpleasant rural areas had a negative effect on mood. In a study 62% of participants associated retail therapy, awarding themselves with a treat, to motivation and the improvement of their mood (Atalay and Meloy, 2011). Lane et al (2007) discovered that meditation training led to significant improvements in negative mood. However, Toneatto and Nguyen (2007) found that meditation and mindfulness techniques had an equivocal effects on anxiety and depression symptoms, however the risk of relapse after successfully treated depression was reduced by meditation training suggesting that the benefits of this approach may help improve mood and alleviate anxiety and depression when used in conjunction with treatment. In another study mood improvements were found after participants did art, painting and music interventions as participants felt like they could express themselves through these activities (De Petrillo and Winner, 2005; Pongan et al, 2017). In a similar manner Jampour et al (2019) investigated whether watching movies or TV series while snacking had an impact on mood. Mood was measured at the end of the movie using a visual analog scale (VAS). It was found that movies/TV series did have an impact on mood and the results suggest that movies/TV series that an individual favours will improve their mood. Consuming caffeine was found to aid the improvement of mood (Dawkins et al, 2011). Results from a study showed that exposure to natural light, being outside, improved mood through pleasantness. Taking a short nap during the day shifted mood to a more positive side through satisfaction and relaxation (Kaida et al, 2007). Pradanie et al (2017) found that cleaning and gardening can trigger comfort to an individual, improving mood. Engaging in frequent social interactions whether in person or over the phone may prevent negative moods (Kuczynski et al, 2022). The app developed for this dissertation incorporates many of these activities, as described in section 4.5.2.

### 2.5.4 Conclusion

Recommender systems play a role in suggesting activities to improve mood to users for promoting positive mental health in this research. What recommender systems are, the challenges faced when implementing a recommender system algorithm, different types of systems and their respective advantages and disadvantages are detailed in this section. Finally a brief overview of some activities that can improve an individual’s mood is discussed in this section.
2.6 Analysis On Mood Apps In The Market

2.6.1 Introduction

The author conducted an analysis on mood apps in the market by looking at 1) popular mood apps through a systematic search on the app stores and 2) the best mood apps for mood disorders according to Valera at VeryWell Mind (2022). Information on the selected apps are detailed below.

2.6.2 Analysis On Popular Mood Apps In The Market

In order to find a set of currently popular mood apps, a systematic search was conducted in the Android Play Store and iOS App Store in March 2022. The following keywords were used for the search: Mood AND (track OR log OR journal OR diary OR record) AND (sensors OR self-report) Apps were deemed eligible if they met the following requirements: 1) mood tracking is the app’s main focus, 2) the app is in English and 3) have at least an average rating of 4 stars. The initial search returned 338 hits on the Android Play Store and 493 hits in the iOS App Store. After screening, 5 apps were selected and are discussed below.

Mind Journal

Mind Journal is a mood tracker app that allows users to journal their mood and get anxiety relief using cognitive behaviour techniques (CBT). The app offers users a diary to journal in, 3 to 10 mood logs a day in the mood tracker, anxiety relief prompts and guided meditation and affirmations. The app has an average rating of 4.8 stars with over 500,000 downloads. A lot of users agree that they enjoy the app, they feel motivated, calm and feel as though the app is rewarding. The downside was that users felt that there was not much activity and mood options.

Daylio Journal

Daylio Journal allows users to choose their mood and activities they have been participating in during the day. Users can add notes and photos to their mood. The collected recorded moods and activities are displayed in weekly, monthly and yearly charts, which can be exported and shared, to help users to understand their habits. The app is very customisable and secure as users can lock the app with a PIN. The app received an average of 5 stars with over 10,000,000 downloads. Users found the app easy to use, loved how customisable the app is and found the charts very helpful to view a breakdown of mood over a period of time.

Mood Patterns

Mood Patterns is a mood detection app that allows users to self-report their mood but also the app links how the user feels to their location, social activities, how they slept and phone usage through a series of ecological momentary assessment daily surveys by asking how the
user feels in the moment. The app has an average 4.2 stars with over 100,000 downloads. Overall users find the app useful and liked that the app did the tracking for the user as it is prompted.

Reflectly

Reflectly is a diary app that gives users a space to vent on their thoughts and track feelings throughout the day. Using AI, the app provides personalised motivation and prompts to improve mood throughout the day. Insights of mood over a period of time is available to users in the form of charts. The app has on average 4.4 stars. According to the reviews users like being able to freely journal and appreciate the prompts to brighten their day.

Sayana

Sayana is a self-care app that has the following features: 1) Users can track their mood and add notes to their mood, 2) the app will suggest activities to improve mood, 3) users can view how they have been feeling over a period of time through graphs and charts and 4) users can chat anonymously with other users going through a similar situation as them and support each other as a community. The app has an average rating of 4.4 stars and looking at reviews users seem to enjoy the app and its features.

2.6.3 Analysis On The Best Mood Apps In The Market

Valera at VeryWell Mind (2022) wrote an article on the best mood apps for mood disorders that was medically reviewed by professionals. The apps selected included:

Moodfit

Moodfit was selected as the best overall app for mood disorders. The app allows users to customise goal and activity tracking, keep a mood and gratitude journal, participate in meditation including breathing exercises and also track sleep in addition to lifestyle. The app incorporates cognitive behavioural therapy (CBT) to teach users coping skills. Mood charts can be shared to therapists and medication alerts can be enabled. All these features are designed to help users track mood, reduce symptoms of mood disorders and improve overall mental health.

Worry Watch

Worry Watch was chosen as the best app for anxiety as it is designed for anxiety self-care. The app lets users record anxious thoughts and see visual charts of thoughts and behaviours. The app provides daily positive affirmations for optimism and is secured with the password protected journal feature.
MoodTools

Mood Tools is an app designed to help individuals with depression. The app incorporates cognitive behavioural therapy (CBT) to help users track, identify and challenge negative thought patterns in order to improve mood. MoodTools offers a thought diary for recording thoughts, activity suggestions like meditation and therapeutic videos, safety plan customisation in the case of a crisis and self-help information.

PTSD Coach

PTSD Coach is an app designed to help users manage their post traumatic stress disorder (PTSD) symptoms. Users can track their PTSD symptoms and be recommended coping techniques. PTSD Coach offers users self-help information on positive self-talk and anger management, support and safety plans where users can get information on emergency and crisis support services and establish a connection with them.

eMoods Bipolar Mood Tracker

The eMoods app was developed for recording, visualising and managing symptoms associated with bipolar disorder (BD). The app is based on CBT principles and provides users with a medication and mood tracker, visualisations including a colour coded monthly calendar and a safety plan offering a support network and coping techniques.

2.6.4 Conclusion

This section discusses the findings from a systematic search that was conducted on popular mood apps from both the Android Play Store and iOS App Store and from an article on the best mood apps for mood disorders. Furthermore, the features of the apps and the opinions of user reviews overall are detailed. The common features from these apps is the self-tracking of mood and visualisations of mood over periods of time. No mood management app from this analysis uses phone sensors to detect mood and most of the apps had ‘call-to-action’ prompts for the improvement of mood however, none use recommender systems for this feature.

2.7 Features Users Desire To Be Included In A Mood App

2.7.1 Introduction

There are a variety of features available in mood related apps. Throughout the course of this research, the author chose to take into consideration features users desire to be included in a mood app from literature when developing the high-fidelity prototype of the mood management app (see section 4.5.2). The features users preferred or requested was reviewed in order to gain insight as to what features to include in the app being developed for this research.
2.7.2 Features Users Desire To Be Included In A Mood App

Flexibility

In many mood app reviews, users ask for the ability to personalise their mood options and update privacy settings for example, having graphs and logs of mood data password protected or not having push notifications containing sensitive information (Calderia et al, 2017). Participants in a codesign of a mood monitoring app highlighted that apps should not over simplify mood states, as there are too many, and instead either make mood scales generic for example, “great, good, okay, poor, bad” or make mood scales customisable (Hetrick et al, 2018). Participants in a study on user perspectives on mood-monitoring applications also referenced the need for an app to offer customisation to suit an individual's needs. This included personalisation on mood scales, having the ability to enter multiple mood entries a day and being able to edit a previous mood entry (Widnall et al, 2020).

Recording & Representation Of Mood

Hetrick et al (2018) co-designed a mobile app to facilitate self- monitoring and management of mood symptoms with young people. From the codesign workshops they found that the young people had a shared vision to include an optional, visible place to record thoughts, notes or potential influences on their mood so that they can reflect, see patterns and be able to identify triggers to different moods enabling them to take action to improve their mood. Participants from a study conducted by Widnall et al (2020) also expressed that just a predetermined set of moods did not allow them to express their mood accurately and desired the ability to add descriptions to the mood with their own words. Participants also valued seeing visual representations of their mood entries as seeing mood over time allowed them to reflect on good and bad days and ultimately observe patterns to link particular moods to certain activities. Calderia et al (2017) conducted an in-depth analysis of 32 mood tracking apps features and user reviews. Users stated that seeing a visualisation of their mood data through pie charts, bar charts, lists, calendars and graphs would be helpful to see the overall effect of mood in their daily lives and identify patterns in mood.

Recommendations To Improve Mood

A study on user reviews to improve mental health apps found that users appreciated the diversity of another component in the app that suggests ways to improve mood like coping methods, activities, games or media (Alqahtani & Orji, 2020). In a survey Chang et al (2012) also discovered that participants found suggestions on mood improvement very helpful. Morton et al (2021) investigated the perceived importance of various app features for people with bipolar disorder, it was found that 63.6% of participants preferred apps that suggested personalised recommendations to manage and improve mood. User reviews on cognitive behavioural therapy (CBT)-based apps suggested that users favour having recommendations provided to them to improve their mood for example guided meditation and relaxing techniques, activities and exercises (Thach, 2018).
In line with recommendations to improve mood, participants agreed that having quick and easy access to helplines or emergency services for immediate crisis intervention somewhere on the app would be very beneficial. They shared that it could be difficult to scroll through contact lists or find the right number to call when they are in distress and that this feature would be a helpful safety measure (Hetrick et al, 2018). Alqahtani and Orji, (2020) also discovered from a study on user reviews to improve mental health apps, that users preferred apps that contained some form of emergency support and liked apps that allowed them to export their mood charts to healthcare professionals. According to an analysis of mood apps through user reviews, users also appreciated being able to share and present their visualised mood data with family members and therapists, counsellors, or physicians so they could monitor symptoms that could lead to a possible diagnosis (Calderia et al, 2017).

Notifications

Cho et al (2020) discovered that there were significant positive behavioural changes in participants after receiving warning notifications when irregular patterns were detected for a specific number of consecutive days. Advice provided in those warning notifications were about incorporating some kind of activity to their day. An analysis on user reviews for CBT-based apps revealed that users liked apps that gave them reminders or notifications to track their mood and preferred if they could personalise the frequency of reminders/notifications (Thach, 2018). Morton et al (2021) found while investigating app features individuals with bipolar disorder prefer that 60.9% of participants prefered apps that gave out notifications and reminders to track mood or medication.

2.7.3 Conclusion

In this section a variety of features users desire or requested to be included in a mood app was explored. These features were taken into consideration during the initial design of the mood management app for this research.

2.8 Conclusion

Throughout this chapter, the rationality of the research question was justified. Theoretical and practical academic literature was reviewed to gain insight and understanding to the research at hand. The literature review was conducted by the author to allow for the idea of possible solutions and methods that were backed up by academic literature to be used for this research. How mood can affect mental health, why tracking mood can help and mood tracking for clinical use was discussed. Within this research, the contrast between tracking mood on paper versus on a mobile app were outlined. Next, how phone sensors can detect and derive mood was explored by reviewing supervised machine learning algorithms. Following this is a discussion on the research undertaken on how activities can be recommended to improve mood which can be done using recommender systems. Finally, by
running a systematic search on mood apps and looking at the best mood apps for mood disorders to conduct an analysis and investigating the features that users desire in a mood app through looking at app reviews, the author found potential features that could be incorporated into the mood management app being developed for this research.
Chapter 3: **Methodology**
3.1 Introduction

The previous chapter reported secondary research conducted to obtain knowledge on mood and mental health, understand the state of the art of popular mood apps in the market, gain insight into what users want in such an app, learn about how phone sensors can detect mood and how activities can be recommended to users to improve mood. The gap in the literature was presented regarding the lack of semi-automated mood tracking apps that provide a ‘call-to-action’, allowing users to not only track but to do something about their mood when it is on the negative side.

The purpose of this chapter is to justify the appropriate method that will be used to discover solutions to the research question: ‘How can machine learning with phone sensors and recommender systems be used to manage mood and promote positive mental health?’. The chapter begins with an explanation behind the literature review that was carried out for this research. Ethics approval was needed for this research, the application process is detailed below. This is followed by a detailed description of the data collection methods and phases and reasons as to why these methods were used. The design of the system is detailed. Aspects of a user-centred design approach were incorporated into the research and its methodologies are discussed in this chapter. Then the implementation tools for the app are described. Next, information on participant recruitment is explained along with the list of eligibility requirements for participation. Finally, the limitations that arose are discussed.

3.2 Literature Review

3.2.1 Introduction

This section lays out the background research conducted for this research, which justifies why particular choices were made when answering the research question. The methods used to review relevant literature are detailed below.

3.2.2 Literature Review

To validate the credibility of satisfying the research question, the author initially conducted a literature review concerning the effect of mood on mental health and why tracking mood can help an individual better their mental health. The author then examined the contrast between tracking mood on paper and tracking mood digitally. The insights gathered from this initial research are discussed in sections 2.2 and 2.3 respectively.

Mood detection and activity recommendations are core elements in this research. For mood detection the author reviewed academic papers on phone sensors that can potentially detect mood, a framework to derive mood from the sensor data and machine learning algorithms. Recommendation systems and activities to improve mood were studied to gain a conceptual understanding on how the application could recommend activities for the promotion of positive mental health. Further detail regarding the academic review on the core elements of this research is provided in sections 2.4 and 2.5.
To gain insight into the features and functionality that could be implemented to the application within this research, the author conducted a systematic search on popular mood applications in the market and performed an analysis on some apps. The author also reviewed papers regarding co-designed mood applications where target end users were involved in the design of the application and examined user reviews of mood applications. The features and functionalities gained from this research are detailed in sections 2.6 and 2.7.

Research revealed after carrying out the literature review highlighted the lack of mobile mood management applications on the market that detects users mood using phone sensors with the purpose of promoting positive mental health through the recommendation of activities. This meant that involving target end-users in the design process was necessary. It was important to incorporate a user-centred design approach to gain an understanding of user requirements and ensure the success of the end designs rather than solely focusing on the functionality of the application without user involvement.

3.2.3 Conclusion

This section provided information on the background research that was carried out for this study. This explained why the research in chapter 2 had been undertaken and included in this report. The key findings of the background research were incorporated into the design and development of the application to be produced for this research.

3.3 Qualitative and Quantitative Research

3.3.1 Introduction

Qualitative research methods played an important role for the success of this research. The development of the application followed a user-centric approach as user input was gathered through a semi-structured interview. Qualitative research methods were used in the interview questions to obtain feedback from participants on improvements that could be made within the application, while quantitative methods were implemented to evaluate whether the second iteration of the application’s development, based on participant’s feedback, resulted in improvements.

3.3.2 Qualitative Research

Qualitative research aims to understand some aspects of social life and its methods. These methods generate words rather than numbers as data for analysis and aim to answer questions about the ‘why’, ‘what’ or ‘how’ of things rather than ‘how many’. Overall qualitative research methods are used if the goal is to gain insight and understanding on how a community or individuals perceive a particular issue (McCusker and Gunaydin, 2015) making it a suitable choice to incorporate qualitative research into improving the app in a way that will satisfy the research question.
For the purpose of this dissertation, a semi-structured interview protocol was applied as the questions were already structured in advance being close-ended and open-ended questions. The semi-structured interview enables the researcher to ask a series of questions in a coherent order while the interviewee can answer in their own terms (Berg and Lune, 2012). Cachia and Millward (2011) stated that the semi-structured interview allows the interviewer to come up with a series of questions that will give some structure to the interview, while additional questions can be introduced if the interviewer feels the need to explore an “unforeseeable answer”. The function and design of the application was primarily altered in response to the qualitative feedback data collected from the interview process, as detailed throughout chapter 3. Further detail about the questions included in the interview for this study is described in section 3.5.2.

3.3.3 Quantitative Research

Quantitative research methods involve measuring things that can be counted and gathered to perform a statistical analysis (Fryer et al, 2018). Brown (2008) proposed that quantitative research methods place more emphasis on generalisability, validity and reliability whereas qualitative methods focus on credibility and dependability.

Some aspects of a quantitative research methodology were used as part of the final evaluation online survey1 to assist in gathering information on the final prototype’s engagement and usability. By analysing this information, it can be deduced whether the second iteration of the application’s development, based on participant’s feedback, resulted in improvements. Relevant findings from the quantitative research are detailed throughout chapter 6. Details of the quantitative questions included are further described in section 3.5.2.

3.3.4 Conclusion

With the research following incorporating a user-centric design approach, qualitative research was the important source of feedback that was referenced when making changes to the application’s design and functionality. Quantitative research was gathered to gain insight into if the alterations improved the application.

3.4 Ethics Approval

3.4.1 Introduction

Ethics approval has to be obtained in order to collect qualitative and quantitative data for this research as input from target users was required. This participation was essential for the development of the mobile application. To receive ethics approval, the author compiled an ethics application as required from the TCD Research Ethics Committee.

1 Survey was created using Qualtrics, https://www.qualtrics.com/
3.4.2 Ethics Application

The author put together an ethics application and submitted it for review by the 10th of December 2021 to the TCD Research Ethics Committee (see appendix 3). The application outlined that there would be two evaluations over the course of the research in order to incorporate target users throughout the development process of the app. One phase involved semi-structured interviews with target end-users and the second phase consisted of an evaluation through an online survey. The ethics committee required that several amendments should be made to the application submitted by the author before approval could be granted.

3.4.3 Ethical Considerations

The TCD Research Ethics Committee requested that eight amendments be made to the ethics application (see appendix 3). Out of the eight amendments listed none resulted in alterations to the data collection, design, implementation or evaluation of this research, however one modification required was regarded as a ‘major omission’ and needed to be addressed. This modification is detailed below.

The author had stated in the application that there were no anticipated risks associated with the research. Since the project relates to mood and mental health, the research committee stated that this relation has the potential to cause distress to participants. The author had to modify the ethics application to include this risk and give details on how the author will deal with the situation of a participant experiencing distress should it arise. In order to address this issue the author stated that since the app being developed is concerned with mood and mental health, there could be a possibility that answering questions about the app could conceivably cause distress to participants. The author composed a detailed description on what would be done if the situation arose; the interview would be terminated immediately and the participant will be directed by the author to their affiliated university counselling services, student niteline services or local GP. The author also mentioned that after each interview every participant will be disclosed a disclaimer stating that if they feel distressed after the interview they should contact their affiliated university counselling services, student niteline services or local GP as soon as possible.

The research ethics committee also required clarification on what participant data was composed of, when the data will be deleted, which data is anonymised, and what form is the survey. It was clarified that participant data consisted of handwritten notes from the interview and online survey answers. The author stated that the data would be deleted following the completion of the relevant exam board.

3.4.4 Conclusion

The author successfully addressed the amendments required by the TCD Research Ethics Committee to a satisfactory level (see appendix 4) and the ethics approval was eventually granted after a review of the amended ethics application. The author received approval on
the 28th of February 2022 to conduct qualitative and quantitative research methodologies for this research.

3.5 Data Collection

3.5.1 Introduction

Two data collection phases took place throughout the user evaluation process of this research with a sample space of eight participants (see section 3.8). User feedback was incorporated into the design of the mobile application, in line with a user-centric design approach. This section discusses the design of the interview and survey questions, the data collection phases involved in the mobile application design, the research methods used when carrying out each phase and what was produced from the data collected.

3.5.2 Question Design

The purpose of the questions asked in the interviews and online survey was to gather constructive feedback that would allow the author to improve the design and implementation of the application being developed. All questions were designed to be open-ended, clear, allow the participant to express how they would interact with the application and be able to provide feedback and recommendations for improvements. The interview questions were essential to the design process of the refined high-fidelity prototype of the application to ensure a suitable application that would be used was developed (Gould & Lewis, 1985). The survey questions were important to ensure that the final design and development of the application following a user-centred design approach resulted in improvements (Rubin & Chisnell, 2008).

Interview Questions

The interview questions were designed to gather information on participants’ thoughts on the high-fidelity prototype application created based on the app demo video. The main functions, mood detection and the recommendations of activities were included in the interview questions allowing the participants to comment on those aspects of the application, would they use the application, do the features look easy to use, was the application visually appealing and discuss any other comments they had (see appendix 3).

Online Survey Questions

The survey questions were designed to evaluate the engagement and usability of the final design and development of the application. The survey was created online using Qualtrics XM as it is affiliated with Trinity and prevented any human error such as ticking more than one box when not required to. A probe to skip a question was provided to the participants and they could confirm whether or not they wanted to submit their responses at the end of the survey (Van Gelder et al, 2010). The questions included in the survey were similar to the interview questions but were closed-ended in order for the author to obtain quantitative data for the
3.5.3 Data Collection Phases

The user-centred design approach is based on the involvement of users to increase the understanding of user and task requirements and allows for the researcher to facilitate these requirements in the next iteration of design (Mao et al, 2005). This research is aiming to develop and implement a mood management app to promote positive mental health, part of that involves incorporating participants during the design and evaluation process by providing them with prototype apps, gathering feedback and gaining insight to potential app improvements from the feedback, and considering these perspectives into an iteration of design and development.

User feedback was gathered on two occasions throughout the duration of this research. Before the first phase of data collection, a high-fidelity prototype app was designed and implemented by the author influenced from the academic research that had been conducted (see chapter 2). This prototype app was evaluated by participants during the first phase of data collection. During the second phase of evaluation, participants were presented with a high-fidelity prototype app that had been altered considering the feedback gathered through the first phase of data collection, regarding changes in design which should be made and/or functionalities that should be added to the high-fidelity prototype app. This stage of data collection was used to accumulate final user feedback on the mood management app (see section 6.2).

<table>
<thead>
<tr>
<th>Phase</th>
<th>Data Collection Method</th>
<th>Resulting Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Literature Review</td>
<td>High-Fidelity Prototype App</td>
</tr>
<tr>
<td>1</td>
<td>Semi-Structured Interview</td>
<td>Refined High-Fidelity Prototype App</td>
</tr>
<tr>
<td>2</td>
<td>Evaluation Survey</td>
<td>Final Feedback Gathered</td>
</tr>
</tbody>
</table>

*Table 3.1: Phases of Data Collection*

Data Collection Phase 1

The first phase of data collection involved two steps. Participants were asked to a) watch a short video (1:13 minute) demo of the app and b) take part in a semi-structured interview giving participants the opportunity to provide feedback on the app and provide recommendations on how they believe functions and/or designs of the app could be improved to better manage mood and promote positive mental health. An app demo video was shared to participants
instead of a downloadable version of the app to avoid scaring participants who would be worried about data protection in terms of phone sensor data. A sample of the questions asked during the interview can be found within the ethics application in appendix 3. As explained in section 4.5 and detailed throughout chapter 5, a high-fidelity prototype android app was developed by the author with the information gathered from the literature review, seen in chapter 2. The aim of the first data collection phase was to conduct semi-structured interviews with participants to collect participant feedback on the design, proposed functionalities, usefulness and engagement of the app.

Data Collection Phase 2

The aim of the second and final data collection phase was not to be used for refining the prototype app but to gather final user feedback on the final design and implementation of the mobile app. This was included in the research to conclude the user-centred design evaluation, ensuring that improvements based on user feedback were incorporated into the final design and implementation of the app. The information was gathered through an online survey. Amendments recommended by participants during the phase of data collection are recorded in section 4.5.3.

3.5.4 Conclusion

Influenced by the user-centred design approach, the information collected during the first phase of data collection contributed to the development in the second iteration of design and implementation of the app to produce the refined high-fidelity prototype app as the app was exposed to and evaluated by target end-users. The final phase of data collection allowed the author to gather user opinion on the final prototype app, and a detailed analysis of the final app was collected, as detailed in section 6.2.

3.6 Design

3.6.1 Introduction

A system was designed to validate the research question which consisted of three components; mood detection, activity recommendation and the application interface. Each part of the system was designed during this study. Two application prototypes were designed during the course of this research in two phases. These phases involved the development of a high-fidelity prototype and a refined high-fidelity prototype application. Firstly the high-fidelity prototype app was designed based on theoretical research carried out by the author during the literature review that was conducted. After the first phase of evaluation involving participants, a refined high-fidelity prototype app was designed incorporating the feedback and opinions from the participants.

3.6.2 Conceptual Framework Design

To answer the research question, the author designed a system that will incorporate machine
learning and recommender systems into a mobile application to manage mood and promote positive mental health. The system includes three components 1) mood detection using machine learning techniques with phone sensor data, 2) activity recommendation through the use of recommender systems and 3) a mood management application for user interaction. These components interact with each other to satisfy the research question. Through the literature review the author designed each component and created a use case diagram of the system. The application interface was the component that was implemented by the author in order to incorporate a user-centred design to discover if such a system would be feasible and useful to users. The author also felt that since a video demo was going to be shared to participants instead of a downloadable app (see section 3.5.3), the mood detection and activity recommendation did not need to be implemented but simulated in the demo video. The appropriate algorithm for mood detection and activity recommendation was decided after the author reviewed literature and compared different algorithms. Details of the design of each component is discussed in chapter 4.

3.6.3 User-centred Design Approach

Through the literature review the author discovered a gap in the literature regarding the lack of semi-automated mood tracking apps that provide a ‘call-to-action’, to do something about their mood to improve it. With this gap there was not sufficient research available to validify that a mobile application would be beneficial to users in this regard. This meant that involving target end-users in the design process of this application was essential to ensure the success of the final designs. According to Monk (2000), many applications are unsuccessful because they are not designed to perform the functions needed by users and that it is important to involve individuals’ input in the earliest stages of design. The author decided to follow a user centred approach for the design process of this research. User centred design involves the understanding of the context of use, specifying the user requirements, developing designs and evaluating the designs against the requirements (Bevan, 2003). Participant’s feedback was gathered through the interview process and allowed for the second phase of design to be influenced by the information gathered from participants. The designs were then evaluated in the final round of data collection when participants were encouraged to complete an online questionnaire about the refined high-fidelity prototype app.

3.6.4 Application Design Phases

Phase One - High Fidelity Prototype

The high-fidelity prototype design was influenced by the theoretical and practical literature review conducted by the author. The findings from the literature review that derived the main design choices for the high-fidelity prototype is detailed in chapter 2. This high-fidelity prototype was drawn up by the author, developed into a functional app using Android Studio and an app demo video was filmed and edited using CapCut to allow participants to grasp the functionality and purpose of the app. This prototype app was evaluated by participants during the interview process, the first data collection phase.
Phase Two - Refined High Fidelity Prototype

The information gathered in the first data collection phase involving participants led to the design of the refined high-fidelity prototype to produce the final mobile application in Android Studio. Existing features were improved and new features were designed based on the feedback participants provided during the interview process described in section 4.5.3. Details regarding the evaluation of this prototype are discussed in section 6.2.

3.6.5 Conclusion

A system was designed to validate the research question and was influenced by findings from the preliminary research conducted by the author. The application interface part of the system was implemented to ensure if the system being designed would be beneficial to users. A user centred design approach was decided to be the most appropriate approach to the design process for the application interface component. The application had two design stages. The first stage involved the design of a high-fidelity prototype app ideated and designed based on existing literature. The second stage of design incorporated the feedback from participants during the interview process of the research resulting in the development of the final application.

Figure 3.1: Final Research Evaluation of the Application Interface Created Using LucidChart
3.7 Implementation

3.7.1 Introduction

For the implementation process of the research, the author used several tools to build the mobile application and create the app demo video for the evaluation process. The tools are detailed below.

3.7.2 Android Studio

Android Studio is a free Integrated Development Environment (IDE) for android developers building android apps. Android applications are developed using Java or Kotlin as the programming language and contains an in-built emulator allowing the developer to run their app on a virtual device for testing (Esmaeel, 2015). Android Studio was used by the author to implement the mood management app for this research as the author owns an android phone and is familiar with android. The author also knew the Java programming language very well which influenced the decision of choosing an IDE.

3.7.3 Github

Github is a version control system that allows developers to host their code in repositories, update them, roll back to a previous version of code, work on code from anywhere and collaborate with other developers on a project. Github is the largest code hosting site in the world (Kalliamvakou et al, 2014). The author used Github to store the code for the mood management app as the author already had been using Github for other projects. The source code of this project can be accessed on GitHub available in appendix 1.

3.7.3 CapCut

CapCut is a free video editing app, available on Android and iOS. With money constraint the CapCut allowed the author to create the app demo video without having to purchase a plan.

3.7.4 Conclusion

Several tools had to be used during the implementation phase of the research. The author was able to use tools that aided to the success of the research. Android Studio was used to build the app and it was uploaded to a private Github repository to be stored safely. The app demo video was filmed by screen recordings and edited using CapCut to make the video engaging and appealing.
3.8 Participants

3.8.1 Introduction

Eight individuals were selected to participate in the qualitative and quantitative research methods associated with this research. As discussed in the design section concerning the use of some user-centred aspects in this research in section 3.6.3, it was essential that the participants involved were target end-users. It was important that those selected had an interest in mood management and self-care.

3.8.2 Participants

According to Glaser and Strauss (1967), a sample size of less than 30 participants is appropriate when carrying out mainly qualitative research methods, as sample sizes over 30 participants tend to produce data saturation. Marshall et al (2013) recommended that grounded theory qualitative studies should include 15 to 30 participants. Eight individuals were included in the study. This research involves the development of a mood management mobile app. This means that the participants associated in this study had to be interested in mood management and self-care as they are the target end-users. The participants’ input provided the author valuable information on what features and designs were the most beneficial to incorporate into the mobile app. It was essential that all participants could speak and understand the English language as the app demo video, interviews and online survey were all conducted in English. All participants also had to be 18 years of age or older, able to grant consent and could be of any gender, ethnicity or culture.

3.8.3 Participant Recruitment

Participants were recruited through word of mouth. The recruitment process began among the author’s immediate contacts and social network who expressed an interest in mood management and self-care. The author also encouraged anyone who ‘knew anyone’ that would be interested in the research to get in touch with the author to include individuals outside of the immediate circle of the author. Eight participants were interested to participate, were made aware of the two phases of evaluation through the information sheet that was provided and all agreed to participate giving consent by signing the informed consent form. A sample of the information sheet and consent form can be found in appendix 3.

3.8.4 Conclusion

Eight individuals who expressed an interest in self-care and mood management took part in the user evaluation process of this research. The findings from the first phase of evaluation were used to develop and improve the application that was being developed and the information gathered from the second phase of evaluation was used for evaluating whether the second iteration of the application development resulted in improvements.
3.9 Limitations

3.9.1 Introduction

Theofanidis and Fountouki (2018) define limitation in research as an obstacle that is out of the research’s control that may reflect on the outcome of the research. Several limitations arose throughout the duration of this research. These limitations had to be dealt with and ‘workarounds’ had to be established in a way that would hinder the success of the research minimally. The limitations and the methods carried out to deal with these limitations are detailed below.

3.9.2 Limitations

Literature Review Limitations

There was little information on the performance and need for mood detection in academic literature. The author discovered that there were little to none mood tracking apps implementing tracking through phone sensors available in the market. As a result of this limitation the author chose to incorporate a user centred design approach and involve participants in the evaluation process to gain insight into the need of the app being developed for this research.

Ethical Limitations

Ethics approval was essential to this research in order to allow the author to gather qualitative and quantitative data from participants. The timeline (see appendix 5) receiving ethics approval was longer than originally anticipated and this resulted in a delay in being able to commence the data collection phases. The author had planned to start the interviews in early February and send out the survey in mid-March. This was pushed back due to the delay and the interview process was conducted in early-March and the survey was given out in early April.

Though this limitation was initially thought to threaten the success of this research, it did not hinder the study. This delay allowed for the author to spend more time on implementing the mood management app and create a demo video for the interview. The author had never developed an android app independently so the extended time was beneficial to learn how to use android studio, the chosen IDE for this research, to develop the first functional prototype app to be used for the first phase of data collection and evaluation. The extended time allowed for the author to film and edit a high quality app demo video using CapCut, a video editor tool that the author is familiar with to be used for the interviews.

Another limitation associated with ethics was that the app being developed for this research required that it can detect mood through phone sensors. Providing a downloadable version of the app to participants for testing could scare off participants worried about data protection.
To overcome this limitation the author created an app demo of the developed application for participants to watch before the interview to gain insight into what the app is like without having to worry about having their personal data being looked at.

Participant Limitations

Numerous individuals declined participation in this research due to busy schedules. This limitation threatened the evaluation portion of this research as participants were essential for the evaluation process. To address this issue the author reached out to contacts to encourage anyone they knew who had an interest in mood management and self-care to contact the author. This was effective because it provided the author with eight participants who were willing to participate for both phases of data collection for this research.

Data Collection Limitations

Ethics approval was required regarding the interview and online survey questions to be asked to participants. The author therefore, had to compile the questions during the early phase of this research and was constrained to only ask these questions during the data collection phases. To combat this limitation the author incorporated some open-ended questions within the semi-structured interview (see appendix 3) prior to submitting the ethics application. When it came to the interview process, participants could provide more detailed information and explanation of their thoughts.

Since the pandemic is still ongoing, the author gave all participants the opportunity to choose to attend the interview either in-person or online. Every participant opted for online interviews so Zoom was used for interviews. The mobile application only existed on the author’s device as it was not deployed in a downloadable format making it challenging for participants to be able to evaluate the application. In order to overcome this limitation the author created an engaging app demo of the developed application for participants to watch before the interview. This solution was effective in negating the threat of not being able to allow participants to evaluate the application.

Implementation Limitations

Android Studio, an integrated development environment for building apps for Android was used to build the mood management app for this research. This was the author’s first time building an android app independently. It therefore involved a learning curve and took a lot of time and consideration for the author to truly grasp its capabilities and understand how to build a high-quality complex app with multiple pages and numerous functions. To address this limitation, the author spent time learning how to use the platform and built a simple app, that was irrelevant to this study, early on in the research before fully conducting the literature review. This helped the author develop some understanding into android app development ensuring the author could implement the app in a timely manner before conducting interviews. Another limitation associated with the implementation of the app for this research was that the laptop the author was using is old and does not contain the requirements to
make android studio run smoothly; the laptop had 4GB of memory while it is recommended to have 8GB of memory and the laptop is equipped with just a hard drive disc while it is recommended to use a device equipped with a solid state drive (SSD) to run android studio smoothly. Failure to meet those requirements caused the author to experience slowness and crashing while using android studio increasing the time spent on developing the app. To address this limitation the author allocated more time to development and ran the app on the author’s own device for testing instead of running it on the emulator, android studio virtual phone, to stop the platform from crashing.

3.9.3 Conclusion

Every limitation mentioned above are those which the author was concerned may pose a threat to the success of the research. The author addressed each limitation to minimise their potential negative impacts to the overall research. Although the delay in ethics approval resulted in a major time constraint leading to a shorter time frame for data collection, it ended up being beneficial for the author in other ways as discussed in this section. All the other limitations were dealt with and did not heavily threaten the success of the research.

3.10 Conclusion

This chapter displays a brief overview of the theory and discusses the research approach taken. Justification was provided as to the reasons behind the theoretical and practical studies mentioned in the literature review chapter were deduced to show their importance to the research. The qualitative and quantitative research methods used for this research were detailed and the influence of the user-centred approach taken was explained. An explanation of the methods for data collection and design processes is followed by a discussion of ethical considerations that arose and how they were handled to gain ethics approval. This section then details the use of participants and the requirements for eligibility to participate accompanied by an explanation of the project and evaluation design and a description of the tool used in the implementation process of the mobile app after. Finally this section concludes with a description of limitations associated with this research and how they were dealt with.
Chapter 4: Design and Data Collection
4.1 Introduction

This chapter provides an insight to the design process of the system and the prototypes throughout this research. Firstly, it details the design of the entire system followed by a breakdown of the designs of each component within the system. The design of the mood detection algorithm was influenced by the findings from the background research that was conducted on different machine learning algorithms and a framework that was proposed to detect mood from phone sensor data. The activity recommendation component design choices were discussed and are accompanied by a diagram of how the proposed design would work. Finally, the different aspects that influenced the design of the application being developed is detailed. The two design phases are explained beginning with a description on how the preliminary research influenced the design of the high fidelity prototype app. It then discusses findings from the first phase of data collection which influenced the design of the refined high fidelity prototype app. Screenshots of the designs are presented throughout this section 4.5 to illustrate the design choices that were made on the application design.

4.2 System Concept

4.2.1 Introduction

The author designed a system to validate the research question. Three major components are associated with the system and are detailed in this section. The interactions between these components are illustrated also.

4.2.2 System Concept

The system consists of three main components; the mood detection component, the activity recommendation component and the mood management app interface. The mood detection component involves the use of supervised machine learning to detect mood with phone sensor data, see section 4.3. The activity recommendation component comprises a recommender system to recommend activities that the user is interested in, in order to improve mood. The design of this component is detailed in section 4.4. Finally the mood management app interface interacts with the other two components and displays their outputs tying it all together. The app is where users will be able to view their detected mood, add and edit mood logs, see visualisations of their mood on a weekly and monthly basis, and be recommended activities as detailed in section 4.5. Below is a diagram of the entire system including the functions and interactions between the components.
4.2.3 Conclusion

The system being designed is brought together with three components, mood detection, activity recommendation and an app that ties the mood detection and recommendation together and displays the outputs of these functions in the user interface.

4.3 Mood Detection Design

4.3.1 Introduction

This section describes the design of the mood detection component of the system (see figure 4.2). The design choices were guided by the literature review conducted by the author on machine learning algorithms and mood detection with phone sensor data. This component was only designed and not implemented for this research as discussed in section 3.6.2. An illustration of the machine learning algorithm process is included to visualise the design.
4.3.2 Mood Detection Concept Design

As detailed in section 2.4, mood detection can be implemented using phone sensors and machine learning algorithms. The inputs of the mood detection component are phone sensor data including physical sensors like the accelerometer and the phone’s operating system, and feedback from the user on whether the calculation was correct or not. This allows the system to learn and make more accurate detections. Using the framework proposed by Ma et al (2012), a classifier problem is derived to calculate mood from phone sensor data by using sensor data as input features in the machine learning algorithm. For this system, the Naive Bayes machine learning algorithm, detailed in section 2.4.4, is incorporated into the design of the mood detection component to solve the classifier problem. This is because by calculating the conditional probability of mood with specific values from the phone sensor data will make the algorithm make better detections. The phone sensor data that will be collected will include physical sensors like the accelerometer to track micromotion and the phone’s operating system to derive information on communication frequencies for example call logs and information on social media app usage. The classifier will calculate the likelihood of a specific mood with the associated phone sensor values based on the feedback from the user. If the previous detection with the associated phone sensor values is correct, it will increase the likelihood and if the detection was incorrect, will decrease the likelihood of the specific mood. With the user’s feedback the algorithm will improve and learn to make more accurate detections. The output of this component will be the mood that has been detected using the algorithm. An illustration of the mood detection function is placed below.

![Mood Detection Component Algorithm Created Using LucidChart](image-url)
4.3.3 Conclusion

This section discussed a mood detection algorithm designed for the mood detection component of the system being designed. The design of the mood detection algorithm was influenced by the literature review on different machine learning algorithms that was conducted and the framework that was proposed to detect mood from phone sensor data discussed in section 2.4.3. An illustration of the algorithm design was drawn up by the author to visualise how such an algorithm for mood detection would be implemented.

4.4 Activity Recommendation Design

4.4.1 Introduction

This section details the design decisions the author made based on preliminary research on how the activity recommendation part of the system would be implemented. The design will be simulated in the application interface but not implemented as discussed in section 3.6.2. A diagram of the designed structure is provided in this section also (see figure 4.3).

4.4.2 Activity Recommendation Concept Design

A review on literature concerning recommendation systems was conducted (see section 2.5.2) and influenced the design of the activity recommendation for the application being developed for this research. The author had to weigh out the advantages and disadvantages of each recommendation system discussed in the literature review. Initially a content-based recommendation system was considered to be incorporated into the design of the activity recommendation component of the system. This meant that each activity would be assigned unique features in order for the recommendation system to work well. However, this system would not facilitate users adding their own activities into the system. From this it became apparent to the author that a pure content-based recommendation system would not fit the system being designed as it would not be user friendly to ask the user to add features for each activity they add and assign values to them. Using a collaborative filtering approach was then considered where only ratings would be needed for each activity. Even so, as mentioned in section 2.5.2 this approach skips new items that have no ratings meaning activities the user has not used will not be included in recommendations.

In the end the author decided a modified collaborative filtering approach could be used to design this system as the recommendations will be based on the user’s history along with popular activities being incorporated into the suggestions for diversity. To tackle the challenges of building a recommender system as detailed in section 2.5.2, the recommendations will mainly be based on the user’s history with one to two activities that are popular amongst users. Users will be aware of where the recommendations came from as they will give feedback on what activities had a positive impact on their mood and this will influence the recommender system. To avoid cold starts, the user is asked what activities interest them when registering for the app. The default activities that are part of the
A recommendation system was designed for the activity recommendation component of the system being designed for this research. The design of the recommendation system was influenced by the literature review on different recommendation system algorithms carried out by the author. This section described the decisions made for the design of this component and an illustration of the structure design was drawn up by the author to visualise how such a recommendation system would be implemented.

4.5 Mood Management App Interface Design

4.5.1 Introduction

This section details the different aspects that influenced the design of the mobile application being developed for this research. The section explains the two design phases in chronological order beginning with a description on how the preliminary research influenced the design of the high fidelity prototype app. It then discusses findings from the first phase of data collection which influenced the design of the refined high fidelity prototype app. Screenshots of the designs are presented throughout this section to illustrate the design choices that were made.
4.5.2 Design Phase One: High Fidelity Prototype App

The high fidelity prototype app of the mood management app was designed primarily in response to the literature review that was carried out by the author. Mood detection and activity recommendation are core elements in this research. Features were designed to incorporate the core elements, discussed in sections 2.5 and 2.6 respectively, into the application.

Design Choices Implemented from ‘Mood Detection’ research

As detailed in section 2.5, phone sensors can be used to detect mood using machine learning. The author incorporated this method when designing the simulation on how mood detection can be seen in the app. A mood detection modal was introduced to display the simulation of mood detection. This modal pops-up when mood is detected notifying the user that a mood has been detected. The author wanted to be transparent about what resulted in the mood being detected, therefore a 'learn more' button was placed in the modal where users can read on how the detection came about. To incorporate machine learning, the user is prompted to confirm whether the detection was correct or not. This indicates that the algorithm is learning and adapting to each user. A 'detection' tag is added to every mood entry that was detected by the application enabling the user to distinguish the difference between their own inputs from the detected ones.

Figure 4.4: Mood Detection Modal

Figure 4.5: Modal after clicking 'Learn More' button in mood detection modal
Design Choices Implemented from ‘Activity Recommendation’ research

Recommending activities can be done using recommender systems as detailed in section 2.5.2. To convey this, an activity modal was incorporated into the design of the application. The modal is shown when a negative mood is detected or selected. The modal shows a grid of suggested activities that the user can do to improve their mood. The user can select one or multiple activities from this modal that they want to try. In the activity section of the app the user can also see a list of all the activities available. To illustrate the recommendation system, the user can select in the activity section which activities helped them improve their mood which would be used to improve the suggested activities.

![Figure 4.6: Activity Modal](image)

![Figure 4.7: Activity Section](image)

Design Choices Implemented from ‘Users desired features’ research

Other features were incorporated into the design from section 2.7.2, were based on co-designed mood apps that were designed with young adult participants and user reviews on relevant mood apps. Having a place to record thoughts, notes or potential influences of mood to enable users to reflect and identify triggers to different moods was a feature users wanted in mood applications. To allow for this, in the home screen a section was added to allow users to add notes to their recorded mood. This section also displayed the current mood status with a colour and icon associated with the mood. Displaying visual representations of mood entries was another feature users appreciated in apps. The author incorporated an insights section in the application where users can view visualisations of their

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2 Activity icons were downloaded from Flaticon, [https://www.flaticon.com/free-icons/activity](https://www.flaticon.com/free-icons/activity)

3 Mood icons were downloaded from Icons8, [https://icons8.com/icons/set/mood](https://icons8.com/icons/set/mood)
mood on a weekly basis and see their past mood entries on the monthly basis too, allowing users to see their mood over time giving them the ability to see patterns and trends in their mood. Allowing for the modifying and adding of mood entries was also incorporated into the design of the high fidelity prototype.

Figure 4.8: Very Happy Mood Screen

Figure 4.9: Happy Mood Screen

Figure 4.10: Ok Mood Screen
Figure 4.11: Sad Mood Screen

Figure 4.12: Very Sad Mood Screen

Figure 4.13: Insights Section - Weekly Graphs & Mood Logs

Figure 4.14: Insights Section - Monthly Mood Logs

Figure 4.15: Insights Section - Edit/Add Mood Modal
App Style

According to Fling (2009) when designing mobile applications the focus should be keeping the user experience simple. The author kept the app simple with the use of minimal app colours, white space and medium size text. The app was designed to incorporate just the necessary features and functionalities to avoid crowded and overwhelming screens.

4.5.3 Data Collection Phase One

The findings gathered from the first phase of data collection contributed to the second phase of design. This phase of data collection consisted of a semi structured interview based on an app demo video given, conducted with eight participants involved in this research.

Interview Feedback

Usefulness

Four participants (50%) stated that they would use the application to manage their mood. 25% of the participants expressed that they would not use the app a lot because they personally do not like having to be on their phones a lot or they do not usually commit to apps for too long due to trends. The remaining 25% said that they would not use the app. 62.5% of participants found the insights page and visualisations of mood on a weekly and monthly basis to be a useful feature of the application.

Engagement

All participants found the app very engaging and interactive. They liked the icons and pop up modals, notifications, activity recommendations, background colours, the bar chart animation and the ability to add notes to mood logs.

Mood Detection

87.5% of participants liked the idea of mood detection being incorporated into a mood management app. They appreciated the idea of not having to always manually input mood which can become tedious. Those participants did not find the mood detection intrusive as they felt like the app is transparent in how mood is detected from phone sensors. One participant did find the mood detection intrusive and said they would personally not use the app because of it.

Activity Recommendation

All participants were interested in the activity recommendation. They appreciated being given the opportunity to ‘do-something’ in a positive way. All participants said that they would do the activities they chose from the list of suggestions as a method to improve their mood.
Appearance

All participants (100%) were happy with the overall user interface design and layout of the app. They said the app looked easy to use and had a nice simple design. One participant appreciated that the look of the app was unisex allowing for anyone to feel comfortable using the app.

Key Findings

This section will detail the features that participants suggested to be added to the app during the interview process. These suggestions influenced the choices made for the second phase of design to produce the refined high fidelity prototype app for this research.

Activity Resources

The activity resources feature was the most highly requested feature. The feature involves users being shown resources to lift the burden of thinking what to do for a specific activity, for example if the recommended activity is exercise, the user may not know what exercises to do and not participate in the activity. Participants stated that users would benefit from a list of exercise session videos when recommended the exercise activity. The resources should be divided by time allowing users to be able to take part in an activity at a time range that suits them for example whether that be a 5 minute or 20 minute exercise session.

Customisation

This feature was suggested by numerous participants. Participants wanted to be able to change the background colour associated with each mood state to make it more personal to them. Some participants would prefer other colours over the chosen default background colours provided on the app.

Connection to Helpline or Contacts

Access to a helpline or a close contact was requested by one participant. This feature will give users the ability to get in touch with someone if they need help or someone to talk to, directly from the app. This access should be visible in a subtle way and easy to access. The participant wanted for a user to be able to add more contacts into the application also if desired.

Information on Mood Detection

Several participants wanted more information on the mood detection to be available on the application for more clarity as it was difficult for them to grasp the concept of machine learning being used for mood detection on their own.
Words of Affirmation

Participants suggested that positivity be incorporated into the app whether the user's mood is positive or negative. A participant suggested that daily words of affirmation could be incorporated into the application. Another participant recommended that a prompt for the user to go outside when the weather is good could bring positivity also.

Rating Moods

A scale for mood states was a feature requested by two participants. This scale should allow users to rate the current mood they are feeling as for example you might be feeling happy but it is not the same level of happiness as yesterday.

General Mood Labels

A participant suggested the use of general mood labels instead of only providing five mood states. The participant felt that the mood states in the high fidelity prototype were simplifying mood states making it hard to decide what mood one is in.

Sound Effects

The addition of sound effects in the application was an interesting feature suggested by one participant. They felt that adding sound effects when mood is recorded on the ‘Mood’ page of the app would add more interactivity and engagement to the application.

Gamification

A participant requested for gamification to be incorporated into the application through a point system or growing a tree the more a user uses the app. According to the participant it adds a sense of nurturing personal mental health and growth.

Diary

Another participant requested a diary page be added to the app. This diary would be a space where users can write their thoughts and be able to look back on them without the visualisations of mood and mood logs for reflection.

4.5.4 Design Phase Two: Refined High Fidelity Prototype App

During the second phase of design, the high fidelity prototype app developed throughout the first phase of design was refined considering feedback from participants during the interview process. In the first stage of data collection participants reported feeling content with the overall design layout of the app. However, participants did request additional features to be implemented to further improve the app. Seven out of ten features were incorporated into the
design of the refined high fidelity prototype app due to time constraints as detailed in section 3.9. Screenshots of the features are included throughout this section to illustrate the design choices incorporated in order to develop the refined high fidelity prototype app. Sequential screenshots of the refined high fidelity prototype app can be seen in appendix 6.

Design Layout

No request was made from participants concerning the design layout of the app during the interview process. A similar layout was implemented into the design of the refined high fidelity prototype app along with the incorporation of the additional features suggested by the participants.

Activity Resources

The activity resources feature was the most highly requested feature. This feature was implemented into the refined high fidelity prototype app design. This feature was accessible from the ‘Activity’ page. When the user clicks on any activity card from the list of activities a modal pops up displaying the resources associated with the activity. The resources are also divided by time allowing users to be able to take part in the activity at a time range that suits them in the moment, for example whether that be a 5 minute or 20 minute exercise session. See figure 4.16 and 4.17 to see an example of this with the baking activity.

Figure 4.16: Activity screen with cards

Figure 4.17: Baking card clicked opens baking activity modal with recipes
Customisation

This feature was suggested by numerous participants. This function was available on the ‘Settings’ page of the app that was implemented and made accessible from the bottom navigation bar (see figure 4.18). On this page the user can change the background colour for each mood to their desired colour when they click the edit button which will open a colour picker modal (see figure 4.19). Once a colour is chosen the user can see a preview of their colour on the box and save the new background colour.

Connection to Helpline or Contacts

A contacts modal was implemented into the refined high fidelity prototype app designs requested by a participant. A call button was added to the ‘Mood’ page of the app that when clicked evokes the contacts modal. The contacts modal displays the names and number of contacts that the user can put in this space. The names and numbers of helplines are also displayed in the modal (see figure 4.22). An add button was added for both the contacts and helpline sections to allow the user to add numbers. When clicked the number will be called from the app.
Information on Mood Detection

Several participants recommended making more information on the mood detection available to users. An information button was added to the ‘Mood’ page of the app that when clicked displayed an information modal. This modal displayed some details about the mood detection and how it adapts to the user (see figure 4.23).
Words of Affirmation

Participants suggested that positivity be incorporated into the app whether the user’s mood is positive or negative. A modal was added to the design of the refined high fidelity prototype app that is evoked when the app is launched. The modal will suggest the user to go outside to enjoy the sun if the weather is good and lists out some daily affirmations for the user (see figure 4.24).

Rating Moods

A scale for mood states was a feature requested by two participants and was incorporated into the design of the refined high fidelity prototype app. When a user confirms a mood detection, or inputs a new mood they are promoted to rate the current mood they are feeling from 1 to 5 with ‘1’ being the least and ‘5’ being the most (see figure 4.25). The rating can be seen in the mood logs also. Finally when a user wants to add or edit a mood log the scale is displayed for the user to fill out (see figure 4.26).
A participant suggested the use of general mood labels instead of only providing five mood states. This fits in line with research on mood apps co-designed with participants. Participants highlighted that apps should not over simplify mood states as there are too many (Hetrick et al, 2018). The original mood states displayed across the application in the high fidelity prototype app has been replaced with generalised moods states: ‘Great’, ‘Good’, ‘Ok’, ‘Not Good’, and ‘Bad’ across the refined high fidelity prototype app design.

4.5.5 Conclusion

The high fidelity prototype app developed during this research was heavily influenced by the insights obtained during the literature review phase of the study regarding mood detection, activity recommendation and additional features. This prototype app was evaluated by participants during the first phase of data collection through semi structured interviews. The feedback received from participants resulted in a number of significant improvements and addition of features that were requested. This allowed for the refinement of the high fidelity prototype app design. Evaluation of the final designs is detailed in chapter 5.

4.6 Conclusion

The system being designed for this research contained three components. All the design choices that were made by the author for each component were detailed throughout this
chapter. The mood detection algorithm and activity recommendation system were designed based on the preliminary research that was conducted by the author. The application was designed in two phases in order to incorporate a user centred design approach. The high fidelity prototype app was designed considering the information gathered from the literature review. This high fidelity prototype app was evaluated by participants during the first phase of data collection. The feedback from this stage of data collection was incorporated into the design of the refined high fidelity prototype app that was evaluated by the same participants. Results of this final prototype app are detailed and discussed in chapter 6.
Chapter 5: Implementation
5.1 Introduction

This chapter details the implementation of the application interface, functionality and the application demonstration video by firstly discussing the application requirements. These requirements were compiled from the preliminary research that was carried out by the author and feedback given from participants during the first stage of data collection. Brief descriptions of the components used, provided by the Android Studio IDE, were given to give the reader some context on how the application was implemented. Next, the implementation of each feature and function of the application was discussed including some code snippets for better understanding. Finally the author discusses the development process of the application demonstration video that was used for user evaluation.

5.2 Application Requirements

5.2.1 Introduction

The application being developed as part of this research is designed for individuals who want to manage their mood. This section details the requirements for this application. As the application is not being deployed, discussed in section 3.6.2, the simulation of the functions was implemented.

5.2.2 Application Requirements

The application is designed to allow users to input their mood, add notes to mood logs, view visualisations of their mood on a weekly basis, see weekly and monthly mood logs and view activities they can participate in to improve mood. The application simulates mood detection and activity recommendation, where users can input feedback to these systems to improve their accuracy. These requirements were acquired after the author conducted a literature review on co-designed mood apps and user reviews on popular mood apps in the market. Following the first phase of data collection (see section 4.5.3), the author received feedback from participants on the initial application that was implemented. For the second phase of design discussed in section 4.5.4, new features were added to the application that is detailed in this chapter.

5.2.3 Conclusion

The application being developed for this research had two implementation phases. The application requirements were derived from the literature review carried out by the author. Following the interviews that were conducted with participants, the author obtained a list of requested features that was incorporated into the application throughout the second phase of implementation.
5.3 Android Studio Components

5.3.1 Introduction

The application was developed using the Android Studio IDE. Android Studio contains various building block components for developing applications and their features that the author had not encountered before but used in order to implement the app. This section provides a brief overview of the components used to implement the application. All the information about each component came from the Android Studio official developer’s guide.

5.3.2 Android Studio Components

Activity

Activities are a core component of Android apps. They provide the window where the user interaction (UI) can be drawn. Generally one activity implements a screen of the app. They can also be smaller or float on top of other screens also.

Fragment

Fragments are part of an activity. They represent a reusable section of the app’s UI. Fragments must be launched by an activity as they cannot be hosted independently. Multiple fragments can be combined into one activity and be added, removed or swapped while the activity is running.

ViewPager2

A ViewPager is a layout manager that displays views or fragments in a swipeable format. They allow users to effectively switch between different fragments inside the same activity.

Figure 5.1: Activities and Fragments (Android Studio Developer Guide, 2021)

4 https://developer.android.com/
ViewPager is now deprecated and ViewPager2 is used instead. ViewPager2 has the same functionality as ViewPager.

BottomNavigationBar

The BottomNavigationBar class is extended from the NavigationBarView class. It represents a regular bottom navigation bar for the application. Bottom navigation bars allow users to switch between different top-level fragments or views in one tap. The BottomNavigationBar enables users to switch between three to five top level destinations.

RecyclerView

A RecyclerView displays large datasets that can be scrolled through in the UI while minimising memory usage by recycling items down the list. A layout manager positions the items of the list inside the RecyclerView. A custom adapter connects the dataset to the RecyclerView and is responsible for creating the look for each item in the dataset.

GridView

Similar to the RecyclerView, the GridView displays items in a two-dimensional scrolling grid. The items for the grid come from the custom adapter also.

Dialog

Dialogs are customisable small windows that prompt the user to enter additional information or make a decision. They are displayed on top of a currently running window like a pop-up window. They are used when users need to take action before they can proceed any further. They come from the AlertDialog class in the IDE.

CardView

CardViews are a layout design where UI features can be placed into. They are a card with round corners and drop shadows that enhance the look and feel of an app.

5.3.3 Conclusion

The application was implemented using some Android Studio’s building block components discussed above. The author had to familiarise themselves with these components in order to incorporate them into the mood management app being developed. A brief description of each component was given to give the reader some context on how the application was implemented.
5.4 Application Implementation

5.4.1 Introduction

The BottomNavigationBar was the main activity for this application. The navigation bar was implemented with four separate top-level fragments; mood, insights, activity and settings. This section will break down each top-level fragment within the application, looking at how they were developed and implemented.

5.4.2 Mood Fragment

The mood fragment is the default screen that is seen when the app is opened (see appendix 6). This fragment is made up of several components and functions.

**Information Button**

An information button was implemented that when clicked opens a dialog detailing information about the app's mood detection. The user can close this dialog by clicking the ‘Ok’ button.

**Call Button**

On the opposite side of the information button, a call button was implemented that opens a customised contacts dialog. The contacts dialog is made up of two CardViews. Each CardView holds a scrollable list of contacts containing 1) personal contacts and 2) helpline contacts. The dialog is closed when the user clicks the ‘Done’ button.

**Reason Text Box & Send Button**

The reason text box was implemented using an EditText which allows the user to type into the text box. A send button was placed beside the text box. When the send button is clicked, the text in the text box field is cleared and a toast message is displayed saying ‘Reason was recorded’ for a few seconds.

```java
sendButton.setOnClickListener(new View.OnClickListener() {
    @Override
    public void onClick(View view) {
        editText.setText("");
        Toast.makeText(getContext(), "Reason was recorded", Toast.LENGTH_LONG).show();
    }
});
```

*Figure 5.2: Code Snippet of send button listener implementation*
Date & Time

Under the mood label the date and time are displayed on the fragment. The date and time is retrieved when the fragment is refreshed. This happens when the mood fragment is selected on the BottomNavigationBar via the mood icon. The date and time are obtained using the SimpleDateFormat java library. With this library a specified format can be given to display the date and time.

Edit Mood

The edit button next to the mood label was implemented to open a list dialog. This is a subclass of the AlertDialog where an array can be inserted into the dialog to form a list. The dialog listener returns what position in the list has been clicked, which corresponds to the array. The list contains the different moods that can be selected. When a mood is selected the corresponding background colour, icon and mood label are displayed on the mood fragment and the dialog closes.

Mood Scale

The mood scale is a dialog customised by the author that contains a RatingBar where the user can select from one to five, on the intensity of their mood.

Word of Affirmation Dialog

This dialog pops-up when the app is opened. An Alert Handler is used to schedule the dialog’s arrival time. After 15000 milliseconds from when the app is opened, the affirmation dialog will be displayed. This dialog was customised by the author, it contains a gradient background with a CardView placed on top of it making it look like there is a border around the dialog. The dialog displays some words of affirmations.

```java
// Start modal simulator
AlertHandler = new Handler();
    public void handleMessage(Message msg){
        switch (msg.what) {
            case 0:
                startModal();
                break;
        }
    }
};

AlertHandler.sendMessageDelayed(0,15000);
```

*Figure 5.3: Alert Handler calling the function to display the dialog after 15000 ms*
Mood Detection Simulation

To simulate the mood detection, when the affirmation dialog is closed it calls the mood detection modal function to display the mood detection dialog. The dialog notifies the user that mood has been detected and contains three buttons: 1) ‘Learn more’: That opens a new dialog window that lists how the detection came about, when this dialog closes and calls the mood detection function again to display the mood detection modal again, 2) ‘Yes’: This means the user confirms that the detection was correct, the background colour, icon, and mood text changes to the specified mood and evokes the scale dialog, and 3) ‘No’: This means that the detection was incorrect, the dialog is closed and a toast message is displayed.

```java
public void moodDetectedModal(){
    AlertDialog.Builder builder = new AlertDialog.Builder(getActivity());
    builder.setTitle(“Mood Detected!”)
    .setMessage(“We have detected that your mood may be ‘Not Good’. Is this correct?”)
    .setPositiveButton(“Yes”, new DialogInterface.OnClickListener() {
        @Override
        public void onClick(DialogInterface dialogInterface, int i) {
            relativeLayout.setBackgroundColor(ContextCompat.getColor(getActivity(), R.color.colorSad));
            moodString.setText(R.string.stringSad);
            moodIcon.setImageResource(R.drawable.sad);
            moodScaleHandler();
        }
    });
    .setNeutralButton(“Learn More”, new DialogInterface.OnClickListener() {
        @Override
        public void onClick(DialogInterface dialogInterface, int i) {
            learnMoreModal();
        }
    });
    .setNegativeButton(“No”, new DialogInterface.OnClickListener() {
        @Override
        public void onClick(DialogInterface dialogInterface, int i) {
            dialogInterface.cancel();
            Toast.makeText(getBaseContext(), “Thank you for letting us know”, Toast.LENGTH_LONG)
                .show();
        }
    });
    builder.show();
}
```

Figure 5.4: Mood Detection Dialog Implementation

Activity Recommendation Simulation

When a negative mood is detected or inputted by the user, an activity modal is displayed. This modal is a customised dialog containing a GridView of activities. A Custom Adapter class was implemented to add the image and activity name of each activity to the grid. When an item in the grid is clicked the image and text are greyed to indicate that it has been pressed. When a greyed out item is clicked it returns to the normal state. Multiple items can be selected also.
5.4.3 Insights Fragment

The insights fragment (see appendix 6) is displayed when the insights icon is selected on the BottomNavigationBar. This fragment contains a ViewPager2 layout to display weekly and monthly insights. This was implemented using the ViewPager2 and TabLayout which allows the user to switch between weekly and monthly insights through tabs.

Mood Logs

Both weekly and monthly pages contain mood logs. The mood logs were implemented using CardViews to display text. Each mood log had an edit button located next to it. When the edit button is selected, a custom dialog is displayed allowing the user to edit the mood, scale and reason field of the log. When they are done the log will be updated as the text will be replaced. An add button is located beside the mood log heading where the user can add a new log. It displays the same custom dialog however, when the user clicks the done button the new log will be displayed with the current time.

Calendar

For the monthly page, a calendar is displayed using the CalendarView component. The user can look through the dates. The current date will always display the predefined mood logs for simulation purposes. When the user selects a new date on the calendar the mood logs will be cleared.

Weekly Bar Chart

For the weekly page, a bar chart of the overall mood for each day is displayed. The MPAndroidChart library was used to generate the bar chart. The bar chart class from the library requires a few components to be displayed: 1) BarChart that is the bar chart, 2) BarDataSet which is the data that will be displayed on the chart, 3) ArrayList<BarEntry>, that is a list containing the data for each individual data point and 4) ArrayList<String> barLabels that contains the list of label associated to the data points. The BarEntry list is created through a for loop iteration of the data points.

```
for(int i=0; i < moodChartData.size(); i++){
    String day = moodChartData.get(i).getDay();
    int mood = moodChartData.get(i).getMood();

    barEntryArrayList.add(new BarEntry(i, mood));
    labelNames.add(day);
}
```

*Figure 5.5: Bar Entry List being created*

This list is then passed to a new object called a BarDataSet. This combined with the list of labels are used to create the final data object that will be used by the BarChart class to display the chart.
5.4.4 Activity Fragment

The activity fragment (see appendix 6) is displayed when the activity icon is selected in the bottom navigation bar. This fragment is associated with the activity recommendation part of the system. The activity displays two major components: 1) The activity recommendation grid and 2) the list of other activities.

Activity Recommendation Grid

This activity grid is implemented with the same layout as the activity recommendation simulation dialog that was discussed in section 5.4.2. The purpose of this feature is to allow users to select the activities that helped them improve their mood and even add their own activities if none or others helped that are not in the grid.

List of Activities

The list of activities was implemented using the RecyclerView. A custom adapter class was implemented to implement each card for the list. Only the baking activity card was implemented with an attached resource to be used for demonstration purposes. When any card is clicked a dialog will be displayed containing a WebView. The WebView is loaded with a URL that is associated with recipes for baking. The user can scroll through this WebView of the URL in the dialog to look for recipes. When a recipe is clicked it will open up that recipe on the user’s default browser. When the back button is pressed on the device it will return the user to the application.
5.4.5 Settings Fragment

The settings fragment (see appendix 6) is displayed when the settings icon is pressed on the bottom navigation bar. The purpose of this fragment is to simulate colour customisation where users can change the colours for each mood. This fragment is made up of a CardView that contains a list of moods. Each mood is accompanied with a view to display the chosen colour, an edit button and a save button. The edit button displays a dialog that contains a colour picker. The AmbilWarna library was used to display the colour picker. When the user selects a colour and selects ‘Ok’, the view changes to the selected colour.

```java
@override
public void onColorPicker()
{
    {
        @Override
        public void onCancel(AmbilWarnaDialog dialog) {
        }

        @Override
        public void onOk(AmbilWarnaDialog dialog, int color) {
            mView.setBackground(color);
        }
    });
    colorPickerDialogue.show();
}
```

Figure 5.8: Implementation when edit button is clicked
5.4.6 Conclusion

This section describes the implementation of the different functions and features of the application from top level to low level parts. Code snippets were provided for extra explanation of the implementation. The source code can be accessed on GitHub available in appendix 1. All screenshots of the application can be found in appendix 6.

5.5 Application Demo Video Implementation

5.5.1 Introduction

In order to allow participants to evaluate the application a demo video was created to convey the features and functionalities of the application in a visual form to participants. This section describes the process of the app demo video implementation.

5.5.2 Application Demo Video Implementation

Following the completion of the app implementation, the author installed the app into their android device. Next, the author ran the app and screen recorded the application that was simulated by them. The clips from the screen recorded were imported to another device where the video editing took place. The video editing application CapCut, was used to edit the app demo video. The author cut clips to shorten the video but present every function and feature of the app. Visual effects, concise descriptions of the features and functions, and copyright free music were added to the demo video in order to make the video informative and engaging to participants. Two app demo videos were created for both evaluation phases throughout the duration of this research following the discussed approach.

5.5.3 Conclusion

Two app demo videos were filmed and edited by the author to present the application’s functions and features to participants during both phases of data collection described in section 3.5.3. CapCut was used to edit the videos and the videos were recorded from the author’s mobile device as they interacted with the implementation of the application to simulate a user using the app. The demo video was designed to be informative and engaging to encourage participants to provide feedback.

5.6 Conclusion

This chapter highlighted the implementation of the application, one of the major parts of the system being designed for this research, and the demo video for the application that was used in the data collection stages. The application requirements were discussed and a brief overview was provided of the building block components from Android Studio that were incorporated into the development of the application.
Chapter 6: Evaluation & Discussion
6. Introduction

This research aimed to answer the research question “How can machine learning with phone sensors and recommender systems be used to manage mood and promote positive mental health?”. A system was designed that uses machine learning techniques to detect mood using phone sensor data and recommends activities to users through the use of recommender systems. A mood management app was implemented to simulate the designed mood detection and activity recommendation in a mood app with various other features for mood management. Participants were surveyed to evaluate the final prototype app in order to validate the success of this research. This chapter displays the results from the final data collection stage and discusses the key findings of this evaluation and the significance these results have in this research. Details on the differentiation and comparison of the developed application from other related applications discussed in the literature review chapter are presented and discussed below.

6.2 Evaluation

6.2.1 Introduction

This section lays out the findings from the final phase of data collection conducted with the eight participants involved in this research, which consisted of an evaluation survey on the usability and engagement of the final prototype app. Through this evaluation the author aimed to gather final user feedback regarding the functionalities of the implemented application including any further improvements that could be incorporated into the application.

6.2.2 Survey Results

Below, questions given to participants during this final phase of data collection have been provided, graphical representation, produced by Qualtrics, visualising the feedback given have been included and the results have been detailed. See the link to the survey in appendix 2.

*Question 1: Please rate the following statement on a scale from ‘strongly disagree’ to ‘strongly agree’. See figure 6.1 for the results.*

**Note:** The statements in the legend in order say:
- I think I would use this app frequently.
- The app looks complicated.
- The app looks easy to use.
- The idea of calculating mood from a phone seems useful.
- The idea of calculating mood from a phone seems intrusive.
- I think I would need help from a technical person to use this app.
- I would follow the activities that the app suggests me to better my mood.
- I think this app promotes positive mental health.
All participants (100%), see figure 6.1, agreed that they would not need help from a technical individual to be able to use the app.

5 participants (62.5%) expressed that they somewhat disagree with the statement ‘The idea of calculating mood from a phone seems intrusive’.

5 participants (62%) strongly agree that the app promotes positive mental health.

4 participants (50%) somewhat agree to feeling like they would use the app frequently.

4 participants (50%) somewhat agree with mood detection using phone sensor data seeming useful and 3 participants (37.5%) expressed that they strongly agree to this.

4 participants (50%) responded that they somewhat agree with the statement, ‘I would follow the activities that the app suggests to better my mood’ with 3 participants (37.5%) strongly agreeing to that statement.

3 participants (37.5%) strongly disagree with the statement ‘The app looks complicated’.

**Question 2:** What score would you rate the user interface of the app from ‘0’ (very bad) to ‘10’ (amazing).
4 participants (50%) rated the user interface (UI) of the app with a score of 9-10, see figure 6.2.

3 participants (37.5%) gave the UI a rating of 7-8.

1 participant (12.5%) rated the UI of the app below 7.

**Question 3: Do you have any thoughts on how to improve the design of the app?**

"Everything is perfect, I love the idea of the hotline help which I have never come across in any app. Nothing really to add about looking at the new update. The only thing I will say is to keep it as a minimalist style, such as a neutral or black and white colour scheme. The simple colour can avoid a messy looking app."

"Rewards / game system to encourage continued use"

"No, I like its very customisable"

"The app is great already and I really liked that the user is now able to customise the design of the app more i.e colours of moods"

"The design of the app looks very good, however adding too much functionalities can complicate a user."

"From an aesthetic point of view, perhaps the shapes could be a bit rounder - I think that’s what’s fashionable these days and it looks less formal than a square. Other than that, I think it’s great!"

"None that I could think of, I thought it looked fantastic!"

*Figure 6.3: Question 3 Results from 7 Respondents*
Overall (see figure 6.3) participants gave positive feedback on the design of the final prototype app that the author implemented with few comments on improvements.

**Question 4a: What do you think are the most useful or helpful features of the app? Choose as many answers that apply.**

![Figure 6.4: Question 4a Results from 8 Respondents](image)

7 participants (87.5%), see figure 6.4, responded that activity recommendation is a helpful and useful feature of the app.

4 participants (50%) selected that mood detection with phones is a useful and helpful app feature.

**Question 4b: Please list the useful/helpful features of the app below.**

![Figure 6.5: Question 4b Results from 1 Respondent](image)

1 participant (12.5%), see figure 6.5, selected the ‘other’ option from question 4a and added that they found the insights feature useful and helpful.

**Question 5a: What do you think are the most frustrating features of the app? Choose as many answers that apply.**
5 participants (62.5%), see figure 6.6, answered that the app suggesting activities that the user may not be interested in is a frustrating feature of the app.

3 participants (37.5%) answered that mood detection with phones is a frustrating feature of the app.

Question 5b: Please list the frustrating features of the app below.

- Maybe the lack of the deeper feelings to express for the day such as anxiousness, frustration, annoyed and more.
- a bit too much functionalities
- Maybe if there are too many notifications/popups throughout the day

Question 6: Do you think the app would help you manage your mood?
Overall, see figure 6.8, 6 participants (75%) agree that the app would help them manage their mood.

2 participants (25%) responded that the app would definitely help them manage their mood, and 4 participants (50%) responded that the app would probably help them manage their mood.

**Question 7: Do you think the app would promote positive mental health?**

2 participants (25%), see figure 6.9, definitely think that the app would promote positive mental health.
4 participants (50%) responded ‘probably yes’ to the question, ‘Do you think the app would promote positive mental health?’

2 participants (25%) expressed that they are unsure whether or not the app would promote positive mental health.

6.2.3 System Usability Scale (SUS)

The SUS is a standardised, and widely used questionnaire that is used to test the usability of systems. It tests the user satisfaction level of a system (Brooke, 2013). Below is a table of the SUS scores calculated from question 1 in the survey, given to the system designed for this research from each participant.

<table>
<thead>
<tr>
<th>Participant</th>
<th>SUS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>78</td>
</tr>
<tr>
<td>P2</td>
<td>72</td>
</tr>
<tr>
<td>P3</td>
<td>75</td>
</tr>
<tr>
<td>P4</td>
<td>75</td>
</tr>
<tr>
<td>P5</td>
<td>69</td>
</tr>
<tr>
<td>P6</td>
<td>72</td>
</tr>
<tr>
<td>P7</td>
<td>59</td>
</tr>
<tr>
<td>P8</td>
<td>72</td>
</tr>
</tbody>
</table>

*Table 6.1: SUS Score Results*

The average score for this System Usability Scale was 71.5. The average score on the SUS scale is 68. Receiving a score above the average indicates the need for minor improvements and receiving a score of 100 indicates that no improvements are required (Brooke, 2013). This means that the system being designed for this research is usable but still needs some improvements.

6.2.4 Conclusion

The findings from the final phase of data collection revealed overall a positive outlook from all participants regarding the final implementation of the prototype app. This section laid out the survey results that participants engaged in and displayed the System Usability Scale (SUS) score that was derived from the results of the first question in the survey. The average SUS score revealed that the system is good but needs some minor improvements. The next section will discuss these results regarding their significance to this research.
6.3 Discussion

6.3.1 Introduction

This section discusses the application that was developed as part of this dissertation and how it compares and differs from the applications discussed in chapter 2. Furthermore the key findings from the final data collection phase (see section 6.2) are discussed and their significance to the research are detailed.

6.3.1 Application Discussion

To answer the research question, a mood management application was implemented centred around the simulation of the main features; mood detection and activity recommendation. As described in section 4.2, the author designed a system that contained three components 1) mood detection, 2) activity recommendation and 3) the mood management app. The mood detection feature was designed to incorporate the Naive Bayes machine learning classifier with phone sensor data as feature inputs. These sensors included physical sensors like the accelerometer to track micromotion and the phone’s operating system to derive information on communication frequencies. This differs from the Funf android app discussed in section 2.4.2, that uses Bluetooth proximity sensing to track face-to-face social interactions to detect mood. This feature could potentially be integrated into the system being designed for this research in the future as a means to tracking social interactions. A semi-automated mood tracking approach was incorporated into the design of this system. OnmiTrack, an android self-tracker app used the same approach and found it to be successful (see section 2.3.2). The activity recommendation feature was designed to incorporate a modified collaborative filtering recommendation system to suggest activities to users. As detailed in section 2.5.2, collaborative filtering is subject to ‘cold starts’ that occurs when there is not much information to make a recommendation typically when a new user enters the system which is why the recommender system was modified as seen in section 4.4.2. Default activities added to the recommendation system were taken from literature as laid out in section 2.5.3. The mood management app simulated these two features but also incorporated other features that are found in mood apps like recording mood, adding notes to mood and displaying visualisations of mood (see section 2.7). The author analysed various mood apps in section 2.6 and found that there was a lack of mood apps incorporating mood detection using a semi-automated tracking approach. The overall mood management app was implemented to feature mood detection and activity recommendation to be used in the evaluation in order to validate the research question.

6.3.2 Evaluation Discussion

The purpose of the application being developed for this research was to help users manage their mood and promote positive mental health. 62.5% of participants somewhat agree with mood detection through phone sensor data not seeming intrusive and 7 participants of 8 felt that the use of phones to calculate mood is a useful and helpful feature of the app. However, 3 participants expressed that the mood detection feature could potentially be frustrating. The
author is unsure as to why this is the case. One participant mentioned that too many notifications/pop-ups of detected mood throughout the day would be frustrating which could also be why the other participants felt that the mood detection feature could possibly become frustrating. The data suggests that participants were more interested in the activity recommendation feature than the mood detection. Seven participants agreed that they would follow the suggested activities from the app and felt that the activity recommendation is a helpful and useful feature of the app. However, 62.5% of participants expressed that the app recommending activities that an individual might not be interested in could be frustrating. As discussed in section 2.5.2, a challenge with building recommender systems is the trade off between diversity and accuracy. Recommender systems should not only recommend items that are likely to satisfy the user but also incorporate new items to allow the user to potentially discover new interests. The author describes in section 4.4.2 that in order to overcome this challenge the system would recommend 1-2 new activities and the rest of the suggested activities will be ones that are likely to satisfy the user. Overall participants had positive responses regarding the usefulness and engagement of the app.

Majority of the participants felt that the app would help them manage their mood and promote positive mental health which satisfies the research question. As mentioned above in section 6.2.3, the average System Usability Score the designed system received was 71.5 meaning that the system is good but needs minor improvements. Participants commented on improvements that could be made to the app that included minor changes to the UI design for a more trendy simplistic design, gamification or rewards to encourage continued use and more expressions of mood states. Participant 8 felt that after the second iteration of design and implementation the app became a bit complicated with “too many functionalities”. The rest of participants overall liked the final design and implementation of the app (see figure 6.3).

6.3.3 Conclusion

In order to validate the research question the author designed a system that incorporates machine learning with phone sensor data to develop the mood detection feature and recommender systems to design the activity recommendation system. A mood management app was implemented by the author to simulate a mood app that uses a semi-automated tracking approach with mood detection and suggest activities to users to hopefully improve their mood. This video demo of this app was used in the final evaluation process with the participants involved in this research. The results of this evaluation satisfy the research question as participants found the mood detection and activity recommendation to be useful features of the app and expressed that the app could potentially help them manage their mood and promote positive mental health. Findings also reveal that the system is not perfect and still needs some minor improvements.

6.4 Conclusion

Overall participants had positive responses regarding the usefulness and engagement of the app. Majority of the participants felt that the app would help them manage their mood and
promote positive mental health satisfying the research question. The proposed system was not found to be perfect and still has some improvements to make it more usable and useful for potential users. The next chapter will provide conclusions of the outcomes of this research, detail the limitations and provide future work recommendations.
Chapter 7: Conclusion
7.1 Introduction

This research aimed to incorporate mood detection and activity recommendation using machine learning techniques with phone sensor data and recommender systems into a mood management mobile app to help users manage their mood and promote positive mental health. This final chapter presents the conclusion of the outcomes of this research, details the limitations associated with this dissertation and explores opportunities for future work.

7.2 Conclusion

The goal of this research was to investigate how machine learning using phone sensor data and recommender systems can be incorporated into a mood management app to help users manage their mood and promote positive mental health. The literature review provided theoretical evidence which provided the author with insights as to how to answer the research question. The author reviewed machine learning algorithms, phone sensors that could potentially detect mood, recommender systems, activities that could potentially improve an individual's mood and features to include in a mood app. As a result of the understanding gained through the literature review, the author was able to design and implement a high fidelity prototype app using Android Studio and is explained in section 5.4.

A user centred design approach was taken through the duration of this research as detailed in section 3.6.3. Following this approach, two design phases paired with two data collection phases were included, where participants were involved in evaluating the prototype app design and implementation. This ensured the creation of an end-user validated mood management app as target end user input was incorporated into the design of the application.

As discussed in section 6.2 the final evaluation with participants revealed that the high fidelity prototype app was perceived as useful and engaging. Comments were made on minor improvements for future works. The author is interested in pursuing the suggestions from both phases of data collection in the future as discussed in section 7.4 below. The results of the final evaluation satisfy the research question as participants found the mood detection and activity recommendation to be useful features of the app and expressed that the app could potentially help them manage their mood and promote positive mental health.

Overall mood detection using machine learning algorithms and activity recommendation with recommender systems can be incorporated into a mood management app to support the management of mood and promote positive mental health.

7.3 Limitations

Time Constraints

The MSc dissertation time constraint of 8 months was a factor that influenced the objectives of this dissertation. There are numerous opportunities for future work and improvements to
this dissertation. These are not feasible to be completed within the scope of the dissertation timeline and so, have been detailed in section 7.4 below.

Ethics Approval

A notable limitation to this dissertation was the ethics approval delay. In order to carry out the data collection phases of this research, an ethics application was required (see appendix 3). It unfortunately took 12 weeks to obtain the approval. This delay deferred the data collection phases. The time available to design and develop the refined high fidelity prototype was impacted, being shortened in comparison to what was originally planned. Though this was a limitation, it did not hinder this study. This delay allowed for the author to spend more time to design and implement the high fidelity application and create a high quality app demo video to be used for the first phase of data collection.

A detailed plan of the evaluation process including the questions was required at the ethics proposal stage. This impacted the flexibility of the evaluation phases as it was necessary to follow the phases of evaluation detailed in the application in the early stages of this research. Luckily, the author included open ended questions within the semi-structured interview (see appendix 3) prior to submitting the ethics application. This resulted in the author being able to receive detailed information and feedback from the participants.

Development

The author was developing the application using Android Studio on a laptop equipped with 4GB of memory and a hard drive disc. This did not meet the requirements to run Android Studio smoothly and as a result the author experienced a lot of slowness and application crashes while using Android Studio, increasing the time spent on developing the app. This factor limited the author’s ability to build every feature into the app and decreased the amount of time on writing the dissertation as more time was spent on implementation.

7.4 Future Work

Implementation of Mood Detection and Activity Recommendation

The core elements of the application being developed for this dissertation are 1) mood detection using machine learning algorithms with phone sensor data and 2) activity recommendation using recommendation systems. These features were designed by the author in chapter 4 and the implemented application simulated these features instead of implementing the actual feature. This is because implementation of these features were out of the scope of this research due to the general 8 month time constraint of the MSc dissertation timeline. An app demo video was created to allow participants to grasp the functionality of the app and so the implementation of mood detection and activity recommendation was not necessary. Potential work could be done to complete the app by implementing these core elements.
Extended Evaluations

The evaluation of the research could be extended to allow participants to use a downloadable version of the application for a week on their personal devices. This would give more insight into the usefulness and engagement of the app and if it helps the user actually manage their mood and promote positive mental health. For this research a downloadable version was not made available to participants as the app only simulated the mood detection and activity recommendation meaning it was not complete. This extended evaluation could be implemented when the app is fully developed in future works.

Diary/Journal Feature

As requested by a participant during the first phase of data collection in section 4.5.3, a diary feature could be added to the application. The diary would allow the user to write how they feel and even add images that are beyond recording a mood log. The user can look back at the diary without seeing the visualisations of mood over time and just read their personal diary entries. This feature could not be implemented for the second data collection phase due to the ethics approval delay which resulted in a time constraint.

Gamification Feature

During the first phase of user evaluation, it was suggested by a participant that gamification could be incorporated into the design of the application (see section 4.5.3). This would involve the implementation of a point or reward system in the app to encourage the continued use of the app. The participant explained in the interview that they felt like a point or reward system could help them continue to use the app, continue to want to manage their mood and do the suggested activities to improve their mood. The author believes that a reward system would be a good approach to motivate users to manage their mood and act to improve their mood. Rewards could potentially include coupons for baked goods or free gym memberships. Again, this feature could not be included in the refined high fidelity app design due to the time constraint as a result of the ethics approval delay.

iOS Version and Deploying to App Stores

Android Studio was the chosen IDE (see section 3.7.2) for this research which resulted in the development of an application that is only compatible with the android operating system. There is an opportunity for future work to develop a version suitable for iOS devices. Due to the limited time frame to fully complete the app and scope of this dissertation the app was not deployed to any app store. As discussed in section 3.9.2, there are ethical considerations in regards to phone sensor data tracking. Before deploying this app there is future work to be done to ensure GDPR standards are upheld concerning the storage of users’ personal information and sensitive phone sensor data.
Usability

Section 6.2.3 revealed that the system designed for this research was good but needs some minor improvements for usability from the System Usability Scale. These improvements could include onboarding to allow users to understand how to use the application, more customisable settings in terms of mood scales and notification times and a more simple design. These have been identified as areas of potential future work.


Fling, B., 2009. Mobile design and development: Practical concepts and techniques for creating mobile sites and Web apps. "O'Reilly Media, Inc.".


Appendix

Appendix 1: GitHub Source Code
https://github.com/divinembunga/mood-management-app/tree/master

Appendix 2: Qualtrics Survey Link
https://scsstcd.qualtrics.com/jfe/form/SV_0IgD1IEKRKS2lzs

Appendix 3: Ethics Application

School of Computer Science & Statistics
Research Ethics Application

Part A

Project Title: To Design & Implement a Mood Management Mobile Application to Promote Positive Mental Health.

Name of Lead Researcher (student in case of project work): Divine Mbunga

Name of Supervisor: Dr. Lucy Hederman

TCD Email: mbungad@tcd.ie Contact Tel No: 0877635882

Course Name and Code (if applicable): Integrated Computer Science, TR033

Estimated start date of survey/research:

I confirm that I will (where relevant):

- Familiarise myself with the Data Protection Act and the College Good Research Practice guidelines http://www.tcd.ie/info_compliance/dp/legislation.php;
Tell participants that any recordings, e.g. audio/video/photographs, will not be identifiable unless prior written permission has been given. I will obtain permission for specific reuse (in papers, talks, etc.)

Provide participants with an information sheet (or web-page for web-based experiments) that describes the main procedures (a copy of the information sheet must be included with this application)

Obtain informed consent for participation (a copy of the informed consent form must be included with this application)

Should the research be observational, ask participants for their consent to be observed

Tell participants that their participation is voluntary

Tell participants that they may withdraw at any time and for any reason without penalty

Give participants the option of omitting questions they do not wish to answer if a questionnaire is used

Tell participants that their data will be treated with full confidentiality and that, if published, it will not be identified as theirs

On request, debrief participants at the end of their participation (i.e. give them a brief explanation of the study)

Verify that participants are 18 years or older and competent to supply consent.

If the study involves participants viewing video displays then I will verify that they understand that if they or anyone in their family has a history of epilepsy then the participant is proceeding at their own risk

Declare any potential conflict of interest to participants.

Inform participants that in the extremely unlikely event that illicit activity is reported to me during the study I will be obliged to report it to appropriate authorities.

Act in accordance with the information provided (i.e. if I tell participants I will not do something, then I will not do it).

Signed: Divine Mbunga
Date: 25/02/22

Lead Researcher/student in case of project work

Part B

<table>
<thead>
<tr>
<th>Please answer the following questions.</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has this research application or any application of a similar nature</td>
<td>No</td>
</tr>
<tr>
<td>connected to this research project been</td>
<td></td>
</tr>
</tbody>
</table>
refused ethical approval by another review committee of the College (or at the institutions of any collaborators)?

| Will your project involve photographing participants or electronic audio or video recordings? | No |
| Will your project deliberately involve misleading participants in any way? | No |
| Does this study contain commercially sensitive material | No |
| Is there a risk of participants experiencing either physical or psychological distress or discomfort? If yes, give details on a separate sheet and state what you will tell them to do if they should experience any such problems (e.g. who they can contact for help). | Yes |
| Does your study involve any of the following? | Children (under 18 years of age) | No |
| | People with intellectual or communication difficulties | No |
| | Patients | No |

---

**School of Computer Science and Statistics Research Ethical Application Form**

Details of the Research Project Proposal must be submitted as a separate document to include the following information:

1. Title of project
2. Purpose of project including academic rationale
3. Brief description of methods and measurements to be used
4. Participants - recruitment methods, number, age, gender, exclusion/inclusion criteria, including statistical justification for numbers of participants
5. Debriefing arrangements
6. A clear concise statement of the ethical considerations raised by the project and how you intend to deal with them
7. Cite any relevant legislation relevant to the project with the method of compliance e.g. Data Protection Act etc.

Part C

I confirm that the materials I have submitted provided a complete and accurate account of the research I propose to conduct in this context, including my assessment of the ethical ramifications.

Signed: Divine Mbunga Date: 25/02/22

Lead Researcher/student in case of project work

There is an obligation on the lead researcher to bring to the attention of the SCSS Research Ethics Committee any issues with ethical implications not clearly covered above.

Part D

If external or other TCD Ethics Committee approval has been received, please complete below.

External/TCD ethical approval has been received and no further ethical approval is required from the School’s Research Ethical Committee. I have attached a copy of the external ethical approval for the School’s Research Unit.

Signed: Date:

Lead Researcher/student in case of project work

Part E

If the research is proposed by an undergraduate or postgraduate student, please have the below section completed.

I confirm, as an academic supervisor of this proposed research that the documents at hand are complete (i.e. each item on the submission checklist is accounted for) and are in a form that is suitable for review by the SCSS Research Ethics Committee
Completed application forms together with supporting documentation should be submitted electronically to the online ethics system https://webhost.tchpc.tcd.ie/research_ethics/ When your application has been reviewed and approved by the Ethics committee, hardcopies with original signatures should be submitted to the School of Computer Science & Statistics, Room 104, Lloyd Building, Trinity College, Dublin 2.

CHECKLIST

Please ensure that you have submitted the following documents with your application:

1. **SCSS Ethical Application Form**
   - [Y]

2. **Participant’s Information Sheet** must include the following
   - a) Declarations from Part A of the application form;
   - b) Details provided to participants about how they were selected to participate;
   - c) Declaration of all conflicts of interest
   - [Y]

3. **Participant’s Consent Form** must include the following:
   - a) Declarations from Part A of the application form;
   - b) Researchers contact details provided for counter-signature (your participant will keep one copy of the signed consent form and return a copy to you).
   - [Y]

4. **Research Project Proposal** must include the following:
   - a) You must inform the Ethics Committee who your intended participants are i.e. are they your work colleagues, classmates etc.
   - b) How will you recruit the participants i.e. how do you intend asking people to take part in your research? For example, will you stand on Pearse Street asking passers-by?
   - c) If your participants are under the age of 18, you must seek both parental/guardian AND child consent.
   - [Y]

5. **Intended questionnaire/survey/interview protocol/screenshots/representative materials (as appropriate)**
   - [Y]
Notes on Conflict of Interest

1. If your intended participants are work colleagues, you must declare a potential conflict of interest: you are taking advantage of your existing relationships in order to make progress in your research. It is best to acknowledge this in your invitation to participants.

2. If your research is also intended to direct commercial or other exploitation, this must be declared. For example, “Please be advised that this research is being conducted by an employee of the company that supplies the product or service which forms an object of study within the research.”

Notes for questionnaires and interviews

1. If your questionnaire is paper based, you must have the following opt-out clause on the top of each page of the questionnaire: “Each question is optional. Feel free to omit a response to any question; however the researcher would be grateful if all questions are responded to.”

2. If your questionnaire is on-line, the first page of your questionnaire must repeat the content of the information sheet. This must be followed by the consent form. If the participant does not agree to the consent, they must automatically be exited from the questionnaire.

3. Each question must be optional.

4. The participant must have the option to ‘not submit, exit without submitting’ at the final submission point on your questionnaire.

5. If you have open-ended questions on your questionnaire you must warn the participant against naming third parties: “Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised.”

6. You must inform your participants regarding illicit activity: “In the extremely unlikely event that illicit activity is reported I will be obliged to report it to appropriate authorities.”
Information Sheet for Participants

Name of Lead Researcher: Divine Mbunga
Contact Information: Email: mbungad@tcd.ie  Phone Number: 0877635882
Research Question: To Design & Implement a Mood Management Mobile Application to Promote Positive Mental Health.

Part One - The Study

Why is this study being done?
This research is part of a Master’s dissertation project. The aim is to help people manage their mood and promote positive mental health by developing an app. This app will attempt to figure out the user’s mood from what they are doing on their mobile phone and suggest activities for them to do to better their mood. The study you are being invited to participate in is designing the app; your participation does not involve use of the app.

Why have I been invited to take part?
You have been invited to take part in this study because you are over the age of 18 and you replied to an invitation to be involved in research about how an app might help people manage their mood and self care.

Do I have to take part? Can I withdraw?
You don’t have to take part in this study. It is entirely voluntary. You can change your mind about taking part in this study and withdraw at any time throughout the study. You don’t have to give a reason for not taking part or withdrawing. If you wish to withdraw, please contact me and I will be able to organise this for you.

What happens if I change my mind?
You can change your mind at any time by contacting me at mbungad@tcd.ie. If you wish, you can ask for your contact details to be removed from the research. If you request this, I will destroy your contact details, email address that is still in my possession. Handwritten notes from the interview (though not identifiable as associated with you) cannot be destroyed after the interview as they will be stored in a way that will not be identifiable. Data (though not identifiable as associated with you) from the online survey cannot be deleted as they will
be anonymous. All data will be disposed of securely when the dissertation is submitted in April 2022.

How will the study be carried out? What will happen to me if I decide to take part?
For this study you are asked to review and evaluate the progressive versions of a mood management app. Evaluation will be done through watching a demonstration of the app. There will be two phases of evaluation. You will be asked to take part in both phases.

- You will be asked to watch a demonstration of the initial app taking approximately 10 minutes and be scheduled for a 30 minute interview to give feedback on the usefulness and engagement of the app and to comment on anything.
- You will be invited to watch a second 10 minute video demonstration of the ‘improved’ app and will be asked to complete a short online survey that will take approximately 5 minutes on the system usability of the app.

What will happen to my feedback data?
Any data collected in the feedback, handwritten notes from the interview and answers from the online survey (though not identifiable as associated with you), will be kept safe and secure. It will be stored in the lead researcher’s OneDrive account. No data will be shared with anyone other than the lead researcher and the academic supervisor. All data will be disposed of after the dissertation has been submitted.

Are there any benefits to taking part in this research?
Taking part in this study will not directly benefit you. However, research performed with your feedback will allow for improvements to promoting positive mental health through a mobile device by managing mood.

Are there any risks to me or others if I take part?
Because the app being developed is concerned with mood there could be a possibility that an interview about the app might cause distress. If you feel like that is the case you can withdraw from the research at any time.

Will I be told the outcome of the study?
Once the results have been concluded, they will be reported in the MSC dissertation. The results of the research will be made available to participants upon request. No information which reveals your identity will be disclosed.

Part Two - Data Protection

What information about me (personal data) will be used as part of this study?
Your contact details, your email in this case and the consent form are the only personal data that will be used as part of this study for recruitment purposes, organising your interview and sending you the link to the online survey. Interview answers will be de-identified and answers from the online survey will be anonymised.
Will my data be kept confidential? How will my data be kept safe?
All information collected throughout this study will be treated as confidential. No information will be shared to anyone other than the lead researcher and academic supervisor in any way. All data from the interview and online survey (though not identifiable as associated with you) will be stored securely in the lead researcher’s OneDrive account. All data will then be destroyed following completion of the relevant exam board by removing all data associated with the study from the researcher’s OneDrive account.

What are my rights?
You are entitled to:
- The right to access to your data and receive a copy of it
- The right to restrict or object to processing of your data
- The right to object to any further processing of the information we hold about you (except where it is de-identified)
- The right to have inaccurate information about you corrected or deleted
- The right to receive your data in a portable format and to have it transferred to another data controller
- The right to request deletion of your data

Which applies to your personal information i.e contact details and consent form.

By law you can exercise the above rights in relation to your data. You can exercise these rights by contacting me or the Trinity College Data Protection Officer, Secretary’s Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie. Website: www.tcd.ie/privacy.

Part Three - Costs

Who is organising this study?
Divine Mbunga is the lead researcher of this study. The academic supervisor is Dr. Lucy Hederman of the School of Computer Science and Statistics in Trinity College Dublin.

Is there any payment for taking part? Will it cost me anything if I agree to take part?
No, I will not be paying people to take part in the study. There is no monetary commitment to take part. There is a time commitment for watching two short videos taking approximately 10 minutes each, an interview taking approximately 30 mins and an online survey taking approximately 5 minutes. All together it will take approximately 55 minutes.
Are there any conflicts of interest?
Participants involved in the study will be individuals who are acquainted with the researcher. This means that there may be some bias in the research.

Who should I contact for information or complaints?
If you have any concerns or questions, you can contact:
- Researcher: Me, Divine Mbunga, at mbungad@tcd.ie
- Data Protection Officer, Trinity College Dublin: Data Protection Officer, Secretary’s Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie. Website: www.tcd.ie/privacy.

Under GDPR, if you are not satisfied with how your data is being processed, you have the right to lodge a complaint with the Office of the Data Protection Commission, 21 Fitzwilliam Square South, Dublin 2, Ireland. Website: www.dataprotection.ie.

Will I be contacted again?
If you would like to take part in this study, you will be asked to sign the Consent Form on the next page. You will be given a copy of this information leaflet and the signed Consent Form to keep.

Thank you for taking the time to read this information sheet. I invite you to direct any concerns or questions to me if you are in any way hesitant to participate.
Informed Consent Form

Lead Researcher: Divine Mbunga  
Supervisor: Lucy Hederman

Background of Research: The prototype app you will be evaluating is a mood management app. It aims to help people manage their mood and promote positive mental health.

Procedures of this Study: To take part in this study, you will be asked to review the prototype by watching a 10 minute video demonstration. You will be scheduled for a 30 minute interview to comment and give feedback on the app. At a later date you will be asked to watch another 10 minute video demonstration of the improved app and fill out a 5 minute online survey on the app's system usability.

Publication: Individual feedback may be used in the dissertation to document what could be improved. This will be anonymous.

Conflicts of interest: Your relationship with the researcher is being used in order to progress with the project. This means that there may be some bias in the results of this research.

DECLARATION:

- I am 18 years or older and am competent to provide consent.

- I have read, or had read to me, a document providing information about this research and this consent form.

- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.

- I agree that my data (handwritten notes from the interview and online survey answers, though not identifiable as associated with you) is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.

- I understand that if I make illicit activities known, these will be reported to appropriate authorities.

- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.

- I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.

- I understand that if the results of the research have been published, then it will no longer be possible to withdraw.
• I understand that my participation is fully anonymous and that no personal details about me will be recorded.

• I recognise that the app deals with mood and mental health.

• I understand that an interview about the app may cause psychological distress and I am proceeding at my own risk.

• I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.

• I have received a copy of this agreement.

By signing this document I consent to participate in this study, and consent to the data processing necessary to enable my participation and to achieve the research goals of this study.

PARTICIPANT’S NAME:

________________________________________________________

PARTICIPANT’S SIGNATURE:

________________________________________________________

DATE:

________________________________________________________

Statement of investigator’s responsibility: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

RESEARCHER’S CONTACT DETAILS:

________________________________________________________

________________________________________________________

RESEARCHER’S SIGNATURE:

________________________________________________________

DATE:

________________________________________________________
Title of study:
To Design & Implement a Mood Management Mobile Application to Promote Positive Mental Health.

Dates and duration of study:
The study will take place from November 2021 - April 2022

Purpose of the project:
The focus of this project is to design and implement a mood management mobile application to help people manage their mood and promote positive mental health by suggesting activities to do.

The application will monitor the user's mood using a combination of user input and phone sensor data to derive the user's current mood. It will then suggest activities for the user to do if their mood is on the negative side via a notification. There will be no need for research participants to login or register as they will be evaluating based on a simulated video demonstration of the application.

The study will look for participants to review two versions of the prototype application and provide feedback and/or comments on the usefulness and engagement of the application. This will help identify whether the application is a success i.e could they see themselves using this app, is it useful and is it engaging? The feedback will also highlight any potential areas of improvement of the application.

Participants:
A sample group of 5-8 persons will be considered in this study.

Participants will be recruited through word of mouth. The recruitment process will begin among the lead researcher’s immediate contacts who have an interest in mood management. The lead researcher will then expand the sample pool to include people outside of their immediate contact circle to encourage anyone who ‘knows anyone’ who is interested in monitoring and managing their mood to contact me if they are interested in participating.

The requirements set in place for the participants include:
Participants must be 18 years of age or older
Participants must be interested in monitoring and managing their mood.
Participants can be of any gender, ethnicity or culture.

**Procedures of the Study:**
Participants will be asked to watch video demonstrations of the progressive versions of a mobile application. There will be two phases of evaluation. Each participant will be asked to participate in both phases of evaluation.

- They will be asked to watch a demonstration of the initial app taking approximately 10 minutes and be scheduled for a 30 minute interview to give feedback on the usefulness and engagement of the app and to comment on anything.
- Participants will be invited to watch a second 10 minute video demonstration of the ‘improved’ app and will be asked to complete a short survey online that will take approximately 5 minutes on the system usability of the app.

**Risks**
Since the app is concerned with mood and mental health, there is a possibility that an interview about the app may cause distress to participants. This is unlikely but measures are being put in place in the case if it does. See measures attached below this application on page 20.

**Conflict of interest**
Since participants are known to the researcher, there may be bias in the results of the research.

**Debriefing Arrangements:**
All participants will be debriefed through a written documentation explaining the process of the study. Once the results have been concluded, they will be presented to the staff and participants of the project.

**Copy of Interview Questionnaire and Survey:**
- Interview Questions: Attached below this form
- Survey:
  - Link: https://scsstcd.qualtrics.com/jfe/form/SV_0lgD1IEKRKS2Izs
  - Copy is attached below this form

**Section Two - Ethical Concerns**

There are some ethical considerations which arise from the study which pertain to volunteering and data collection:

- Since all participants will be volunteers, they hold the right to withhold information, omit an answer to any question or refuse to participate in any aspect of the study.
- Participants hold the right to withdraw from the study at any time before the submission deadline of the dissertation in April 2022.
- Participant identities will not be shared with anyone other than the lead researcher. All information given will be anonymised when presented in the results.
- All data gathered will be disposed of securely when the study is completed.

Legislation:
All data will be held and maintained in accordance with GDPR. All participants' identities will be anonymised and information will be stored securely and will be only accessible to the researcher.

Section Three - Confidentiality & Data Protection

3.1 Does this study involve collecting, using, accessing or sharing personal data?

Yes  [✓]  No  [ ]

If NO, please go to section 4.

If YES, please list all categories of personal data.

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Justification: Why do you need the data?</th>
<th>Data Format</th>
<th>Technical and Organisational Controls</th>
<th>Identifiable coded, or anonymised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email Address</td>
<td>Contact to organise interviews</td>
<td>Excel Sheet</td>
<td>One Drive in encrypted format, on a local machine which is encrypted. Accessible to PI only.</td>
<td>Identifiable</td>
</tr>
<tr>
<td>Consent Form</td>
<td>Evidence of consent from an ethical perspective</td>
<td>Word Document</td>
<td>One Drive in encrypted format, on a local machine which is encrypted. Accessible to PI only.</td>
<td>Identifiable</td>
</tr>
</tbody>
</table>

3.2 Does the study involve collecting, using, accessing or sharing sensitive data[1]?

Yes  [ ]  No  [✓]
If NO, please go to question 3.3.

If YES, please list all categories of the sensitive data collected.

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Justification: Why do you need the data?</th>
<th>Data Format</th>
<th>Technical and Organisational Controls</th>
<th>Identifiable coded, or anonymised</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

3.3 Who determines how and why the personal and/or sensitive data is used?

(Data Controller[2] or Joint Data Controllers)

Provide Details: TCD in accordance with an ethics application approved by the SCSS TCD Research Ethics Committee.

3.4 Will the personal and/or sensitive personal data be shared with any third parties[3]?

   Yes □    No □

If YES, provide details including information on the contractual arrangements in place.

If NO, please go to question 3.5

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This list should include all Data Processing Agreements with external laboratories, Cloud-based Solutions Agreements etc., and any Data Sharing Agreements with Collaborators.

Please contact researchDPO@tcd.ie if you need assistance with agreements and/or for any transfer outside EEA (including England, Wales, Scotland or Northern Ireland).

**Provide Details:**

---

### 3.5 How long will you retain the personal data?

**Provide Details:** The data will be retained until the submission date of the dissertation in April 2022.

---

### 3.6 Will the personal data be fully anonymised or deleted after it is no longer necessary?

**Provide Details:** The data will be deleted after it is no longer necessary.

---

### 3.7 How will you inform participants of their rights under GDPR[4]:
Provide Details: Participants will be informed of their rights under GDPR through the Information Sheet that will be given to them.

Please note that the DPO’s contact details must be included on any information leaflet or privacy notice if you are using personal data for your research.

Email: dataprotection@tcd.ie

Post: Data Protection Officer, Secretary’s Office, Trinity College Dublin, Dublin 2, Ireland
Extra Information on Project Risks

Since the app being developed is concerned with mood and mental health there is a possibility that an interview about the app could conceivably cause psychological distress to participants. However, the nature of the questions being asked in the interview and online survey, see page 20, shows that it would be unlikely as the questions provide no opportunity to disclose self harm.

In the case of a participant being distressed during the interview, it will be terminated immediately and the researcher will direct the participant to their affiliated university counselling services and student niteline services or their local GP. After the interview each participant will be disclosed a disclaimer stating that if they feel distressed after the interview they should contact their affiliated university counselling services and student niteline services or their local GP as soon as they can.
Interview Questions

Question List

For each feature of the application the participant being interviewed will be asked the following questions:

1. Do you see yourself using this app? What for?
2. What was useful about the app?
3. What do you think would make the app more useful?
4. What was engaging about the app?
5. What do you think would make the app more engaging?
6. What do you think about the app predicting mood through phone sensor data? Is it too intrusive?
7. Would you follow the suggestion of activities the app gives to better your mood?
8. Did you like the appearance of the app?
9. What did you like/dislike about the app?
10. What features do you think could be improved?
Online Survey

Consent Form

Lead Researcher: Divine Mbugua
Supervisor: Lucy Hodaman

Background of Research: The prototype app you will be evaluating is a mood management app. It aims to help people manage their mood and promote positive mental health.

Procedure of this Study: To take part in this study, you will be asked to review the improved prototype by watching a 10 minute video demonstration of the app and fill out a 5 minute online survey on the app's system usability.

Publication: Individual feedback may be used in the dissertation to document what could be improved. This will be anonymous.

Conflicts of Interest: Your relationship with the researcher is being used in order to progress with the project. This means that there may be some bias in the results of this research.

DECLARATION:

I am 18 years or older and am competent to provide consent.

I have read, or had read to me, a document providing information about this research and this consent form.

I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.

I agree that my data (online survey answers, though not identifiable as associated with you) is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.

I understand that if I make illicit activities known, these will be reported to appropriate authorities.

I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.

I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.

I understand that if the results of the research have been published, then it will no longer be possible to withdraw.

I understand that my participation is fully anonymous and that no personal details about me will be recorded.

I recognize that the app deals with mood and mental health.

I understand that answering questions about the app may cause psychological distress and I am proceeding at my own risk.

I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.

Do you agree to the above terms?

I agree  I disagree
Please rate the following statements on a scale from 'strongly disagree' to 'strongly agree'.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think I would use this app frequently</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The app looks complicated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The app looks easy to use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The idea of calculating mood from a phone seems useful</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The idea of calculating mood from a phone seems intrusive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I think I would need help from a technical person to use this app</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would follow the activities that the app suggests me to do to better my mood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I think this app promotes positive mental health</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What score would you rate the user interface of the app from '0' (very bad) to '10' (amazing).

<table>
<thead>
<tr>
<th>Very bad</th>
<th>Okay</th>
<th>Amazing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What do you think are the most useful or helpful features of the app?

- Recording mood
- Calculating mood from mobile phone
- The activities the app suggests
- How easy it is to use
- Other

What do you think are the most frustrating features of the app?

- Suggesting activities that one might not be interested in
- Poor user interface
- Using data from phones to calculate mood
- Other
Do you think the app would help you manage your mood?

- Definitely yes
- Probably yes
- Might or might not
- Probably not
- Definitely not

Do you think the app would promote positive mental health?

- Definitely yes
- Probably yes
- Might or might not
- Probably not
- Definitely not
Do you have any thoughts on how to improve the design of the app?

Thank you for taking the time to complete the survey. Please confirm that you would like to submit your responses.

Submit my responses  Do not submit my responses
Appendix 4: Ethics Amendments List

Result of the REC Meeting: REC Amendments Required

The Feedback from the Committee is as follows:
The Research Ethics Committee have reviewed your application and requested that you make the following amendments. Please clearly highlight where you have made the changes in your revised application. Please provide a list of numbered responses to each issue and highlight in the revised proposal all changes made.

1. The application states that there are no anticipated risks. Any project relating to mental health has the risk of causing distress. This risk may be small and manageable, but it must be dealt with in the ethics application. At the absolute minimum, participants would need to be directed towards appropriate resources in case of distress. What will the researcher do in the unlikely event that someone discloses a risk of harm to themselves or others? It should be dealt with in the proposal, the information sheet, and the consent form. This is a major omission and the proposal should not have been submitted as is.

2. Not stated clearly to participants what their data will comprise (e.g. handwritten notes from the interviews).

3. “Once the study is complete” for deletion of data is unclear - following completion of the M.Sc. dissertation (and appropriate exam board) might be more appropriate.

4. Rights under data protection legislation are listed, but it is also stated that data is anonymized, it should be clear what data this actually applies to and up to what point.

5. If you are recruiting people you know for the study, this should be listed (briefly) as a potential conflict of interest.

6. It is not stated in the participant information sheet who is being recruited for the study. Are there any inclusion criteria beyond people being over 18?

7. It is stated that once the results have been produced, they will be presented to the staff and participants of the project. I presume it is unlikely that participants will see the presentation, so I imagine it would be appropriate to say that results will be available to participants on request, and include this in the information sheet.

8. The study questionnaire is online but this is not clear from the materials, including the description of the procedures.
Appendix 5: Ethics Approval Timeline

Timeline of state changes for this application

Monday, February 21, 2022 - 09:24
State change:
from Submitted to Supervisor; Pending Review
 to Assigned to Reviewers; Pending Comments

Friday, February 18, 2022 - 17:25
State change:
from REC Amendments Required to Submitted to Supervisor; Pending Review

Monday, February 14, 2022 - 18:16
State change:
from Assigned to Reviewers; Pending Comments to Commented by Reviewers; Pending REC Meeting

Thursday, February 24, 2022 - 15:40
State change:
from Assigned to Reviewers; Pending Comments to Commented by Reviewers; Pending REC Meeting

Monday, February 21, 2022 - 09:24
State change:
from Submitted to Supervisor; Pending Review to Submitted to REC Awaiting Reviewer Assignment

Friday, February 25, 2022 - 10:55
State change:
from Commented by Reviewers; Pending REC Meeting to REC Amendments Required

Friday, February 25, 2022 - 17:14
State change:
from Submitted to REC Awaiting Reviewer Assignment to Assigned to Reviewers; Pending Comments

Friday, February 25, 2022 - 15:48
State change:
from REC Amendments Required to Submitted to Supervisor; Pending Review

Monday, December 20, 2021 - 12:19
State change:
from Submitted to REC; Awaiting Reviewer Assignment to Assigned to Reviewers; Pending Comments
Appendix 6: Sequential Final Prototype App Design Screenshots

5 Logo image was created using TailorBrands, [https://www.tailorbrands.com/logo-maker](https://www.tailorbrands.com/logo-maker)
15 Desserts You Can Make in 15 Minutes

Alex Loh
March 05, 2021

Reviewed by Dietitian Jessica Bell, M.S., RD