

# Bipolar Mood Prediction Presentations

**Master's Thesis in Informatics**

submitted by

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Submission of the thesis: 25.08.2022

# Bipolar Mood Prediction Presentation

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## ABSTRACT

People with bipolar disorder struggle to maintain stable moods and experience extreme highs, mania, and extreme lows, depression. Mood prediction would be a useful tool to help give warnings about upcoming highs and lows calculated using common mood factors such as previous moods, sleep, and medication compliance. Bipolar Buddy, a start-up company creating a mobile app meant for tracking moods and other factors, aims to achieve just that. They have developed a prediction algorithm that considers mood entries including motivation and anxiety scores, sleep entries, and medication compliance entries to predict one week of mood scores for an individual. However, before this is released to the public it is important to study whether this technology is beneficial and what kinds of impacts it may have on those with mood disorders. This study focused on studying the impact of viewing mood predictions on one's mood, motivation, anxiety and sleep data. It also looked at the current trust level towards mood predictions and factors contributing to that trust. It was found that mood predictions as they are today in Bipolar Buddy have little to no perceived impact on one's mood, motivation, anxiety, or sleep levels. It was also found that mood predictions in their current state are not yet fully trusted and would need more data giving the users more accurate predictions in order to build their trust in the technology.

Keywords:

# CONTENTS

<b>1</b>	<b>Introduction</b>	<b>4</b>
1.1	Motivation for study . . . . .	4
1.2	Research questions . . . . .	4
<b>2</b>	<b>Background and Related Work</b>	<b>5</b>
2.1	Mental health and technology . . . . .	5
2.2	Bipolar disorder . . . . .	5
2.3	Existing apps for bipolar . . . . .	6
2.4	Prediction models for mental health . . . . .	6
2.5	UI/UX for mental health apps . . . . .	7
<b>3</b>	<b>Solution Architecture</b>	<b>7</b>
3.1	Bipolar Buddy background . . . . .	7
3.2	Bipolar Buddy as a business . . . . .	8
3.3	Design and motivation for mandatory categories . . . . . Mood • Sleep • Medication	8
3.4	Mood prediction technology . . . . .	13
3.5	Other app features . . . . .	13
3.6	Bipolar Buddy study customization . . . . . Mood prediction displays • Study phase condition	14
<b>4</b>	<b>Method</b>	<b>15</b>
4.1	Details on study type . . . . .	16
4.2	Motivation for study timeline . . . . .	16
4.3	Recruitment strategy . . . . .	16
4.4	Expectations for participants . . . . .	16
4.5	Data collection and analysis . . . . . Interviews • App data • Survey data	17
4.6	Answering research questions . . . . .	18
<b>5</b>	<b>Participant Overview</b>	<b>19</b>
5.1	Introduction . . . . .	19
5.2	Background . . . . .	20
5.3	Diagnosis . . . . .	20
5.4	Bipolar experience . . . . . Mania • Depression • Frequency of episodes • Current stability	22
5.5	Impression of bipolar . . . . . Approach to bipolar • Doctors and prescriptions	23
5.6	Other bipolar outcomes . . . . . Hospitalization • Potential triggering events • Other challenges	23
5.7	Managing bipolar . . . . . Medication compliance • Mood tracking • Sleep • Diet and exercise • Therapy • Meditation • Reducing alcohol and substance abuse • Going outside • Community • Work leave of absence or quit • Other management strategies	24
5.8	Bipolar technology used . . . . .	27
5.9	Support Systems . . . . . Family • Friends • Doctors	27
5.10	Prediction Strategies . . . . .	28
5.11	Summary . . . . .	28
<b>6</b>	<b>Results</b>	<b>29</b>
6.1	Application data . . . . .	29
6.2	Survey results . . . . .	32
6.3	Post-study interviews . . . . . Study experience • Trust in mood predictions • Effects of viewing mood predictions • Preferred mood prediction display	34

<b>7</b>	<b>Discussion</b>	<b>37</b>
7.1	Limitations and risks . . . . .	38
<b>8</b>	<b>Conclusion</b>	<b>39</b>
8.1	Future work . . . . .	39
<b>9</b>	<b>Acknowledgments</b>	<b>41</b>
	<b>References</b>	<b>42</b>

# 1 INTRODUCTION

Research in the space of mental health technology has been rapidly increasing in recent years. However, there is a gap between what is discovered in research about mental health applications and what is used in industry for commercial products such as mood tracking applications.

Bipolar Disorder specifically is a mental disorder associated with episodes of mood swings ranging from depressive lows to manic highs. 2.8% of the USA population is diagnosed with bipolar disorder in some form [(25)]. Worldwide, bipolar disorder is considered to be the sixth leading cause of disability by the World Health Organization [(10)]. There are several types of bipolar disorder including Bipolar I (having at least one manic episode or major depressive episodes), Bipolar II (having one major depressive episode and at least one hypomanic episode), and mixed episodes (both mania and depression can be experienced at once) or rapid cycling (changing from manic to depressive in short amounts of time).

One major challenge for people with bipolar is the unpredictability of their mood. This makes it difficult to plan in advance or set realistic expectations to their peers. The nature of the disorder also causes people to slip into manic or depressive episodes without even knowing it is happening. Mood prediction may be helpful to people with bipolar disorder so that they can prepare for upcoming extremes. There are some mood predicting algorithms that have been developed, however I have not been able to find any research that has looked specifically at the questions of the trust level in predictions, the impacts of the predictions on the users, or the best way to display mood prediction information. There is still a possibility that it has been considered somewhere, even as a secondary question. Therefore, I sought to discover more about the effects of the mood predictions on people with bipolar and how to effectively display this type of information in a way that is both effective and comfortable for people with bipolar disorder.

I conducted this research in conjunction with a startup company called Bipolar Buddy. They were founded in 2021 and developed a mobile application targeting users with bipolar or other mood disorders. The app offers the ability to track many things that could impact mental health and mood including sleep, medication compliance, stress levels, etc. The main feature that makes Bipolar Buddy quite unique to the market is the ability to predict one's mood based on their personal entries as well as trends found in the overall database containing entries from all users. In order to identify these trends for prediction purposes, users were asked to log their mood rating at least once per day. I leveraged the Bipolar Buddy prototype application for my study as it was already built with controlled categories and easy user input.

## 1.1 Motivation for study

Mood predictions are an innovation intended to help those with bipolar to be prepared for upcoming episodes. As some research has been done in the area of bipolar assistive technology, while other research has gone towards mood or stress and depression predicting algorithms, considerably less is known about the effects on the users of viewing the predictions or how to effectively display this kind of information in a way that is both effective and comfortable for people with bipolar disorder. It is important to investigate this in order to prevent harm or negative effects coming from viewing the mood predictions. It is also important to ensure that this modern technology is optimally utilized to provide the best possible support for those with bipolar.

## 1.2 Research questions

In this study I looked at the response of users of a bipolar factor tracking application, Bipolar Buddy, when they were shown mood predictions. Do they find this information valuable in the daily management of their condition? Does having this information readily available affect their decisions and activities? Does the prediction help them to prevent episodes by changing their behaviors to stabilize themselves when warned about an upcoming extreme? Or, is there a negative effect such as stress that could be caused by the presentation of an extreme prediction? In order to study these effects I also considered how prominent the information is presented to them. If they are forced to view the predictions, it could have a different affect than if they must seek out the predictions. Therefore, I have created the following versions of the Bipolar Buddy app interface:

1. No prediction: This version shows behaviors of a user without the influence of prediction information in order to segregate overall app impact from prediction display impact.

2. Subtle prediction: This version gives the user access to mood predictions when they want to see them, but requires that the user navigate to them intentionally. This sheds light on the desirability of such a prediction feature.
3. Prominent prediction: This version displays the predictions directly on the page after each mood entry, forcing them to take a look at what is upcoming. This provides data specifically on how users feel when viewing their predictions.

In order to study the effects of these mood predictions, I asked the following questions:

**RQ1:** What effect, if any, do mood predictions have on the mood, sleep, motivation, and anxiety levels of people with a mood disorder? What is the nature of these effects?

**RQ2:** Do users trust mood predictions? What factors or context affect their trust levels?

**RQ3:** Do users prefer a prominent summary score of their upcoming mood values or a subtle graph view of daily predictions?

The app collected data on mood, motivation, anxiety, sleep, and medication compliance and compared these values to the predicted moods to determine if there were any objective effects caused by viewing the mood predictions. The participants were also interviewed to ask for their perceived effects, their trust level for predictions, and their preferred display style.

## 2 BACKGROUND AND RELATED WORK

### 2.1 Mental health and technology

Mental health research and technology has picked up since the 2020 coronavirus pandemic. Since so many people were isolated in quarantine, depression was widespread, causing it to be a much more prominent topic for research. The amount of research on depression, even before the pandemic, far exceeds research done on any other mental health disorder. Some depression studies include Sachin et. al. who looked at the growing need for helpline efficiency and several ways to improve the experience to assist those with suicidal thoughts or those in mental crisis to reach the help they need [(23)]. Another common area of study is the social media influence on depression. There is a plethora of research aiming to learn more about depression disclosure on social media [(19)], as well as the influence of social media as a support avenue [(20)].

### 2.2 Bipolar disorder

Research around bipolar disorder technology was encouraged by John Torous in an article written in 2016. Torous highlighted that the mental health community has stagnated in terms of developing technology. He claimed that the best method for tracking someone's bipolar symptoms was still observation and logging by hand. He found many devices used for sensing were impractical for patients to wear and may threaten their privacy. He also claims that many research attempts have prescribed the factors important for bipolar disorder randomly and without proof of relevance. He writes this to call out the need for the research community to take a look at ways to automate data collection and observation to determine what is happening to a patient and diagnose them properly [(29)].

Since then, several research papers have been published around ways to use mobile phones for data collection as well as the features that are in highest demand for a bipolar app. One study found that coaching and community is critical for those with bipolar disorder to stay accountable and feel supported [(17)]. Another study analyzed the existing applications in the market for mood disorders and created a database of these [(22)]. They found that the main features included in the majority of apps were Mood Tracking, Journaling, Psychoeducation, Peer Support, Medication Tracking, Sleep Tracking, and Mindfulness. Mood Tracking and Journaling were included in the majority of cases, meaning that most apps do not collect data outside of this. Although mood tracking is very important for bipolar patients in order to visualize and communicate how they have been feeling, given that bipolar is a mood disorder, it excludes the other factors that contribute to that mood. For example, if a person does not get much sleep for a few days in a row and skips their medication, this could result in a mood disruption. In reality, mood is the result of several factors, so the mood value itself can often be calculated from the other input.

In Bipolar Buddy, several factors are collected from the user and used to calculate a mood prediction. This mood prediction is trained with mood input from the user to confirm or disprove a prediction. This

way, the common triggers that impact those with bipolar the most are tracked by the user and can be utilized to warn the user that their behaviors may lead to an extreme mood experience.

Bipolar specific technology is even rarer. Lagan et. al. in 2020 wrote, “Our analysis reveals substantial limitations in the current digital environment for individuals seeking an evidence-based, clinically usable app for bipolar disorder. Although there have been academic advances in development of digital interventions for bipolar disorder, this work has yet to be translated to the publicly available app marketplace. This unmet need of digital mood management underscores the need for a comprehensive evaluation system of mental health apps, which we have endeavored to provide through our framework and accompanying database (apps.digitalpsych.org).”[(22)]

### 2.3 Existing apps for bipolar

Another thing I noticed while researching bipolar apps is that there is a clear separation from the research community and the commercial businesses. Based on my observations of working with the Bipolar Buddy team, some key differences include that research does structured user testing while commercial apps often take an unstructured approach to testing. Research uses formal evaluation criteria for usability and usefulness of apps while commercial apps use unproven evaluation criteria such as surveys with basic questions like, “How would you rate our app?”. In research, privacy is a priority to protect the user’s data, while commercial industries only consider data privacy some of the time, often not having a Privacy Policy accessible to the end user. Finally, the focus of research papers is to discover something new to introduce to the scientific community, while the focus of new start-up companies is often profit and investment. This leads to a different kind of driver, causing a different approach to the whole development of the app. The benefit of the commercial strategy, however, is they reach the market of bipolar users much quicker and more often than the scientific community does, for obvious reasons. The key solution here is to introduce research approaches and strategies into the development of a commercial product, Bipolar Buddy. Below are a few examples of research specific applications.

*Monarca:* Bardram et. al. did research using a dedicated bipolar app called Monarca. They found that using a digital system for daily self-assessment was positively received by patients compared to paper-based alternatives that do not offer the same visualization and feedback mechanisms. This study showed that adherence to tracking improved, the system was considered easy to use, and the perceived usefulness was high [(17)]. The study concluded that, “personal health systems should allow for personalization both in terms of what data to collect (self-reported and sensor-based) as well as how to visualize this data.” These results are considered in the design of Bipolar Buddy in the form of offering various visualizations. However, the app does not receive data from any sensors yet.

*LiveWell:* Another app used specifically for research is called LiveWell, which was dedicated to daily check-ins for those with bipolar disorder. Participant feedback indicated that developing additional content and tools to address building and engaging social support may be an important avenue for a positive result. Their study found that support and coaching was an integral part to the success of a bipolar application. According to their results, only half of the individuals with bipolar disorder received any therapy [(13)]. Using this information I ensured that all participants in my study had external professional care in the form of a therapist or psychiatrist. In addition, I contacted them before the study, mid-study, and after the study as a form of accountability that was valued in the coaching role.

The research in this thesis attempts to bridge the two worlds of research and commercial to contribute some research techniques into the development and testing of Bipolar Buddy. The apps listed above were not available in the app stores that I checked and may only exist for research purposes. It is important that the findings of these papers are considered in the design and further development of existing bipolar apps available to the public. The features of Bipolar Buddy were prioritized based on scientific evidence and research. The user testing consisted of proven question sets to gauge usability as well as proper handling of user data for privacy and a focus on discovering the best way to design the application to produce the best user experience and help those in the bipolar community.

### 2.4 Prediction models for mental health

Others have worked toward producing a mood prediction model with a sufficient reliability. Constantinides et. al. performed a study on 129 users and achieved prediction accuracies of 89% and 58% in personalized and generic models respectively [(11)]. Their prediction strategy, however, used sensors within a mobile phone in addition to self reported mood scores. This study was not limited to bipolar disorder but predicted for unipolar (depression) as well. The study found that the personalized model was much more accurate.

The personalized version was specified as a model that received several days of data collected from the user before the initial prediction was given. Although Bipolar Buddy has a different prediction algorithm, it is important to be tailored to the individual for highest chance of accuracy. For this reason, this study included a data collection period before the first mood prediction was shown to the user. Another finding in the research of Constantinides was that the accuracy was dependent on the labeling strategy, which refers to the way patients report their emotional state. Using the Bipolar UK Mood Scale [(4)] helped to remove the subjectivity of inputs.

In 2016, Valenza et. al. took a different approach to predicting moods for bipolar using heartbeat nonlinear dynamics exclusively [(32)]. Their study consisted of 14 bipolar patients wearing a t-shirt with fabric electrodes and sensors to acquire ECGs overnight, twice a week for 14 weeks. Using this data they were able to forecast mood states with an accuracy of 69% on average. Although my study does not address the accuracy of mood predictions, it is interesting to see where the state of the technology is overall so that it may be used to optimize mood prediction presentations in future implementations.

Speech is another method that can be used to predict moods. Research shows that speech contains patterns that change based on the mood of an individual. Gideon et. al. explored speech collected from phone recordings for analysis of mood in individuals with bipolar disorder [(15)]. This speech approach is also being used by Ellipsis Health for vocal analysis targeted toward depression sensing [(ell)]. Ellipsis has products on the market that consist of a user answering a few emotion provoking questions while recording their audio and then submitting it to calculate a score for stress, anxiety, and depression levels. Bipolar Buddy does not yet implement this technology, but plans to integrate it in the future for more accurate mood predictions.

## **2.5 UI/UX for mental health apps**

Unlike common mobile apps used for social media, planning and scheduling, or shopping, mental health apps have a target audience that are prone to mental upset and instability. This needs to be taken seriously when designing apps specifically for their benefit. One study looked at a stress reduction app and varied the difficulty levels to measure if the user compliance or the level of achievement would be impacted [(7)]. They found that the Self-Efficacy Theory holds that successful completion of planned goals is more important than the goal itself. They also found that the version of the app that adapted its difficulty level to the user's achievement resulted in participants sticking with it more. Bipolar Buddy is designed to be an easy daily task that does not necessarily challenge the user but rather give them the satisfaction each day of entering their mood data.

Halko S. and Kientz J.A. looked at persuasive technology specifically in health-promoting mobile apps [(24)]. Their results showed a link between personality types and the effectiveness of persuasion techniques. Mental health apps are relevant to this as they are still health-promoting and the personality traits that may accompany a bipolar diagnosis can also influence the success of certain persuasive techniques. Therefore, a variety of feature offers and designs should be available to tailor to the personality traits of the target audience. Bipolar Buddy implements various visualizations of data and basic congratulations messages to encourage users to stay while addressing more than one personality type.

# **3 SOLUTION ARCHITECTURE**

## **3.1 Bipolar Buddy background**

The Bipolar Buddy company and application was first founded in February 2021. The founder and CEO, Anish Suri, described his mission by saying, "The idea is that Bipolar Buddy will be a tool that can support people with bipolar to achieve remission. We do this by tracking triggers and predicting with AI. The aspiration is to build better awareness of people's behaviors with bipolar and triggers that affect them." He worked with a development team for several months to build a minimum viable product to bring to the market. After a few rounds of beta testing attempts the solution was getting feedback that it was not yet stable and in need of user experience improvements. The next several months were focused on implementing the user feedback as well as making several other UX improvements.

I first found Suri through listening to a podcast called "Bipolar Diaries". He was a guest invited on the show to share his story about Bipolar Buddy. After contacting him on LinkedIn, we met virtually to discuss our shared goal of improving the lives of those with bipolar disorder using technology. It was December 2021 when we agreed to collaborate. We agreed that I could use my education and experience to improve the app in exchange for his permission to modify the app temporarily for my study purposes.



### 3.2 Bipolar Buddy as a business

Bipolar Buddy as a company consists of the CEO, Anish Suri, technical leadership, financial managers, marketing specialists, a small development team, and several business interns assisting with outreach. This small start-up team is working to improve the application as well as market the concepts of Bipolar Buddy to relevant crowds such as hospitals, clinicians, and those diagnosed with bipolar. Their marketing and outreach efforts range from Facebook marketing, podcast interviews, and cold email and calls to hospitals and clinicians in their area. The financial side of the business is mainly handled by the CEO who regularly speaks with investors and grants programs to obtain the means to continue the growth of the business as well as grow its network of supporters.

Since Bipolar Buddy was already an established start-up before I requested their assistance on my study, they have their own trajectory and prioritization in place. At the start of our collaboration, their focus was on improving the user experience of the app in order to grow their testing user base. In addition, their overall goal is to be published on both the iOS AppStore and the Google PlayStore. In order to be approved for this publishing, the app store evaluators required a medical study to be executed. This is specifically because Bipolar Buddy targets an audience with a mental disorder (Bipolar) and offers mood prediction technology that may impact such a vulnerable community. It is also a risk that users may consider the app as treatment for their disorder, which is not true as it is meant to be used alongside professional care such as medication and therapy. All of these factor into the motivation for Bipolar Buddy to partner with hospitals in the UK to undergo a full size user study.

In the meantime, their next direction is to temporarily remove the mood predictions and bipolar name and create a new version of the app called “Mood-Mentor” to be published without the necessary medical device obstacles. This will help them to grow their user base and gather valuable feedback on the user experience to make even more improvements before being released as “Bipolar Buddy”.

Since my involvement began I have been serving as a product owner for the app, working alongside the development team to improve the user experience and implement new features upon request. This work was done in exchange for freedom to manipulate and customize of the app specifically for my study.

### 3.3 Design and motivation for mandatory categories

Bipolar Buddy consists of many categories available for tracking. Given the options, there are three main categories that are most essential for mood prediction and highly recommended by doctors and experts to track: mood, sleep, and medication. The Bipolar UK organization also identified these three factors as being the most important to track daily as they included them on their own mood diary form [(3)]. The input forms are intended to be used daily, however the functionality is available to navigate to a previous date and input past data.

#### 3.3.1 Mood

Tracking one’s mood is an important activity for those with mood disorders because it allows them to reflect on any trends they may be experiencing over a given period of time. The medical community offers many mood scales to indicate where an individual identifies their mood to be. The one chosen for this app is called the Bipolar UK Mood Scale [(4)]. This scale provides descriptors for all ratings from 0 - 10 for one’s mood (Figure 1). The Bipolar UK Organization says in their March 2022 paper, Hidden in Plain Sight, “For people living with bipolar, their range of emotions is much wider. They can experience a 0, which is deep depression with recurring suicidal thoughts. At the opposite end of the spectrum, they can experience a 10, which is an extreme manic high where people experience psychosis and hallucinations, completely losing touch with reality. When someone living with bipolar goes above a 6 or below a 4, they are said to be relapsing” [(30)]. Therefore, using this scale allows those with bipolar to enter a number that corresponds to stability on a more universal bipolar scale. The descriptors prevent users from entering a 9, for example, to mean simply having a good, happy day. Instead, the happiness they feel fits more in a 6 if they are not experiencing no sleep, paranoia, or reckless behavior.

The input form consists of a mood ranking (0 - 10 on the Bipolar UK Mood Scale), a motivation rating (0 - 10), and an anxiety rating (0 - 10). Motivation and anxiety are said to be factors that change when you are experiencing mood swings according to a psychiatrist supporting Bipolar Buddy. Therefore, each day the users are asked to rank mood, motivation, and anxiety levels to visualize themselves as well as contribute to the mood prediction model. The measures are shown on a one page form with sliders for the users to select their score (Figure 2). At the end, there is a text field allowing the user to enter any



**Figure 1.** Bipolar UK Mood Scale

notes that may provide an explanation to why they entered that mood score. This can also be used as a type of journal for users to reflect and process their feelings and thoughts from the day.

After inputting data for the mood section, users can view their past mood entries on a line graph. They are shown a week view and can choose to switch to the month view where they are able to scroll left and right to see all of the days of that month. The graph colors can be customized to the user's preferences. See Figure 3 for the default graph displaying a week of mood scores.

In addition to the graph, they are shown a congratulations message according to their entry. Therefore, if a user inputs a mood score that is between 4 - 7 they are shown a congratulations message saying "Your mood is stable today". This is intended to uplift the users and encourage them to maintain stability. On the contrary, there are no messages with negative connotations when a user inputs a more extreme mood score. There is also no reward for days of stability since the risk of losing that streak or any other game reward when they are feeling down can be discouraging and make their mood even worse. That is why the design was decided to include only a simple congratulations message to encourage stability.

### 3.3.2 Sleep

Sleep was proven to be a large contributor to one's mood swings. A low amount of sleep could be an indicator that one is experiencing mania or a large amount of sleep can mean one feels depressed. However, it is not only the amount of sleep that is important. According to the study done by Etain et al. the quality of sleep can often have an even bigger impact on mood than the sheer number of hours slept [(14)]. Even further, the routine of sleep time and wake up time can affect things such as medication compliance and mood as well. It is advised by experts that those with bipolar should keep a consistent routine in life, which includes sleep schedules.

The input form in Bipolar Buddy for sleep covers all of these aspects (Figure 4). It first asks the user for the time they fell asleep the previous night and the time they woke up in the morning. Following that, the form has slider input for the user to indicate their quality of sleep on a scale of 0 - 10. There is also

Back Mood Next

< 21 Aug >

Input mood Mood scale

Mood in balance, no symptoms of depression or mania. Life is going well and the outlook is good.

What is your mood at the moment?

0 10

Severe depression Mania

Add Notes for specific day

Enter any thoughts here...

How motivated do you feel?

0 10

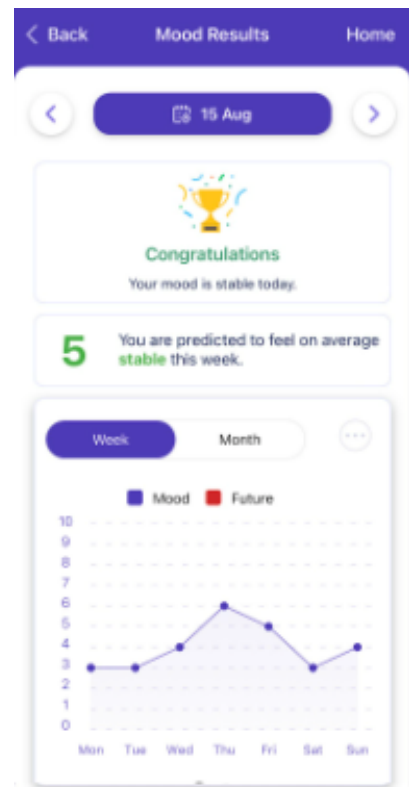
Not at all Extremely

How anxious do you feel?

0 10

Not at all Extremely

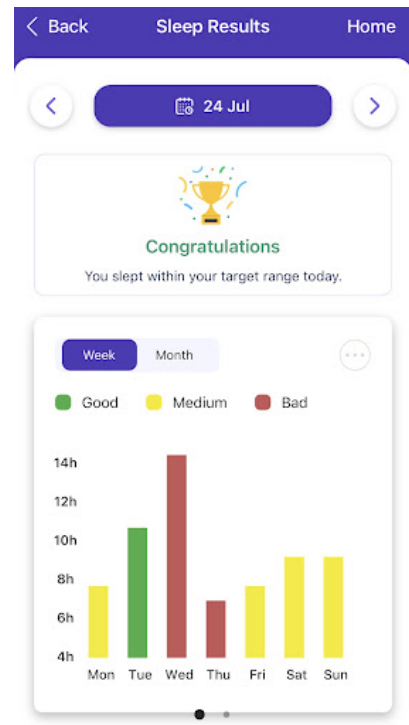
**Figure 2.** Bipolar Buddy Mood Form



**Figure 3.** Bipolar Buddy Mood Results - Week View

a space to log naps. This section asks the user to insert their total sleep time in their nap(s) with a unit of minutes. As in many of the categories, there is also a notes section here for the user to provide an explanation for their sleep data. After filling in the sleep form they are shown a week overview of the total number of hours they slept in a bar graph (Figure 5).

**Figure 4.** Bipolar Buddy Sleep Form



**Figure 5.** Bipolar Buddy Sleep Results - Week View

Upon registration and onboarding to Bipolar Buddy, users are asked to enter their target sleep time in hours as well as their minimum and maximum sleep range that they accept. These values are used as conditions for showing a congratulations message. If the user enters a sleep amount below their maximum acceptable and above their minimum acceptable they are given a congratulations message saying “You slept within your target range today.”

With the collected sleep data the results page displays a bar graph showing the total sleep time per day. This is calculated by taking the difference in the time they woke up and the time they went to sleep and adding on any nap time minutes of sleep. As seen in the mood category, the default view will show a week of sleep data, but the user can choose to navigate to the month view and scroll through their sleep totals for that particular month. The bar graph is color coded based on sleep amount being “Good”, “Medium”, and “Bad”. The default green color is reserved for those that sleep above their given target sleep and below their maximum sleep. The yellow is used for when they did not reach their goal amount but they are still above their minimum hours of sleep. Finally, red is used for those that slept outside of their acceptable range indicating that they either did not sleep enough or slept too much the previous night. These can be indicators of relapse which is why they are displayed with a warning color. These colors can, however, be customized to the user’s liking.

### 3.3.3 Medication

Medication compliance is an important factor to managing bipolar disorder. Tracking medication can benefit users in many ways. Firstly, making a list of medications and times to take them can help to ensure users do not forget their prescribed recipe and time schedule. Secondly, since mood swings can be caused by skipping medication or taking medication at an irregular time, documenting the exact medication compliance can help a user to identify high risk times when they have perhaps forgotten to take their medication several days in a row or consistently taken it late.

9:41

< Back Medication Next >

< Today, 30 Mar >

+ Add medication

Medication Name  
Acetaminophen.

8:30 AM

Took it in-time ☒

Took medication but it was late ☐

Forgot to take medication ☐

Medication Name  
Azithromycin

8:30 AM

Took it in-time ☒

Took medication but it was late ☐

Forgot to take medication ☐

2:30 PM

Took it in-time ☐

Took medication but it was late ☐

Forgot to take medication ☒

**Figure 6.** Bipolar Buddy Medication Form

The best way we found to implement this capability into the Bipolar Buddy was to allow the user to set up their medication types and times during their onboarding process. After which they are still able to update their medication selections and times on a day to day basis in the event that their prescriptions change or they take medication that is not a daily routine. The first step is to select a medication name from a list of those commonly prescribed for bipolar disorder. The app also offers the ability for users to enter their own custom medication in the event that they want to track something that is not listed. Then, they input at which time(s) they take this medication. Once their medication details are established their daily medication form will reflect these details.

On a day to day basis a user could go into the medication form (Figure 6) and see their medication names and time slots. Under each time slot are three options, “Took it on-time”, “Took medication but

< Back Medication Results Home >

< 21 Aug >

Congratulations  
You took all of your medication today.

Medication Log

Week Month

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Amisulpride	✓	✗	✓	✗	✗	✓	✓
Joy Meds	✓	✓	✓	✗	✗	✓	✓
Ativan, Lorazepam	✓	✓	✗	✗	✗	✓	✓

**Figure 7.** Bipolar Buddy Medication Results - Week View

it was late”, and “Forgot to take medication”. For each medication time the user can select whichever option applies to their compliance for that medication. After updating their selections for the medication status, they are taken to the results page.

On the results page the medication data is displayed in a table with colored dots to identify if the medication was taken on time, taken late, or forgotten, as shown in Figure 7. On the left side is the list of the medications they entered. Then along the line for each are seven circles representing compliance for the days of the week, as labeled on the bottom. The circles can take many styles corresponding to the data entered. A light gray X indicates that the user did not log any data for that medication for that particular day. A green check mark means that the user took that medication at all times it was prescribed to take. It is also a green check mark in the event that the user took their medication late. A yellow outlined circle shows that the user only took part of that medication. For example, if they are supposed to take something twice per day and took it the first time and forgot the second time, they would see a yellow outlined circle for that medication on that day. Finally, a red X is shown when the user forgot to take the medication altogether.

While the week view shows the list of medications, the Month view shows a circle for each date in the month and a colored circle corresponding to the status, as explained previously. The main difference is that now the circle represents the entered day of medication compliance, not just a specific kind. So, if the circle on that date is green, all medication was taken, even if it was late. If the circle is yellow it means some of the medication was taken and some was forgotten. Lastly, a red circle means medication was forgotten or that the user did not log their medication data yet for that day.

As with the previous categories, a conditional congratulations message is shown when the user takes all of their medication for the day.

### **3.4 Mood prediction technology**

The mood prediction algorithm was developed by a student named of Pratik Kedia who created a machine learning model to predict moods for his study program at Indian Institute of Technology, Delhi. The model takes in the mandatory categories listed earlier, mood, sleep, and medication, and produces seven days of mood prediction scores. Weightings are put on each of the categories with the heaviest weight being on the past mood entries and sleep and medication compliance having less impact on the prediction. The model works overtime to evaluate patterns and indicators of extreme mood. It was initially trained on a given dataset of which the source is unknown, but is now improving using the Bipolar Buddy app usage data. The prediction scores are a product of the individual’s inputs as well as comparing against the overall dataset to identify trends or insights that can be found from other user’s data entries. This allows for new users to receive predictions even on their first time using the app. The algorithm can take their initial mood, sleep, and medication data and match it to other users’ previous inputs to produce a conceivable seven day mood prediction outlook. The accuracy has not been measured for this particular algorithm, but reliability of the predictions is not the focus of this study.

### **3.5 Other app features**

In addition to the Mood, Sleep, and Medication categories, Bipolar Buddy offers several other categories a user can choose to log. These include Alcohol, Drugs, Stress, Exercise, Food, Water, Events, Relationship, Travel, Menstruation, and Weather. The list of categories was recommended by health professionals as factors that have the highest impact on mood changes. Alcohol and Drug abuse can reduce the effects of medication or dangerously react with it [(16)]. In addition, alcohol and drugs are stimulants and depressants that have direct impacts on one’s mood. This could be a risk for someone trying to manage their mood disorder with a specific prescription of drugs and balanced routine. Stress is a general trigger that can drive one into an extreme episode. Exercise, food, and water consumption are important for overall health and can also be signs of mania or depression. If a user logs exercise quantities much higher than usual, it is likely they are moving to a manic state. When it comes to food, the composition can affect one’s mood such as high sugar foods or anything with high amounts of caffeine [(9)]. If significant events occur in life these can often have situational side effects on one’s mood and are often worth noting down as potential triggers. Relationships are also situational and can indicate how well someone is doing socially as well as how supported they feel at the time. Travel introduces changes to one’s daily routine that can put them at risk for imbalance during that period. Menstruation comes with many hormones that are proven to influence mood and emotion levels. Finally, weather is not a manual entry but rather a weather forecast pulled from a weather API. Those with mood disorders can be brought down by cloudy

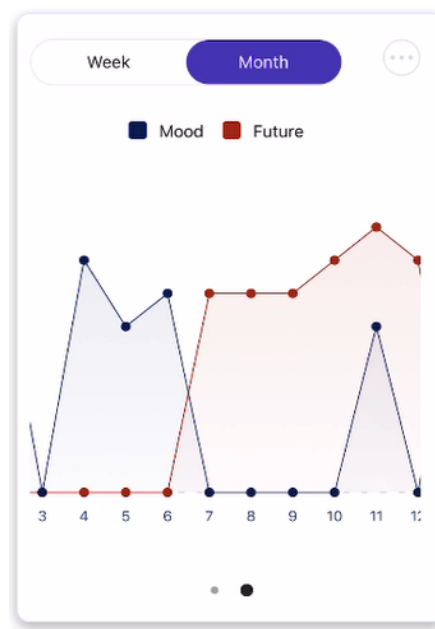
or rainy days where there is a lack of sunlight. Therefore, having dreary weather documented could be a possible indicator of falling into an episode of depression. Although these various features are included in Bipolar Buddy already, there is still work to be done on the user interface and user flow of them. For that reason, participants in the study were only asked to log Mood, Medication, and Sleep regularly.

### 3.6 Bipolar Buddy study customization

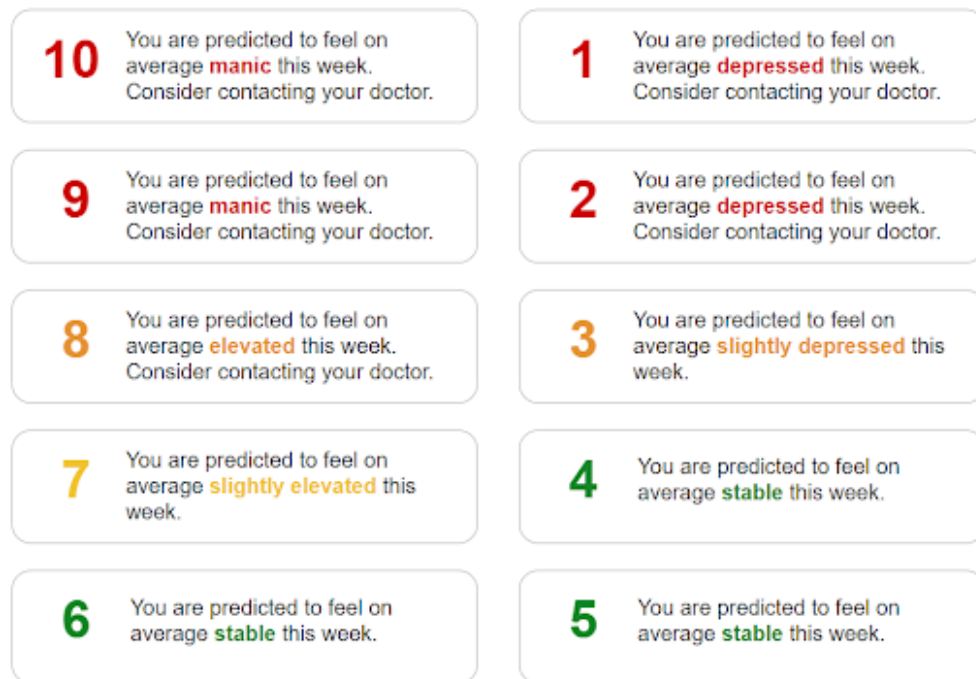
The Bipolar Buddy app already contained many of the features that were needed for this study. As mentioned above, mood, sleep, and medication tracking was already implemented as well as mood prediction technology. There were only a few features that needed to be included in order to run the study effectively. These included the various mood prediction displays as well as a mechanism for switching a user's display manually and remotely.

#### 3.6.1 Mood prediction displays

In order to measure the impacts of mood predictions on users as well as assess their preferred display for mood predictions, a couple different visualizations needed to be created. Two designs were produced that aligned with the two study phases. The first was the subtle mood prediction presentation in the form of a graph of the overall month (Figure 8). This visual shows various dots of multiple colors. The purple dots represent the mood entries the user has made, claiming they are the actual truth of their mood for that date. The red dots represent their predicted mood over the next seven days, labeled as "Future". This graph is only seen in the mood results page after selecting "Month" above the default "Week" graph. The mood results page can be accessed either by going directly to the Results tab and clicking Mood, or it appears every time after submitting a mood entry. Therefore, it is assumed that if the user enters their mood each day, they will be given the opportunity to select the "Month" graph to view their predictions if they choose to. The other mood prediction presentation display is much more prominent (Figure 9). This display shows a summary of the upcoming week by printing the average prediction score and a single sentence stating "You are predicted to feel on average X next week." The X is completed with either "stable", "elevated", or "depressed". These words as well as the prediction number change color depending on the extremity of the prediction. Green is used when the prediction score is stable, between 4 - 6. Yellow is used for a score of 7, slightly elevated. Orange is used for 8 or 3 indicating elevated or slightly depressed mood. Finally, red is used for scores 9, 10, 1, and 2, warning the users that they are predicted to be manic or depressed and they should seek help from their doctor. The corresponding text box is printed just above the mood graph in the app's user interface.



**Figure 8.** Subtle Mood Prediction Display



**Figure 9.** Prominent Mood Prediction Display

### 3.6.2 Study phase condition

In order to manipulate which prediction display the participants were shown, we added a data point in the UserProfile database table for “StudyPhase”. The value was defaulted to 0 indicating that new users would not see a prediction at all. After the first week of the study I manually updated the database entries for the participants corresponding to which study group they were placed in, one or two. Those in study group one were assigned StudyPhase: 1 which corresponded to the subtle mood prediction display of the month graph view. Those in study group two were assigned StudyPhase: 2, meaning they were shown both the graph and the prominent mood prediction display including the summary sentence and average prediction score. Before the final week of the study those in group one were switched to StudyPhase: 2 and those in group two were switched to StudyPhase: 1. The implementation of the StudyPhase dependency was integral to updating the user’s interface without requiring any action from them and ensuring the updated display was immediate. This was a luxury that the participant did not have to update the app version or take any action on their part. The only necessary step was that they closed the app and opened it again, which was a common practice to do anyway and therefore did not need to be requested.

## 4 METHOD

In order to answer the research questions I recruited a participant pool of about 17 people diagnosed with bipolar disorder. These people agreed to use Bipolar Buddy daily for a total of three weeks. Before the study began all users were interviewed for about 30 minutes to understand their bipolar story and experience and gain some background information on them. The first week of the app usage focused on data collection where the app did not present any mood predictions to the participants. The second week the participants were broken into two groups where one group could access a mood prediction but was not particularly encouraged to look at it (“subtle presentation”), and the other group were presented with a summary score for upcoming moods each time they entered their mood score (“prominent presentation”). In the final week, those two groups switched versions, meaning the group with subtle mood prediction access will now view it prominently after every mood entry, and vice versa. Following the study time each participant was interviewed to understand their experiences using Bipolar Buddy and their perceived influence of the predictions on their behaviors and mindset.



#### **4.1 Details on study type**

This study was designed to be a between-subjects study. Therefore, although all participants began the first week together seeing no predictions at all, they were then broken into two groups to experience the mood prediction presentation styles at different times to prevent novelty effects impacting the results. The idea is that if one group is first exposed to the mood predictions subtly, they may never access them proving they had little interest in their predictions. The following week their predictions changed to prominent, forcing them to view their mood prediction in order to study the impact this could have on them. However, the other group began with the prominent predictions and then lost them the following week, observing if they noticed the loss of information, implying how much they valued it.

#### **4.2 Motivation for study timeline**

Based on the focused effects for the study, three weeks was the minimum amount of time needed to address the research questions. The original plan was to have a study duration of at least six weeks to allow two weeks in each phase of the study. This would ensure that the participants, if they were interacting with the predictions, could check if their next-week's predictions were accurate or not. This would also allow me to investigate if the prediction presentation impacted the accuracy of the predictions by measuring all of their input mood ratings for the predicted week and comparing it to the first predictions they viewed. The study also may have benefited from an extra week or two in the beginning of the study to better calibrate the predictions to the individual participant as suggested in the research of Constantinides et. al. [(11)]. Ultimately, due to multiple delays in the ethics approval of the study, the timeline needed to be shortened to as little as possible that would still address the research questions given. It was decided that the benefits of elongating the timeline to gather data on accuracy of predictions was not the target of this study. Rather than aiming for quantitative data given by more input over more weeks, I decided to primarily obtain qualitative data and discuss the meaning of the participant responses in interviews more than the numeric results.

#### **4.3 Recruitment strategy**

In order to recruit participants I first needed to find groups of people with a mood disorder diagnosis that were above the age of 18. I did not limit myself to one location or region. Given that the study was remote, only using the mobile app and video calls for interviews, I could recruit participants from anywhere around the world. I joined communities such as Facebook Groups and listened to Podcasts with support groups. Before my study began, I posted a flier on the Facebook pages and communities to recruit through their trusted platforms. This approach yielded 25 volunteers that signed up using the online form. Since my target cohort size was closer to 10 or 15, it was important to recruit more than needed to account for possible attrition. It turns out, in this study of the 25 volunteers, 17 signed up for the interview before the three weeks of app usage began, 11 used the app at least half of days of the study period, and 10 participated in post study interviews. Therefore, the additional volunteers were a necessity, especially when working with people who are vulnerable to mood changes and instability. It was encouraged to them in the beginning that if the study had any negative impact on their mental health or if other circumstances led them to a manic or depressive state, they were welcome to drop out of the study with or without notification. This was the case for those who ultimately were not able to participate in the final interviews.

#### **4.4 Expectations for participants**

When the participants signed up they were asked to sign a consent form allowing their data to be used as a part of the study. This included recordings of their interviews, any data they logged in the app, and survey responses. They were assigned an alias in the form of "PX" where X was a serialized number given to each of the 25 volunteers. After they gave consent, they were asked to schedule a pre-study interview meeting with me to discuss their experience with their bipolar diagnosis as well as get their initial thoughts on mood prediction technology and experience with other applications that are meant to aid their mental health. Following the interview they were onboarded to the app, Bipolar Buddy, and asked to use it daily for three weeks to log their mood score, including motivation and anxiety levels, their sleep information, and their medication compliance. More details on these forms can be found in the Solution Architecture chapter.

## 4.5 Data collection and analysis

### 4.5.1 Interviews

The data given by the participants are analyzed in various ways. The interviews held both before and after the study period were recorded. I took notes throughout the interview on their answers to the questions. Following the completion of all interviews the transcriptions were reviewed and open coding done. Using the concepts collected I generated an affinity diagram grouping the data by question topic as well as themed answer. Finally, the interviews were summarized in the Participant Overview chapter covering all of the groups shown on the affinity diagrams.

### 4.5.2 App data

The usage data collected by the Bipolar Buddy app was stored in a SQL database. This data consisted of the following structure for the mandatory categories:

*Mood:* Captured are the given mood on the scale of 0 - 10, the motivation and anxiety scores on the same scale, and any notes the user submitted.

```
{
  "CurrentModeScale": 1,
  "MotivatedScale": 2,
  "AnxietyScale": 0,
  "Notes": "string"
}
```

*Sleep:* Collected are the time the user fell asleep the previous night ("PreDayFallSleepTime"), the time they woke up ("WakeUpTime"), a rating on the quality of their sleep ("SleepRateScale"), a duration given in minutes of potential nap(s) taken ("NapDuration"), and any notes they chose to enter.

```
{
  "PreDayFallSleepTime": "12:00",
  "WakeUpTime": "8:00",
  "SleepRateScale": 0,
  "NapDuration": 0,
  "Notes": "string"
}
```

*Medication:* Collected in this section included a list of the medications the user takes daily. They can provide a name, as well as multiple times it should be taken per day. When filling in their medication data each day, if the user indicates that they took the medication on time or late, the "IsMedicationTaken" will show as true. If the user indicates they took the medication late, the "MedicationStatus" will show as 1. Finally, if the user logs that they forgot to take that particular medication that day, the "IsMedicationTaken" will be false, and the "MedicationStatus" will be 2. Similar to the other categories, the user is shown a text box where they can provide notes for that particular day that are also stored in the database.

```
{
  {
    "MedicationName": "Lamictal, Lamotrigine",
    "MedicationInfo": [
      {
        "MedicationTime": "07:30",
        "IsMedicationTaken": true,
        "MedicationStatus": 0,
        "MissMedicationQuantity": 0,
        "Notes": ""
      },
      {
        "MedicationTime": "21:30",
        "IsMedicationTaken": true,
        "MedicationStatus": 0,
        "MissMedicationQuantity": 0,

```

```

        "Notes": ""
    }
]
},
{
    "MedicationName": "Zoloft, Sertraline",
    "MedicationInfo": [
        {
            "MedicationTime": "07:30",
            "IsMedicationTaken": true,
            "MedicationStatus": 0,
            "MissMedicationQuantity": 0,
            "Notes": ""
        }
    ]
}
}

```

Given the data in this format, I used a combination of SQL queries and python data analysis steps to better visualize the results. The graph created displayed the entries per participant across the dates of the study to visualize their app usage as well as their overall state. These graphs are intended to be primarily used as references to explain particular participant responses and situations that they described in their interviews. It is also worth looking for trends when comparing this data to the given predictions the users may have been presented with during the study weeks. This was considered in assessing prediction accuracy as well as checking if any low or high predictions affected the users mood information, sleep, or medication compliance.

#### 4.5.3 Survey data

Finally, the survey collected a combination of quantitative ratings on a 1 - 5 Likert scale and short answer responses to qualitative questions. The survey focused on gaining feedback on the mood prediction displays and overall view of mood predictions as well as trust levels from the users. The survey also asked for feedback on the Bipolar Buddy app overall in order to validate its usability or suggest improvements for future usage.

#### 4.6 Answering research questions

All of the data collected above is interesting and could lead to insights around bipolar technology as a whole. However, the main focal point of the study is answering the three research questions listed in the Introduction about the effects of mood predictions on people with mood disorders, the trust people have for mood prediction technology, and their preferred display.

**RQ1:** *What effect, if any, do mood predictions have on the mood, sleep, motivation, and anxiety levels of people with a mood disorder? What is the nature of these effects?*

In order to address RQ1 the participants are asked directly in a survey for quantitative ratings on their perceived effects on each of the categories (Figure 10). Using a Likert Scale they rank from 1 - 5 how much of an impact viewing the mood predictions had on their mood, sleep, motivation, and anxiety. Then, the followup question asked what kind of effect it had from very negative to very positive on a 1 - 5 Likert Scale. Another way to evaluate this is to analyze the data entered into the app to see if any users changed patterns once they were presented with mood predictions. If their data showed a change in pattern, and it was not easily explained by situational factors that they were asked about in the interview, then this could potentially be effects from viewing the mood predictions.

**RQ2:** *Do users trust mood predictions? What factors or context affect their trust levels?*

Similar to RQ1, the first approach to answering this question was in the form of a survey question to get a quantitative measure for the amount of trust and a written explanation for what contributes to their trust. In the survey they were asked to distinguish between their trust level for mood predictions in

How much did viewing the mood predictions impact you in the following categories?

	1 - Not at all	2	3	4	5 - A lot
Mood	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sleep	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Motivation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Anxiety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What kind of impact, if any, did the mood predictions have on you in the following categories?

	1 - Very neg...	2	3	4	5 - Very posi...	N/A
Mood	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sleep	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Motivation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Anxiety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**Figure 10.** Survey Questions for Prediction Impact

general as well as specific to the Bipolar Buddy mood predictions. After collecting the survey data the users were also asked in their interviews for a verbal response about their opinions on mood predictions and what would build or lose their trust.

**RQ3:** *Do users prefer a prominent summary score of their upcoming mood values or a subtle graph view of daily predictions?*

In line with the previous research questions, the preferred prediction presentation was evaluated using a survey question as well as discussed in the user interviews. The survey offered images of the various displays including the prominent summary overview, the subtle graph view, a combination of both together, and a view with no predictions at all. There was a previous question asking if the participant noticed any mood predictions at all during their usage of the app. If their answer was no, they were not asked their preference since they did not experience them. However, in the interview they were given the opportunity to view the various displays in their app and provide their feedback.

## 5 PARTICIPANT OVERVIEW

### 5.1 Introduction

I interviewed 17 participants before they began the study. In the interview I asked about their background as well as questions about each of their experiences with their specific bipolar diagnosis. The participants gave a variety of stories, proving to come from many different stages in the process of their diagnosis. This made the cohort a valuable diverse study group. You can see the basic data on each participant in Table 1.

How much do you trust mood prediction technology overall (outside of Bipolar Buddy)?

1

2

3

4

5

1 - Not at all

☐

☐

☐

☐

☐

5 - A lot

How much do you trust the mood prediction technology used in Bipolar Buddy?

1

2

3

4

5

1 - Not at all

☐

☐

☐

☐

☐

5 - A lot

What are the main factors that contribute to your trust level in mood predictions? (either positive or negative)

Short answer text

**Figure 11.** Survey Questions for Prediction Trust

## 5.2 Background

Out of the 17 participants, four were in their early twenties, four were in their late twenties, four were in their thirties, two in their forties, two in their fifties, and one in their sixties. They came from many different backgrounds ranging from three South Africans (all living in Europe now), four Americans, two Canadians, and the others from various countries in South America and in the eastern hemisphere. Seven of the participants were married and living with their spouse and four of the participants had children. Although many of the children had already grown up and moved out of the house, some were still infants in need of constant care. Their careers included teaching (P6, P7, P12), nursing (P2, P23), designer or photographer (P15, P20), student (P8, P9), social worker (P1), trust manager (P12), and concrete engineer / safety construction officer (P18). Most of them spoke about their professions and past careers, however, many of them took substantial breaks from work to recover their mental health. Some even chose to leave work altogether. P2 decided after nursing they preferred to pursue their own ventures, writing a blog called “Bipolar Diaries” and courses about emotional intelligence to help others. Many expressed feeling overworked in their current or previous jobs leading to stress and instability, while a couple mentioned loving their work and feeling their personality traits were finally viewed as strengths rather than weaknesses. All but two participants seemed to live with roommates, their partners, or family. They enjoy various hobbies such as sports including crossfit, horse riding, softball, running club, and rugby, as well as more artistic hobbies such as painting, crafting/making stamps, and participating in local musical bands.

## 5.3 Diagnosis

A prerequisite for the study was that all participants must be diagnosed with some form of bipolar disorder. Surprisingly, many of them had multiple diagnoses throughout their lives in search of what best fit them and what treatment worked best to reach stability. Of the 17 participants, four identified as having Bipolar I (P1, P3, P17, P22), and ten mentioned having Bipolar II (P2, P6, P7, P8, P12, P13, P15, P18, P20, P23). Two claimed to have Bipolar mixed episodes of which one said rapid cycling (P5) and the other said unspecified type (P9). Finally, P25 was previously diagnosed with bipolar but it was recently changed to Borderline Personality Disorder (BPD). Alongside bipolar disorder, many described simultaneous diagnoses including dyslexia, eating disorder, attention deficit hyperactivity disorder (ADHD), migraines,

P#	Age	Bipolar Type	Nationality	Current Location	Profession
P1	29	Bipolar1	Canadian	Canada	Social Work
P2	50	Bipolar2	Australian	Australia	Nurse, Entrepreneur
P3	22	Bipolar1	USA	USA	Student
P5	32	Rapid Cycling	South African	Netherlands	Projects?
P6	35	Bipolar2	UK	UK	Teaching Assistant
P7	61	Bipolar2	Australian	Australia	Music Teacher
P8	24	Bipolar2	Algerian	Spain	Student
P9	23	Mixed State	Indian	India	Student
P12	52	Bipolar2	South African	Scotland	Teacher, Charitable Trust Manager
P13	26	Bipolar2	USA	USA	Service
P15	25	Bipolar2	Italian	UK	Photographer
P17	28	Bipolar1	Philippine	Philippines	?
P18	48	Bipolar2	Canadian	Canada	Safety Construction Officer
P20	35	Bipolar2	USA	USA	Graphic and Interior Designer
P22	24	Bipolar1	South African	UK	Student?
P23	40	Bipolar2	USA	USA	Nurse
P25	31	None	Venezuelan	Switzerland	Software Engineer

**Table 1.** Participant Background Overview

anxiety disorders, borderline personality disorder (BPD), and trauma background. P9 was once given medication targeting alzheimers due to memory issues. Before coming to the bipolar diagnosis, many participants were previously diagnosed with something else. The majority were given depression (P1, P3, P5, P23) or general anxiety (P5, P6, P17) for several years and were treated for those. The amount of time the participants have been aware of their diagnosis ranges from 22 years to 1.5 years. This variation showed as well in the way they spoke about their management strategies and their confidence in preventing episodes in the future and maintaining stability.

At least three participants mentioned having a family member diagnosed with bipolar disorder. This is not surprising as bipolar is known to be genetic. Therefore, if a sibling or parent has bipolar disorder it is more likely that one can develop it as well. These specific genes have not yet been discovered, but genetic factors account for 60 to 80 percent of the cause of bipolar disorder [(8)]. This means there must be other causes of bipolar including environmental factors such as traumatic events, high-stress environments, or sudden major life changes. These concepts were discussed in the pre-study interviews as well. Two participants lost a parent recently (P1, P3) and one nearly lost their partner due to a heart attack and now parkinson's disease (P12). These could all be causes or triggers for their mood swings leading to the bipolar diagnosis. However, in this study there was no further investigation as to the root cause of each individual's bipolar diagnosis.

Many of the participants described mixed feelings towards their diagnosis. At least ten of them said they were relieved when they received their diagnosis as they could finally put a name to what they were experiencing. P3 said "I don't feel crazy anymore" while P6 said "I was finally properly crazy". Both of them expressed this as a positive response. In addition to the new ability to research their condition and learn about treatment and medication to help keep balance, many of them felt that their past had more of an explanation than ever before. Seven participants said they experienced mood swings or episodes long before they were diagnosed. They just did not know at the time what to call them.

In addition to the ten participants feeling relief, six described more negative emotions towards their diagnosis. P22 said getting the diagnosis was a "tremendously turbulent and confusing time". They described grappling with the diagnosis and not believing it was long term. In addition to the denial, there was a sense of discomfort about having the label of being "bipolar" and all of the stigma that could come along with it. P13 said they never enjoyed the diagnosis. P12 said they felt 10% devastation knowing this is lifelong and they may never be stable again. Others went through cycles of acceptance and rejection. P18 said they would often read a story about someone with bipolar and say "I'm not THAT bad. . . well, there was that one time. . . and that other time". Ultimately, each individual had their own way of coming to terms with their diagnosis and accepting the similarities in their experience and those symptoms defining bipolar disorder.

## **5.4 Bipolar experience**

Bipolar itself comes in many varieties. As mentioned before, some common forms include Bipolar I, Bipolar II, Rapid Cycling, and Mixed Episodes [(18)]. Although they all fall under the same diagnosis of “bipolar” they each display different behaviors. In addition to the bipolar type differences, each individual experiences their bipolar differently. They all described going through ups and downs, living through a manic episode or a depressive episode, but some found themselves in depressive episodes much more often, while others faced more time in mania. This is a key difference between Bipolar I and Bipolar II. “The main difference between bipolar 1 and bipolar 2 disorders lies in the severity of the manic episodes caused by each type. A person with bipolar 1 will experience a full manic episode, while a person with bipolar 2 will experience only a hypomanic episode (a period that’s less severe than a full manic episode). A person with bipolar 1 may or may not experience a major depressive episode, while a person with bipolar 2 will experience a major depressive episode” [(1)]. These differences were demonstrated in the stories of the participants as they described their experience living with bipolar disorder.

### **5.4.1 Mania**

Those who have Bipolar I told stories of their extreme manic episodes. Many lost sight of reality and said it felt like they were in a “dream state” (P22). Three of the participants mentioned spending a lot of money while manic (P6, P8, P22). Others had psychotic features or experienced paranoia. P6 went into detail about how they heard voices in their mind saying “someone is coming to hurt you” and they proceeded to set booby traps around the house to keep themselves safe. Although they knew they had a pet that would alert them if someone really did enter the house, it did not settle the fears. They also acknowledged that their particular experience and fear is likely tied to the trauma they witnessed in childhood. P5 said they were fully aware of one hallucination experience because they saw ninjas jumping around the house, which they knew could not be reality. P23 said when they were in a manic state they did not sleep for 2-4 days and it was the first time they cried in front of their kids.

While some participants had an extreme manic episode to reference, others have only endured hypomanic episodes. At least six of the participants said they don’t always recognize when they are in mania. The episodes go by unnoticed because the person simply feels really good, productive and driven. Oftentimes they had friends, family, or professionals point out to them that their behaviors were not normal and could be seen as unhealthy. P12 said in their hypomanic episode they visited 16 friends in just nine days, staying up until 1:00am and waking up at 7:00am to fit everything into their travel plans. P18 said they would feel as if things they were saying sounded “remarkable” regularly while feeling manic, but ultimately knew it was likely an illusion and their words were not so noteworthy. Overall, the attitude towards mania for these participants was more accepting than the attitude towards depression.

### **5.4.2 Depression**

The descriptions of depression were along the same line of intensity for most of the participants. When they felt depressed, they did not feel like doing anything. Most of them explained how when they are experiencing depression, they stay in bed, and often cannot find the motivation to get up to dress or feed themselves, and certainly not to leave the house for any reason. P13 went so far as to say that when they went through their depression after a month or two they got divorced and could not even get up from bed. Their new partner helped to dress them as well as get them to the bathroom. In the extreme cases participants said they felt extremely low self-esteem and self-worth (P6) coupled with passive or active suicidal thoughts. Four of the participants mentioned having a suicide attempt during their depression, but it is possible that others may have taken similar actions but did not feel comfortable enough to share this in the interviews.

### **5.4.3 Frequency of episodes**

Considering that the participants have had varying amounts of time with their diagnosis to understand their particular patterns, many still experience regular episodes, while others have not experienced mania or depression for years. Most of them gave an estimate of the frequency of their mood swings. Four participants said they go up and down on a weekly or biweekly basis. Five participants said they live through several months of a depression or months of a mania before recovering. Four claimed that depression was their main driver leading to the diagnosis, P20 saying outright, “depression is worse than mania”. Having one extreme mood is tough enough, but some participants suffer from mixed episodes, meaning they could flip from high to low by the minute. P13 told about their experience in 2019, the

year of “extremely severe mixed episodes” and how it led to their divorce and deep depression. With all of these mood swings at varying levels, it is important for those with bipolar to get support from professionals.

#### **5.4.4 Current stability**

With a lot of work to manage stability, several participants claimed they had been stable for a long time. P23 said “for the last 2.5 years I haven’t really experienced mood swings” and P12 said “the last 2 years have been quite stable... particularly the last 6 months”. Only one participant confessed they had a recent episode where a week prior to the interview they were hospitalized for recovery. It was emphasized to this person, and all other participants, that there was no pressure to participate in the study and they were welcome to leave at any time with or without notification in order to prioritize getting back to a stable place.

### **5.5 Impression of bipolar**

While there may be some commonalities in the bipolar experience, each individual has their own personal take on what “having bipolar” or “being bipolar” means to them. Depending on their view on the diagnosis they approach their treatment differently. Their view also could be impacted by their professional support and treatment experience.

#### **5.5.1 Approach to bipolar**

While they all may seem as if they accept their diagnosis, they each take on a different level of responsibility to remaining stable. Seven participants described having mood changes regularly and having no control over them. For example, P12 said, “generally the episodes just overtake me,” P1 said, “I usually just let the moods sweep me up,” and P7 said “I have fast triggers. One moment I’m okay, then suddenly I’m not.” Others felt a bit more sense of control over the matter, claiming, “I’m used to bouncing back from episodes” (P15). Five participants said they think about their diagnosis daily, describing it with titles such as “having a disability” (P5) or a “full time job” (P23). Many of them check in with themselves often, explaining how they wake up each day and ask, “Have I surged” (P12). Some ask themselves upon any sense of elevated or depressed mood, “is it coming, is it coming?” (P18). An important approach to managing bipolar is taking the prescribed medication. One participant reflected on the time before they were diagnosed and prescribed medication and wondered how they made it through without mood stabilizers. Then they said, “you have coping skills before medication, until you don’t” (P23). This highlights how imperative medication compliance is and how the self-driven coping skills are not likely to work forever on their own.

#### **5.5.2 Doctors and prescriptions**

Finding a trusted doctor that is a good fit for the patient was a struggle for many of the participants. As mentioned above, some participants were diagnosed with something different before their bipolar diagnosis, and many of them blamed their doctors for being wrong or not paying enough attention to them. Even after identifying a good doctor or team of doctors to work with them, if the patient ever moves to a new location, they must begin their search again in their new city. One participant in the study, P8, is currently having such a hard time finding a therapist in their new location, that they travel across Europe every three weeks specifically for their therapist appointment. It is a whole different challenge to figure out the appropriate medications and dosages that fit each individual. Several participants said it took a long time to sort out their medications and the process of making changes while the medication was not quite right was rigorous, leading to many side effects. One side effect of medication that was mentioned by five of the participants is weight gain and another three mentioned lack of sleep. This often motivates someone to change their medication dosage for the pure reason of maintaining a healthy weight for their body type or consistent or reliable sleep habits.

### **5.6 Other bipolar outcomes**

In addition to the symptoms described in previous chapters, there are many other side effects to having bipolar. Sometimes the experience becomes so extreme that it has led many of these participants to medical facilities to seek help. Some of the participants also had life changing events that may have triggered their bipolar diagnosis in the first place.



### **5.6.1 Hospitalization**

At least four of the participants said they were admitted to a hospital or psychiatric facility for a period of time. This was often the result of an extreme episode of mania or depression or a possible suicide attempt where a family member or friend brought them into emergency care. Some stayed just overnight after a big unspecified incident (P1) while others talked about the month or multiple month long programs they attended to reach stability again. Given that so many were admitted to a hospital for some time, this is an indicator that the chosen sample of participants are fully aware of their condition being abnormal and have accepted help in the past for recovering and achieving remission.

### **5.6.2 Potential triggering events**

On top of struggling to manage their bipolar, many of the participants mentioned external factors and events that triggered their instability. Two recently had surgery, two moved several times internationally, one had a recent heart attack, five were in bad relationships, and three had a parent pass away.

### **5.6.3 Other challenges**

Although medication can help to lessen the effects of bipolar disorder, it still leads to further challenges in everyday life. For example, many participants described having a hard time with relationships. While some had their moods most influenced by their significant other, three others mentioned its impact on friendships. P5 said they feel guilty being a burden to people around them, and P1 has a fear of being unreliable due to their illness, steering them to avoid making friends altogether. Other challenges include “issues with memory and associations” (P15), postpartum leading to major depression (P17, P23), having low self-esteem (P6) or feeling like “failing, useless, and incompetent” (P12), and difficulty playing with kids while depressed (P13). Many also explained their challenge to continue working due to symptoms like agitation or sensitivity to criticism.

## **5.7 Managing bipolar**

There are many strategies recommended for managing bipolar symptoms. When participants were asked what strategies they use, their answers aligned quite well with the categories available to track in Bipolar Buddy, the application used for this study. The most prevalent topics mentioned below consist of medication, mood tracking, sleep consistency, diet and exercise, and therapy. These are proven triggers found in previous studies [(12)]. This further reinforced the importance of monitoring a few core triggers to prevent mood instability.

### **5.7.1 Medication compliance**

One strategy mentioned by every single participant was medication compliance. Some take it once a day while others take medication up to four times a day. Some described not being satisfied with their current prescription (P8) and one confessed they were currently inconsistent with taking their medication and wanted to get better (P3). However, despite the challenge to stay compliant with this, they all expressed how essential it was to be taking the proper dosage of medication in order to stabilize their moods and balance out their reactions. Taking their medication late, skipping it, or consuming something that blocks its effect or reacts with it are all potential causes for manic or depressive episodes.

### **5.7.2 Mood tracking**

In addition to management in the form of prescribed medication, many participants were also advised by doctors to track their moods or to journal. Several of them did this with varying approaches. Seven participants claimed they journaled or tracked their moods at one time using paper or google docs, while two participants said they have a mobile application they are currently using to track their moods. Two of the participants described other organization tactics they use, such as making lists of triggers and to-do lists as well as toolkits for what to do during an episode. Although many recognized mood tracking as a useful practice, most of them could not stick with it and often forgot or got tired of logging something on a daily basis. The few that have an app to track their mood hoped this would minimize the time for entry. Unfortunately, they got bored when using the apps or the apps were not structured enough (P5), taking too much energy to record things at times when they're feeling low (P17).

### **5.7.3 Sleep**

Another important factor to maintain consistency is sleep. While all participants recognized this as something with a strong impact on their mood, there were varying opinions on what aspect of sleep was

most important. Some said that the amount of sleep is the important part, one claiming that “If I don’t get a good night’s sleep, I forget to take my meds” (P12). Some said the priority is on the quality of sleep. This means that if they just sleep for four hours instead of the recommended eight, as long as they wake up refreshed and having experienced a deep sleep, they believe they will stay balanced (P9). Others suggested that consistency in the exact times they go to bed and wake up are essential for them to maintain balance. A few participants have strategies to achieve these sleep goals. One participant uses a sleep tracking app through the Apple Watch called Pillow (P5), while another participant says they take half a sleeping tablet when they are struggling to sleep to ensure they get enough rest (P7). Sleep is no doubt one of the primary influences on people’s mood and health, so that is why it was selected as a mandatory category for this study.

#### **5.7.4 Diet and exercise**

While discussing management strategies, many participants mentioned taking care of their physical health through diet and exercise. They claimed that this has a direct relationship with their mental health and mood score. While many of them mentioned it was essential to prevent episodes, some had a primary motivation to lose weight that they had gained as a side effect to medication. At least five participants mentioned their goal was to lose weight and many of them had success with their approaches. One participant went so far to say, “I have to do some kind of exercise every day. I walk for at least 30 minutes and I do a one hour crossfit workout” (P23). There are ample good outcomes from exercise, however a few participants claimed that they tended to overdo the activity level when they were manic. This was something they needed to monitor. One participant said “When I get the feeling that I want to go for a run, then I know that’s a sign that I’m slipping into mania.” (P20)

#### **5.7.5 Therapy**

A very important part of treating bipolar or any mental health condition is seeking professional help. Therapy comes in many different forms and is recommended to those with both physical and mental illness to work towards recovery or stability. Talk therapy is specific to addressing mental illness and is recommended for treatment of bipolar [(31)]. The majority of participants mentioned they were seeing a therapist on a regular basis. Most enlisted this support in addition to a psychiatrist who had the ability to prescribe or refill their medication. Some had one on one sessions with their therapist, while others mentioned group therapy or a program they attended over several weeks. Cognitive Behavioral Therapy (CBT) was the most popular mentioned therapy, explicitly discussed with P3, P7, and P18. “Cognitive behavioural therapy (CBT) is a talking therapy that can help you manage your problems by changing the way you think and behave. It’s most commonly used to treat anxiety and depression, but can be useful for other mental and physical health problems” [(21)]. Dialectic Behavioral Therapy (DBT) was also mentioned as a program that P18 insisted was the most effective. “The term ‘dialectical’ comes from the idea that bringing together two opposites in therapy – acceptance and change – brings better results than either one alone. . . DBT may be used to treat suicidal and other self-destructive behaviors. It teaches patients skills to cope with, and change, unhealthy behaviors” [(28)]. These therapy methods are all similar in that they help patients to gain control over their emotions and reactions and work through their problems. Luckily, several patients expressed that their healthcare allowed them to check into a hospital to receive this therapy treatment consistently for several days or weeks. Many expressed that they took this strategy directly after a major episode, landing them in the hospital anyways. They said it had a big impact on their recovery and are thankful for the ongoing support the medical organization often offers.

#### **5.7.6 Meditation**

One recommendation from medical personnel is different forms of meditation and breathing exercises. Five participants said they do breathing exercises or meditate in order to keep themselves calm and prevent anxiety or overreactions. P6 and P18 made meditation a regular practice and P23 says they read the bible and pray for 30 minutes a day which can be viewed as a form of meditation. P25 uses breathing exercises mostly when they are feeling something coming on, as does P7 who chooses to spend time with their horses on days when they are feeling down. Experts say that meditation can be used to help one relax and reduce stress. It can also help to disengage from stressful or anxious thoughts, and better control one’s mood [(33)].

#### **5.7.7 Reducing alcohol and substance abuse**

For people with bipolar disorder, chemical balance within their body is essential for their medication to be effective. This means it is important for them to avoid consuming things that block or dangerously react with their medication. In addition to reactions to their medication, those with bipolar are also more susceptible to influence of stimulants and depressants such as caffeine and alcohol than the average consumer. Lithium is the most common medication prescribed to bipolar patients [(31)]. One article wrote, “Drinking alcohol while on lithium is not safe. For patients on lithium, alcohol may decrease the benefits and increase the adverse effects of the medication” [(16)]. Despite this impact, it is often tempting for those with bipolar to seek methods to “turn their brain off”. Alcohol and substance abuse are common strategies for this. “The abuse is possibly an attempt to self-medicate or to treat their disturbing mood symptoms, and they may also cause mood symptoms that can mimic those of bipolar disorder” [(9)]. A few participants discussed their past filled with alcohol and drug abuse through partying. Knowing the overall negative impacts of this behavior as well as the fact that a lifestyle of partying is completely unsustainable, many participants mentioned their efforts to reduce their alcohol or drug intake. P6 and P12 said they are now sober, while P5 aims to limit their drinking to one glass of wine and P18 does not drink much, knowing that it leads them to a down time. P22 says when they begin to feel manic it triggers them to cease all alcohol consumption for a while to take it easy until they are calm again. This is why the app, Bipolar Buddy, offers a space to log one’s alcohol intake, as well as drug consumption to give users a better sense of what could be leading them to a manic or depressive episode.

#### **5.7.8 Going outside**

One participant connected to the initial interview from an outdoor location (P3). They claimed that sunlight at particular times of the day, especially in the morning, was good for their mental health, as advised by the host of The Bipolar Now Podcast that they regularly listen to [(2)]. This was also mentioned by P20 who said they worked to be sure they got enough outside time. P8 said one strategy they use to combat depression is to get up and go for a walk. Several others mentioned the impact of the season on their mood, claiming that winter is more challenging than summer to avoid depression due to the cloudy days and lack of sunlight. P23 has a lightbox specifically for these cloudy days to give them the feeling of sunlight directly from their desk. It is clear that exposure to sunlight and being outside in fresh air is a common tip for those managing bipolar.

#### **5.7.9 Community**

There is a Swedish Proverb that states “Shared joy is a double joy; shared sorrow is half sorrow” [(26)]. Those with bipolar often seek comfort from communities that share their diagnosis or similar experiences. The participants in this study were all recruited from Facebook Groups and personal networks. Therefore, all of these participants found it helpful to be a part of a community of some kind to share learnings of how to best cope with their symptoms as well as celebrate wins for those who overcame obstacles with their condition. One of those social media groups was called “The Bipolar Now Podcast” group. This was a collection of those who found the group via a podcast hosted by Mike Lardi where he shares his own experience and learnings with bipolar disorder as well as interviews those in the network who have interesting stories or new-found coping strategies [(2)]. Another group was called “Research and Conversations About Bipolar Disorder Inc.”. As the name implies, this group focuses on the research and innovation happening in the bipolar space and encourages people to contribute to the growing research area, often by means of study participation. In addition to online groups, many participants mentioned the importance of spending time with their friends to avoid isolating themselves into depression. Overall, those with bipolar can benefit from such communities to gain knowledge about their condition as well as share both their joy and suffering with friends.

#### **5.7.10 Work leave of absence or quit**

Full time work is often a challenge for those with bipolar disorder. “Stress and unpredictable challenges in the workplace can take a big toll. Managing bipolar at work – with the highs of mania and the lows of depression – is no small feat” [(27)]. For this reason, at least four of the 17 participants said they left their job either for a period of time, six weeks (P23) or two years (P5, P12), or they left their careers behind for good (P13). As mentioned in the background of the participants, many of them are still in the workforce in some capacity. However, common strategies they use to manage their bipolar in the workplace consist of part time work, flexible working schedules, communication with supervisors on their mental health

situation, or actively taking sick days to recover from work stress or other situational triggers. When bipolar brings so many challenges to the work environment, and work often brings additional stress and anxiety on those with bipolar, it is often a good decision to separate the person from work responsibilities for a while until consistent stability is achieved.

#### **5.7.11 Other management strategies**

In addition to the many management strategies already listed, there are a few miscellaneous tips that participants mentioned they use. For example, P12, P13, and P17 set alarms throughout the day to help them stick to a daily routine. The alarms are mostly used as reminders to take medication, but some also used them as a trigger to log their information in the app for this study. P5 and P20 created a crisis plan or toolkit for themselves to be prepared with actions to take when they feel their mood taking a dip or a peak. As a form of a contingency plan, P25 keeps a tray of low calorie ice cream in the freezer at all times. This reassures them that there is available comfort if they are feeling down at any point.

### **5.8 Bipolar technology used**

Some participants tried using mobile apps for tracking their triggers and symptoms in order to manage their bipolar symptoms. Several participants tried mood tracking apps including “eMoods” and “Moodnotes” in the past to log their moods each day. Their feedback was that these apps were quite complicated to read the results and tedious to enter each day. P20 still uses the “Bearable” app to log their mood each day. P3 used the “WayOfLife” app for tracking various habits such as exercise, breakfast and medication. All the participants who tried using these apps (with the exception of P20) claimed the apps themselves had value, however they all got bored of using them or claimed they were not structured enough or took too much energy to record each day. This was especially the case when they were in a low period. Consistency was the biggest challenge when it came to manual inputs in an app. Ideally, the participants would like something that could take in data passively or from other sources where the data is already being captured. For example, P5 already uses the Pillow app to track their sleep and many of the participants have smart watches to track their exercise. Although it was not suggested by the participants, there are even ways to passively track medication using solutions such as smart pillboxes [(you)] that can alarm to remind users to take their medication as well as sense at what time medication was taken, alerting doctors if it senses poor compliance. All of these innovations are potential ways to help people manage their bipolar symptoms with minimal manual effort on their part.

### **5.9 Support Systems**

Bipolar is a disorder that impacts one’s moods and emotional stability and control. In cases where it gets out of hand, people can be dangerous to themselves or others. That is why it is important that everyone diagnosed with bipolar has a support system of some kind to check that they are okay and get them professional help when needed. Within the pool of participants in this study, they all described some sort of support system they had in place.

#### **5.9.1 Family**

Of the 17 participants, 12 mentioned family members that supported them with their diagnosis and management. This included sisters, husbands, mothers, boyfriends, an uncle, and children. They are supported in various forms. Oftentimes family or parents show their support by way of financial help for medication and treatment. Husbands and boyfriends show sensitivity, look after kids, and maintain other household responsibilities to allow for their partner to keep a consistent routine or recover from low moods. Several participants talk to their mother often, staying in touch. On the flip side, family is not the most reliable in all cases. Some participants expressed that their family judged them or never understood what they were going through. Some families did not believe in mental illness due to religious or cultural reasons, and others simply did not like to talk about it, even though mental illness often ran in the family. Some families try to help but do not realize that they are hovering too close, not offering effective support but rather smothering their loved one.

#### **5.9.2 Friends**

In addition to family, friends were often an outlet for support for the participants. Some told of friends they have that feel even closer than family. P9 said their long distance friend “takes the upper hand” giving weight to their opinions and advice above all else. P18 said they have a friend that calls or sends a text message to check in after work every single day (95% of the time). Others have a large group of

friends or multiple communities they are in. P18 is so active that they have a group of friends for all of their hobbies including: high school alumni, rugby, bagpipe band, politics, pride, and work. Many of these friends offer support by means of an ear to listen when things are getting tough. P25 says they call their friends when they are feeling anxious to help vent through their feelings in order to calm down. P8 says their friends help calm them when they're too high. They even had a friend from school who was studying psychology and helped to educate them on bipolar when they first were diagnosed. However, as with the family, not all friends understand bipolar enough to be supportive. Even those who really want to help and really care for the person, they often make mistakes or don't have the patience for the mood swings. P6 said they lost two friends because once they began taking their diagnoses seriously and taking medication regularly they said "I wasn't the wild and fun one anymore." The same participant had some friends that often referenced a movie about a serial killer with bipolar anytime the diagnosis came up in conversation. This is rather insensitive and demonstrates the challenges people have with understanding a diagnosis. P22 received motivational advice from their parents stating "If you keep neglecting yourself and it [manic episode] repeats, people won't want to be there [for you] anymore." Friendships for those with bipolar can be tough, but for those friends that understand the needs that come along with such a diagnosis, their support can be immensely helpful.

### **5.9.3 Doctors**

Beyond family and friends comes the essential professional support. Psychiatrists in particular can prescribe mood balancing medication to help the bipolar patient to maintain stability. Most of the participants expressed that they meet with their psychiatrist monthly or quarterly to quickly check in and work out the best medication combination and dosage for them. Since many of the participants in the study are diagnosed with more than just bipolar disorder, it generally takes some time to discover the right medication recipe that works for them without triggering other responses.

## **5.10 Prediction Strategies**

This study is mainly concerned with the view of mood predictions by these patients. As predicting mood technology improves, it is important to first understand how people with bipolar predict their own moods. In order to develop the prediction algorithm as accurately as possible, the strategies used by individuals are important to consider. That is, as long as they feel their own predictions are accurate. However, it was discovered in the pre-study interviews that the participants of the study either have no independent prediction strategies, or they attempt to predict their upcoming mood using a few cues and internal signals but are not very confident in their accuracy. Six of the participants directly stated that they had no prediction strategies whatsoever (P1, P2, P8, P13, P15, P23). P15 said "Episodes come suddenly. It's hard to recognize them." For those that do make an effort to guess their upcoming moods, they use various cues including energy levels (P20), desire to socialize or have fun (P7, P15), work stress (P5, P12, P18), sleep changes (P5, P15, P20, P22), past mood patterns (P3), and future triggering events (P5, P7, P12). P7 discusses potential upsetting events with their psychiatrist once per fortnight to prepare for the possibility of upcoming mood swings attached to those events. The Bipolar Buddy app uses a machine learning model to predict moods. This algorithm factors in many of the mentioned prediction strategies. It takes in previous mood entries (past mood patterns), motivation and anxiety levels (energy and work stress), and sleep hours and quality (sleep changes). The app itself also has the functionality to capture events, however they have not yet been integrated in the prediction algorithm. These participants further emphasized that the primary elements of mood prediction are upsets in balance in the categories of mood, sleep, and stress.

## **5.11 Summary**

The purpose of these pre-study interviews was twofold. Primarily, it was to gather background data on the participants to better understand their experience with bipolar in case certain considerations needed to be made about their data input in the study. The other purpose was to gain an understanding of the challenges with bipolar disorder and how technology can play a part in addressing those. Although, prior to the start of this study some research was done via interviews to determine where the biggest technology need was in the bipolar community, this was a formal way to report the findings and emphasizes why building an application to help manage common triggers and potentially assist in predicting upcoming moods is a valuable endeavor.

## 6 RESULTS

Following the pre-study interviews three weeks passed where the participants were expected to use the Bipolar Buddy app to log their mood, sleep, and medication each day. There were several participants who began the study with the initial interview but were not able to meet for a post-study interview. Therefore, the results show user data from the 17 participants that used the app, and survey responses from 12 and interview information from 10.

### 6.1 Application data

While all the participants were asked to use the Bipolar Buddy app daily for three weeks, totaling 21 days, many of them did not successfully create a habit of using it daily. Two participants, P13 and P20, logged for the full 21 days. The lowest number of data entries was only a single entry, likely made upon registration during the first onboarding meeting by P7. Due to unforeseen circumstances, P7 and P12 were not able to continue the study or meet for a post-study interview. P8, P17, and P22 never responded to the request for survey responses for interviews, so the answers they provided in the pre-study interviews are considered as well as their app usage data, as minimal as it may be.

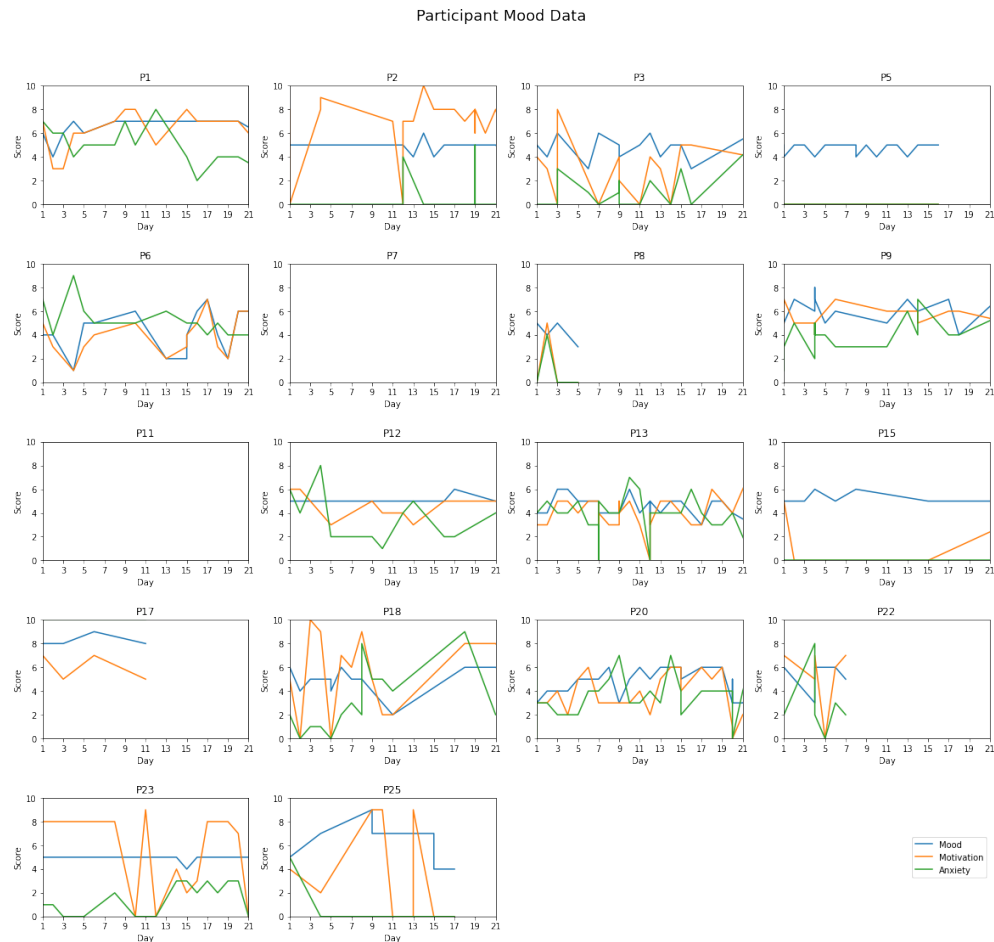
P#	Start Date	End Date	Mood	Sleep	Medication	# Entries
P1	2022-06-30	2022-07-21	15	15	13	15
P2	2022-07-01	2022-07-23	14	15	16	17
P3	2022-07-03	2022-07-18	11	7	7	16
P5	2022-07-03	2022-07-18	16	13	11	16
P6	2022-06-30	2022-07-25	18	18	17	17
P7	2022-07-04	2022-07-04	1	1	1	1
P8	2022-07-02	2022-07-06	4	1	2	4
P9	2022-07-01	2022-07-25	12	10	10	12
P11	2022-07-01	2022-07-04	1	1	0	2
P12	2022-07-03	2022-07-24	11	12	9	11
P13	2022-06-30	2022-07-25	25	21	22	23
P15	2022-07-01	2022-07-15	7	2	2	7
P17	2022-07-01	2022-07-11	4	1	4	4
P18	2022-06-30	2022-07-20	13	8	8	13
P20	2022-07-01	2022-07-24	23	16	0	22
P22	2022-07-12	2022-07-18	5	4	4	5
P23	2022-06-30	2022-07-24	19	21	20	20
P25	2022-07-01	2022-07-17	8	0	1	8

**Table 2.** Participant Usage Overview

Table 2 includes the date of their first entry (Start Date), the date of their final entry (End Date), and the number of entries made in each category. According to the table the average number of days that users made an entry over the 21 day period was 11.83. There are various reasons that led to them not making entries that will be further explained by the user interview responses. However, more than half of the three weeks is a sufficient average to introduce the participants to the mood predictions. Bipolar Buddy allowed for only one sleep entry and one medication entry per day (since you cannot have more than one night's sleep in a day and the medication entry form contains all the medication necessary for a single day). On the other hand, a user can enter multiple mood entries per day to indicate their changing moods even within a single day. This explains why there are some participants that have more mood entries than they do days of entry.

In terms of functionality, the users faced a few issues using the app in the start of the study. Several participants reported issues with submitting any form prior to submitting the mood data. The system was originally set up to only accept a mood entry first, followed by sleep and medication entries. Once the Bipolar Buddy team was notified of this issue we worked to address it immediately and before the end of the first week we released an update that allowed for the users to now enter their sleep or medication information before a mood entry. This was particularly important because it was common for users to want to log their sleep data as soon as they woke up, but they were not yet sure what mood score was

appropriate since the day had just begun.

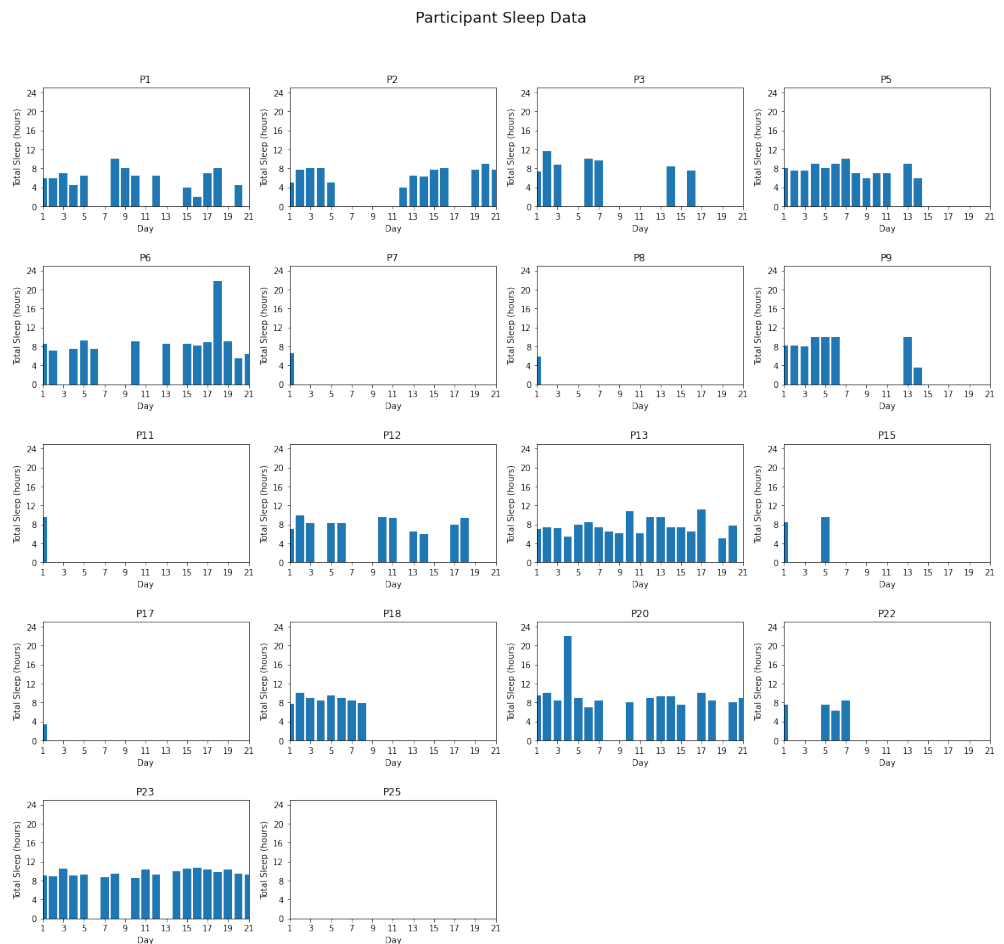


**Figure 12.** Mood entries

Figure 12 shows the mood, motivation, and anxiety information that the participants logged each day. It is clear, as discussed above, that some participants logged much more frequently than others. There is no clear pattern to their moods since each individual experienced their own mood patterns throughout the study time. However, the purpose of the graph is to provide further information about the users participation as well as their mood experience throughout. These mood scores will also be referenced in comparison to the prediction graphs to see if any trends can be identified implying the predictions having an impact on a user's mood, or implying something about the accuracy of the predictions.

The sleep graph shown in Figure 13 are meant to demonstrate the number of hours of sleep that the participants entered each day. This consists of their overnight sleep combined with any nap time entered for that same day. One user, P25, never entered any sleep information. In the interview they explained that their main focus with the app was logging their medication data, so they did not utilize sleep at all. As shown in the figure, most of the participants had fairly consistent sleep when they logged the data, with a few of them having one day with more than 20 hours of sleep (P6, P20). There were also a few participants who slept less than five hours for a few nights including P1, P9, and P17. This is, perhaps, an indicator that some participants may be more stable and follow their routine more successfully than others.

The medication graph (Figure 14) shows that the majority of the participants throughout the study that logged their medication information took their medication mostly on time. P2, P3, P6, and P13 took their medication late more often than they did on time. In addition, P1 logged that they forgot to take their medication 25 times and took medication 30 times. One cause of this seeming incoherent data could be explained by a query made by P1 at the start of the study. They expressed that they were



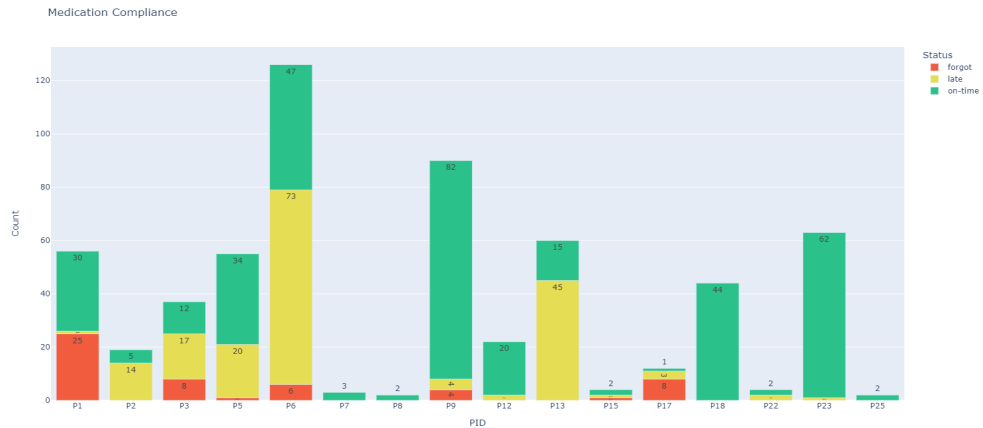
**Figure 13.** Sleep entries

prescribed a PRN medication that was to be taken only when needed. They entered the medication into Bipolar Buddy, but since it was not often needed, they logged it as forgotten. This is not a medication noncompliance but rather a misuse of the medication form. In the future the Bipolar Buddy team will work to better communicate how to handle PRN medication to prevent inaccurate predictions and displays showing incompletion. Outside of these few participant examples, all that logged their medication mostly took them on time. A potential cause for the seemingly good compliance could be explained by the fact that users will only log their medication information when they take their medication. There could very well be days throughout the study that they forget both to take their medication and to submit the form confessing to this fact. That being said, one cannot assume that all the days without an entry means medication compliance or noncompliance. The medication taken on non-entry days is unknown.

The prediction graph (Figure 15) shows a red line representing the mood predictions given over the duration of the study. The blue dots show the user's actual mood entry for that corresponding date. The figure shows no clear trend between the mood predictions and actual mood entries. While some participants entered mostly stable mood scores such as P2, P5, P12, P15, and P23, others showed much more variation in their entries. The mood prediction line is a visual indicator of the variety of entries as well since stable mood entries generally led to stable mood predictions. One obvious pattern in nearly all of the mood prediction lines have a mood spike in the first third of the study. This does not seem to be a product of the past data entries, so it therefore may be a result of an error caused by an incorrect data type coming from a premature app version release. This is discussed further in the Discussion section.

Although it was anticipated that users may experience changes in their mood trending toward their predictions, the graphs do not support this. For example, P18 logged several low mood scores before the prediction spike. Following the spike they logged only one above stable ( $> 5$ ) mood score and then





**Figure 14.** Medication entries

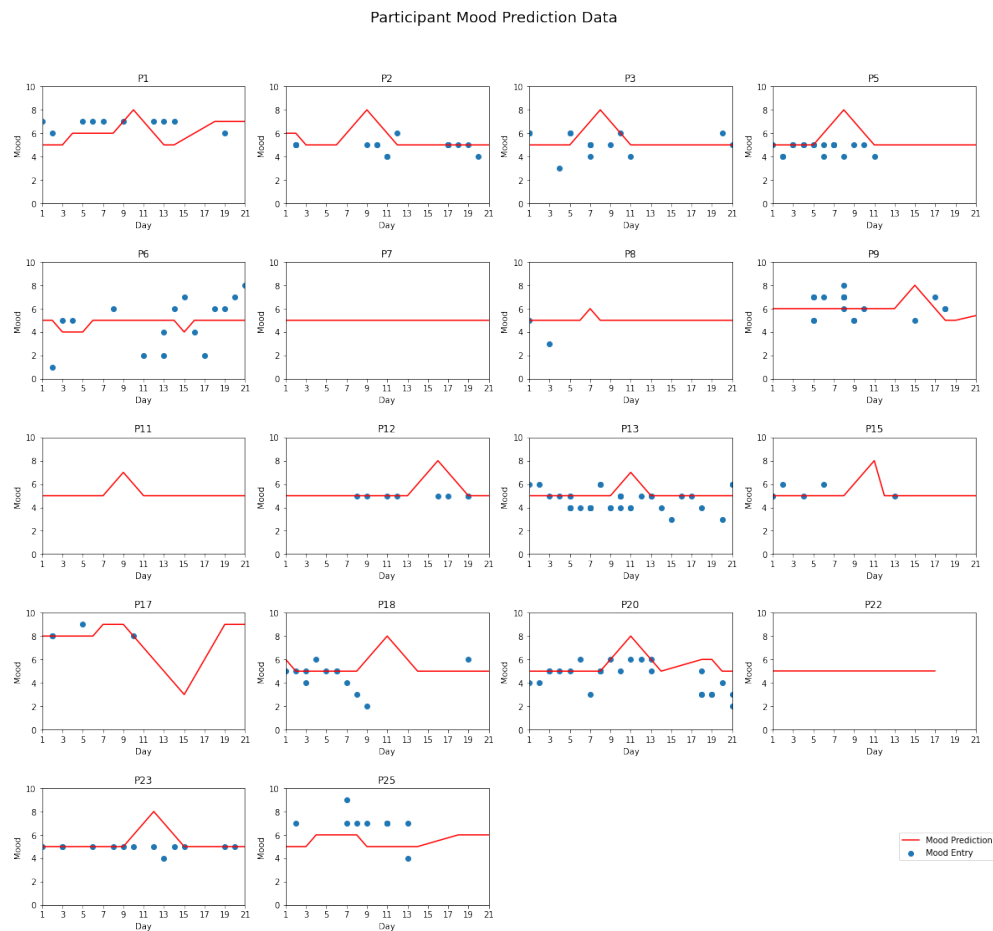
continued in their lower period, seemingly unphased by predictions shown to them. The graph for P3 shows a similar pattern of not increasing their mood to match the higher predicted values. P20 is perhaps the closest to showing this correlation of mood predictions to mood entries. They initially logged a variety of higher mood scores and when the predictions showed a dip, their actual mood entries also dipped. As some background, in the interview data to be discussed in a later section, this participant was on holidays visiting friends and when they were shown the elevated prediction they took it as a warning and chose to stay inside and rest more often than they were originally doing. This is the primary participant that expressed taking action based on the shown mood predictions, and their app data supports that.

## 6.2 Survey results

At the end of the three week study the participants were all emailed a survey to respond to in order to generate some quantitative data. The questions were mostly in the form of likert scale answer choices from 1 - 5 allowing the users to rate their opinions. The survey was broken into three parts. The first was generic questions about comfort with technology, overall impression of bipolar buddy, and overall view towards mood predictions. The next section was dedicated to mood prediction presentations. For this reason, users were only asked these questions if they claimed to have seen the mood predictions in the app. If they answered “no” that they did not notice the mood predictions, they skipped to the final section to optionally give Bipolar Buddy feedback to contribute to future improvements of the app. The reason that the set of mood prediction questions were reserved for those who had seen the displays was to prevent people from answering how viewing the predictions impacted them if they never experienced viewing the mood predictions at all.

Since one of the research questions specifically targets the impact of viewing the mood predictions on people’s mood, sleep, motivation, and anxiety levels, this question was asked directly to the participant. This demonstrated the perceived impact of the predictions according to the participants. As shown in Figure 16, of the eight responses, most of them indicated that there was little to no impact on any of the categories. On the scale of 1 - 5 with one being no impact at all and five being a lot of impact, the average score for mood impact was 2.125. The average score for the mood prediction impact on one’s sleep was 2. The average score for motivation was 2.25 and for anxiety was 1.25. After interviewing the participants most verbalized answers that aligned with these survey results. The majority claimed they did not feel anything when viewing the mood predictions, while a few said the prediction motivated them to work toward stability.

The second research question asks how much the users trust mood predictions given their existing experiences. This question was also asked directly to the study participants in order to get a quantitative response to their trust level. Twelve people answered this question on a scale of 1 - 5 with 1 meaning no trust at all and 5 meaning a lot of trust in the technology. The average trust score was 2.83 with 58.3% of the users choosing a 3 for neutral feelings toward mood predictions. There were two separate questions asking them for a rating on their trust level in mood predictions overall, outside of Bipolar Buddy, versus



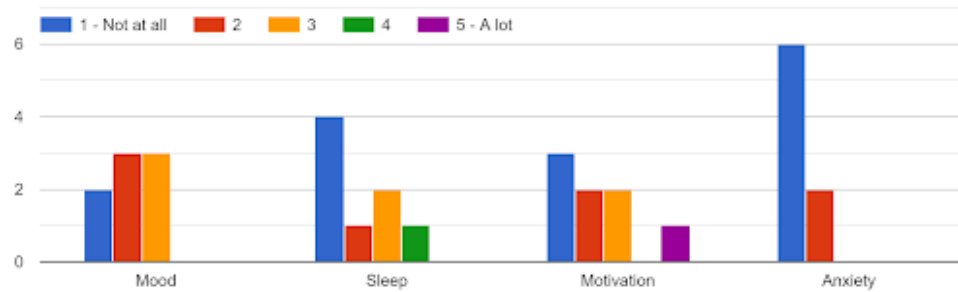
**Figure 15. Mood Predictions**

their trust level within Bipolar Buddy. However, this generated the same resulting distribution showing that Bipolar Buddy either had no impact on their view toward moods predictions, or their own perception of mood predictions were first introduced to them through Bipolar Buddy. So their opinions were the same considering the app and outside of the app. This indifference towards trust was further validated in the interviews where the majority of the participants said they liked the idea of mood predictions but had too little experience with it to fully trust it.

In the survey they were also asked to list some factors that contributed to their trust level in mood predictions. Many said their trust was dependent on evidence in data with P25 saying “I’m a tech related person and I trust in predictions based in data.” A few responses did not have much hope in the technology saying “Mental health disorders are complicated...” (P6) and “...since I have BPD, [Borderline Personality Disorder], as well as bipolar my mood is overall very unstable day by day and often minute by minute reacting to external events that cannot be predicted... I think trying to predict that would be way too ambitious.” (P15). The overall tone of the responses was skeptical with P1 saying “Generally it’s hard to trust technology to predict a bipolar mood because there are so many triggers that present for different people which can alter a mood beyond what technology can predict. These things (stressful job, fight with a loved one, loss, acute stress, financial stress, lack of sleep, social events, etc.) can all make a stable mood become less stable over time.”

When looking at the desire for mood prediction technology the results were mixed. The majority of the participants had a strong desire for the predictions. One of the participants in particular felt strongly that if the predictions were accurate it could have a huge impact on the bipolar community. P13 wrote “I think there’s a lot of potential for mood prediction technology. It just needs more data to work with. I’d love to see the technology developed and perfected because it could be a game changer for people who have been diagnosed with bipolar disorder.” The question was answered on a scale of 1 - 5 with 1 being

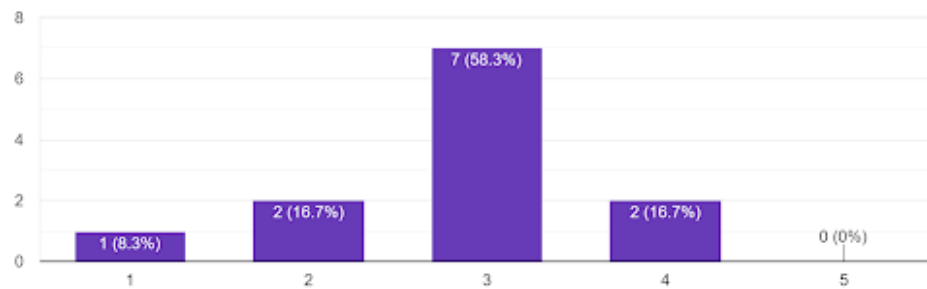
How much did viewing the mood predictions impact you in the following categories?



**Figure 16.** Mood Effects

How much do you trust mood prediction technology overall (outside of Bipolar Buddy)?

12 responses



**Figure 17.** Mood Prediction Trust

really dislike seeing no mood predictions, indicating a strong desire for predictions, and 5 being really like seeing no mood predictions. The average score was 2.625 showing that overall the predictions were preferred but without a strong desire for them.

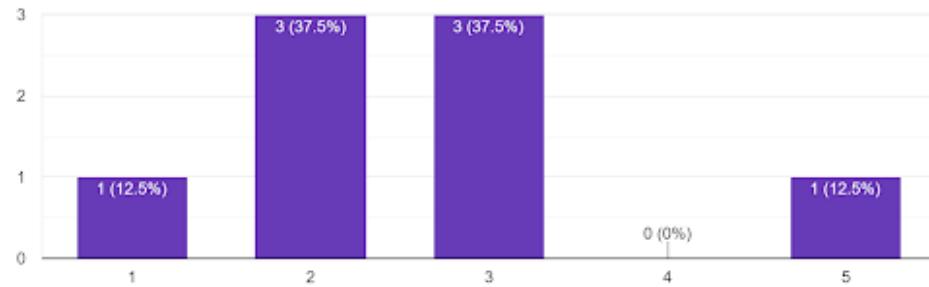
Aside from the mood predictions, the final section of the survey focused on overall app feedback. One noteworthy question asked if the users felt that tracking their mood was helpful (Figure 19). Out of the eight respondents, they all gave a positive or neutral answer proving that they recognize the importance of mood tracking and support the efforts to create something that makes this task easier for them to benefit from. On the 1 - 5 scale with 1 being not helpful at all and 5 being very helpful the average score was 4.125.

In summary, the survey responses show a general interest towards mood prediction technology, but not a huge need or a full trust in it quite yet. According to user perception there is little to no mood prediction impact on one's mood, motivation, anxiety, or sleep. Beyond the mood prediction technology, general mood tracking was agreed to hold some importance to all participants responding to the survey.

### 6.3 Post-study interviews

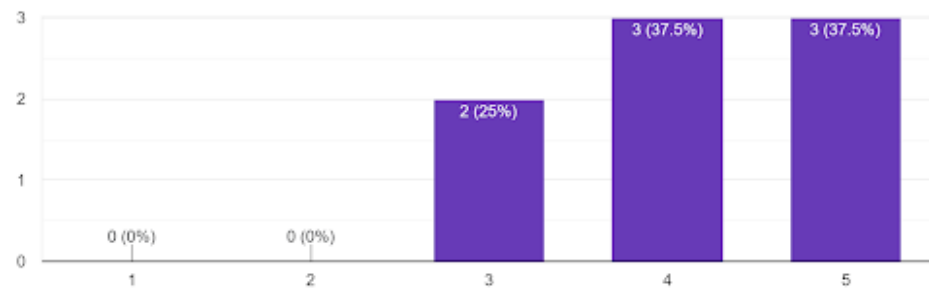
The primary motive for the post-study interviews was to collect qualitative data from the participants in order to better understand their view towards mood predictions and the possible impact they may have had on the lives of users, specifically their mood, motivation, anxiety, and sleep. The interview was broken into three parts. In the first part the participants were asked questions about their overall experience during the

How do you feel about seeing no mood predictions at all?  
8 responses



**Figure 18.** Desire for Mood Predictions

When managing your bipolar symptoms, how helpful is it when you track your moods?  
8 responses



**Figure 19.** Importance of Mood Tracking

study. This covered any external events that may have impacted their participation as well as background on how they interacted with Bipolar Buddy and how it compared to other apps they were familiar with. The second section covered the topic of mood predictions, asking the participant about their general view towards mood predictions as well as their perception on the effects the predictions had on them. Although these questions were asked in the survey, there were a few times that the verbal explanation did not exactly align with the survey score, making it important to collect it in both forms. This section also asked about the preferred mood prediction presentation and the users trust in the predictions. The final section was dedicated to overall app impressions to collect feedback on Bipolar Buddy to improve its usability. The last section will not be discussed in this paper as it is not relevant to the mood prediction topic that was studied here.

### 6.3.1 Study experience

For some background, several of the participants named events going on in their lives during the study period that were out of the ordinary. For example, some had changes in their medication. P15 introduced lithium for the first time and P3 mentioned they had some prescription issues and went off of antidepressants for a week during the study period. Some discussed acute, temporary events such as P20 going on vacation for one week, P1 saying they had to put down their family dog, or P23 being fired from their job, while P5 experienced ongoing work stress explaining that the previous week was particularly stressful and P9 continued their recovery from two surgeries and a COVID-19 diagnosis. There were two participants that ended up in the hospital during the study period. Unfortunately, P12 had a stroke and P7

had a concussion from a horse riding accident. These events caused them to be unavailable for the final interviews.

The participants took various approaches to integrating Bipolar Buddy into their daily routine. Several of them tried to use it in the morning each day, but oftentimes switched to the afternoons as they felt their mood score could not be given until later in the day when they really knew how they felt. Some attached it to an event in the day such as P2 saying they knew when they ate breakfast was the trigger to enter their data. Others used the notification feature of other apps to remind them that they had to enter their data in Bipolar Buddy as well. A few of them did all of their entries at night before bed, sometimes making it difficult to remember the time they went to sleep the previous day.

Some users had experience with other applications where they logged data regularly. P1 and P5 used eMoods for a while, P20 uses Bearable, P15 uses Daylio, and P3 uses WayOfLife habit tracker. All of the participants using other applications said they preferred the user interface of Bipolar Buddy and felt it was generally easier to use and more tailored towards them for bipolar. The main feature that existed in their other apps that they wished Bipolar Buddy had was the notifications to remind them to log their data. Those using eMoods claimed the mood scale with descriptions in Bipolar Buddy was much less prone to error allowing them to enter a more objective score rather than entering their own skewed view of their mood. For example, P20 said “Some days I ask myself, is this a 3, 2, 4... but the scale descriptors are helpful so I can choose a number.”

### **6.3.2 Trust in mood predictions**

Overall, the participants were all fairly optimistic about mood prediction technology. It is possible that this is a biased group since they all volunteered for the study knowing the topic was regarding mood predictions. Many stated they had little experience with such technology which meant their initial impression and opinion was likely formulated solely off of their introduction to Bipolar Buddy and this study.

As seen in the survey responses in Figure 17 most of the participants had a fairly neutral trust already, but P6 scored their trust at one for “no trust at all,” describing Bipolar Buddy as more of a record keeping tool for them and not so useful for mood predictions. While there was some optimism that the technology was surely useful, some participants significantly doubted its ability to be accurate. P1 said “How would it know [my mood] if I don’t even know [my mood]?” They believed that having some stability or regular cycles would be necessary for more accurate predictions. This stability could come from time with the diagnosis and an effective medication dosage. However, even with stable entries P5 experienced manic predictions, which did not make sense to them and caused them to lose trust in the accuracy. On the other hand P13 believed that the prediction model could learn their patterns and cycles and eventually make more accurate predictions similar to period predicting applications.

In order to gain trust the participants expressed various factors. Many claimed that it may take several months to a year to train a model to accurately predict. Since the model takes into account all data from all users, P1 found this interesting noting that within their bipolar communities on Facebook it is common to have similar experiences and the same types of cycles depending on their phase or bipolar type. Others felt their trust in the prediction model could be gained with data and evidence. “If someone does a study with 100 people and on average 80% of people found it accurate, then I’d trust it more” (P5). This was the case for Constantinides et. al. reaching 89% accuracy on average [(11)], however that study required sensing data which is not implemented in Bipolar Buddy.

### **6.3.3 Effects of viewing mood predictions**

For the most part, the users expressed no noticeable impacts from viewing the mood predictions. P1 believes that if the predictions were lower than it might have impacted their mood, however they were not given any unusually low predictions during the time of the study. P6 noted that most of the predictions were high, and said “going upwards doesn’t worry me because I have good coping strategies.” Several of the participants were somewhat detached from the predictions. P3 saying “I didn’t really take the predictions personally. I liked to see it said that I’m predicted to be stable, but I knew it wasn’t necessarily the case.” On the other hand P5 felt the predictions were too far from stable and couldn’t possibly represent their future. As many lost trust in the predictions it is logical that the predictions would not have an effect on them since they did not take them seriously. Two of the participants claimed that logging their mood, however, helped them to identify issues and trends, aside from the predictions. P6 discovered conflict with a coworker impacting their mood and P9 realized a Ritalin effect on them and could adjust their

prescriptions in response, both crediting Bipolar Buddy for helping them come to these conclusions.

P1 had one day where they logged an 8 and knew it was not good, noting it was on the ramp toward mania. That night they made sure to get enough sleep and tried not to be over-stimulated. This action was motivated by reading the description of the 8 mood score, describing symptoms of mania, but not directly from viewing the mood predictions. P2 said the only action they took in response to viewing the mood predictions was to fill in past data from the previous week in hopes that the mood prediction could be more accurate. Overall there were three participants that claimed to adjust their actions based on the predicted scores. P20 was on vacation during the study period and when they were given a prediction of 8 - 9 they started making an effort to take an afternoon nap, get to bed on time, and stay healthier than they might have otherwise. This was a very positive experience with the mood predictions.

#### **6.3.4 Preferred mood prediction display**

The majority of the participants were indifferent to the displays. They mostly saw value in each version for different applications. P1 said that the graph (subtle prediction display) is useful to show to a medical provider, but that it may not be clear to interpret for some people. P3 and P15 preferred the prominent display of the prediction summary because they believed predicting day by day is not realistic but an average has a better chance of showing the trend. The average view, however, was not always clear to users. P13 thought the number in the box represented the mood prediction for the following day, and not the average of the upcoming week. If this display is used it will be important to properly define it so users can understand the meaning of the number better.

## **7 DISCUSSION**

The purpose of this study was to discover how mood prediction technology can impact those with bipolar disorder as well as their trust level for predictions and their preferred display. According to the results, there was an overall optimism toward the technology, but full trust has not been achieved and could take a long time to achieve. In addition, the prominent and subtle mood prediction displays were both liked and said to serve different purposes. In this section, the meaning of these findings are discussed. The most obvious use of the results is in the development of future applications for people with bipolar.

The importance of mood tracking to aid in bipolar stability was already studied many times, but this research further supported the fact that mood tracking provides people the opportunity to reflect on their past mood data and identify trends. It was said several times by the participants in this study that it helped them to see their mood graphs as well as their sleep graphs to notice any red flags or signs they are going to relapse. These findings should be considered in the future design and development of apps targeting bipolar. Some apps exist specifically for mood tracking, but perhaps it would help the mental health community for them to have the word “bipolar” mentioned in their description or title in order to help those with bipolar find the app and get the benefits of mood tracking.

A frequently mentioned piece of feedback was that the Bipolar Buddy app was easier to use than other existing mood tracking apps. The reasons given were that it was tailored to bipolar, helping them to enter objective mood scores, it offered many different categories of things to track which met the majority of the topics that would influence mood, and the user interface was clean, making entering data easy and quick. Given this information, other mood tracking applications should reconsider their user interface and work to optimize the time it takes to make an entry and the simplicity of their design. This is especially important for those who are in a depressed state because it takes them more effort to do things than those who are stable or manic. This means the effort required to enter their mood or other essential data should be minimized. It could be the case that a given app may not be targeting bipolar people, but it is likely that the mood tracking is meant for those with some kind of mood instability or mood disorder where having a clean interface and clear data interpretation would benefit all users.

Mood prediction technology is still being researched and developed and is not yet widely used. The results of this study show that people with bipolar are optimistic about the possibility of mood predictions and claim that it would benefit them to be warned of upcoming extremes. This should motivate the further development of mood prediction models using artificial intelligence to improve its accuracy, making it more useful for those with mood swings. The study also shows that there is very little risk of the mood predictions having a negative impact on users. Although this small scale study is not sufficient to prove that users are not at risk for harm from viewing mood predictions, it is a small-scale introduction to the safety of mood predictions. This can, however, change once mood predictions improve their accuracy.

Many of the participants in this study expressed no effects from the mood predictions, but also often did not take them seriously as they seemed to be inaccurate. A few said that if the predictions were more reliable and they were shown a low mood prediction, it may impact them more than in this study. So, it is recommended to continue mood prediction development in line with a greater scale study to verify the safety of such a technology.

As mood predictions become more reliable this will need to be conveyed to users somehow. According to the interviews and survey data, most people base their trust on their own experience. While there is a group of people who may be willing to blindly trust the technology, others base their trust on factual data and numbers. Hence, for mood prediction technology to be trusted to a widespread audience it will be important to perform a study with a large group of people to provide an accuracy score that can be trusted by users. Even with such data, some users require a positive experience of their own before they would trust the predictions. This suggests that whatever app is using mood prediction technology, it should properly set the expectations to users of when their predictions are expected to be accurate, perhaps after several weeks of mood entries. It could also be an option to not show mood predictions until a minimum number of entries are made, in order to avoid losing trust from the user due to false predictions. Allowing users to test their predictions for themselves on their own individual version of bipolar is essential to the user's trust in mood predictions.

This study contained two different mood prediction displays and gathered feedback from the users on their preferred presentation. Overall, both of the displays had some value. Some participants preferred the graph of their upcoming moods since it gave a better indication of their upcoming week on a daily scale. Others did not believe daily predictions were feasible and preferred to see an overall average for the upcoming week. Ultimately, as mood predictions become more common, these results suggest that they are presented both in a graph manner to see daily values as well as giving a weak summary in the form of an average value. Both an overview and a detailed view are preferred by users.

## **7.1 Limitations and risks**

The obvious limitation of this study is the low number of participants. In order to be scientifically significant there should have been 30 participants. However, we were only able to recruit 25 at first and only had interview responses and commitment initially with 18 and eventually with just 10. The low user numbers is one factor, but the short timeline also is a limitation in this study. Expecting mood predictions to be trained for an individual with only one week of mood data is not reliable and quite rushed. With more time the predictions may have produced more accurate results upon first presentation, eliciting a higher level of trust from the users. Instead, some participants using Bipolar Buddy noticed the predictions were far from their general mood scores, and concluded that they must not be right. In general, improvements to the accuracy of these mood predictions could result in a different conclusion than what was found in my study. Participants may have more trust for the predictions and with more trust they may be more impacted by the prediction in terms of their mood, motivation, and anxiety levels. However, given the lower trust levels, there was little to no impact.

Another limitation in this study were the few technical difficulties experienced by the users. One major drawback was that there was not a functional notification feature implemented in Bipolar Buddy. Due to the lack of reminders several participants forgot to log their information each day. If all of the participants had made an entry each day and viewed the predictions in the various display forms for two weeks in a row, this would have led to a more reliable result on the perceived and quantifiable impact of mood predictions on mood, motivation, anxiety, and sleep. Along with the lack of notification reminders, the app still had a few bugs that were not caught during the testing phase before release to users. These bugs included the inability to log sleep or medication (or any factor) prior to making a mood entry. This led to participants submitting a sleep form, unaware that it did not save the data they just entered. While some noticed this in the graph on the results page and continued making the entry until it appeared on the graph confirming its submission, others left the app and their data was never stored for that date. On days like this or days when users forgot to log their data on previous dates, they attempted to backtrack and enter data for those dates in the past. Bipolar Buddy does have this feature, however the user flow was not always clear leading to a lot of frustration for users. At times their graphs would show that changes in their past data led to changes in their existing data. The bug was resolved after one week of the study, but not all users trusted that it would work again and abstained from making further past data entries. If this was more reliable before the study the data may have been more complete for the full three weeks of

entries.

Finally, due to a new version of the app being released with small changes, the prediction model experienced an error and stopped producing predictions for about four days. The development team targeted this immediately, locating the issue as a variable type issue and reverting it back to its original form to enable mood predictions again. This is a limitation because it impacted the prediction view and caused the main focus of the study to be altered unexpectedly for a few days. There is a risk that a participant may have only logged their data on the days that no prediction was being made or displayed, causing them to never see a mood prediction.

The app, Bipolar Buddy, was not specifically designed around this study. Therefore, the study was somewhat designed using the existing app features rather than prioritizing the study needs. This could be a limitation in that some phrasing of questions or factors in the app may have been prioritized differently had the study taken precedent. The slider of 0 - 10 is a likert scale, however the mood scale used is not as vetted as some other internationally used scales such as the Behaviorally Enhancing Adolescents' Mood (BEAM) chart. The app improvements and features are prioritized by the business with some input from me for the study.

There is also a risk for novelty effects impacting the participants' perceptions of the mood predictions. In order to mitigate this the study group was split into two so that some of them were first introduced to the mood predictions in the subtle graph view and the prominent summary view, and some began with only the subtle graph view. After one week with their assigned displays the groups were switched so that they all had the opportunity to see both prediction displays in order to compare them.

## 8 CONCLUSION

This study gave insight into the perception of mood predictions on those with bipolar disorder. It was found that there is a high interest in tracking mood patterns for those with bipolar, and there are currently no applications available that sufficiently address this need in a simple, easy to understand manner. In addition, most mood tracking applications are not specific to bipolar disorder and lead to more subjective mood scores and insufficient interventions. Mood prediction technology is quite new and unfamiliar in the bipolar community. While the technology is still developing and improving, those with bipolar are generally optimistic for its success. However, given the mood prediction performance from Bipolar Buddy, those with bipolar may not yet be ready to fully trust the predictions they are given as they are not accurate enough to know them as an individual. However, the overall perception is that mood predictions would not have any strong impact on one's mood, motivation, anxiety or sleep. Although before the study there was anticipation that extreme mood predictions may lead to increased anxiety, which would lead to a recommendation to not release predictions until design improvements and more thorough studies had been performed, it was found that nobody experienced increased anxiety with any of their predictions. If anything, there was a slight increase in motivation, meaning that some users found the prediction as inspiration to get back into their routine and prevent an episode. This means that, in theory, if these findings hold for an even larger study group size, then mood predictions could be released to the market without putting users with mood disorders at additional risk. The findings also show that the trust level of mood predictions is not very high yet, so it is important for research and technology developers to continue iterating on mood prediction models to improve the accuracy and provide a more useful tool for those with bipolar. Mood prediction technology can have a positive impact on those with bipolar by giving them warning for upcoming extremes and allowing them to work to stay in remission and maintain a balanced and stable mood throughout their lives.

### 8.1 Future work

While this study provided some insight on the perceptions of mood prediction impacts, a larger scale study would need to be done in order to make a legitimate claim of mood prediction impacts. In addition to more participants, it would be better to have a longer study period to allow for better prediction model training and more accurate results. In addition to repeating this study for more significant results, there should be further research into the overall accuracy of mood predictions, specifically with the Bipolar Buddy app as well as any other prediction model out there. Improving mood prediction technology and its ability to foresee and warn users about upcoming extremes is expected to not only benefit those with bipolar, but it is likely to benefit the entire mental health community.



Beyond the mood prediction research, more research can be done on mobile applications for those with bipolar. Bipolar Buddy was designed based on input from psychiatrists, those with bipolar disorder, and users. It would be better to have a study to take advantage of the data input into these tracker apps to determine which factors impact bipolar the most (i.e. sleep, food), and what indicators distinguish users from each other.

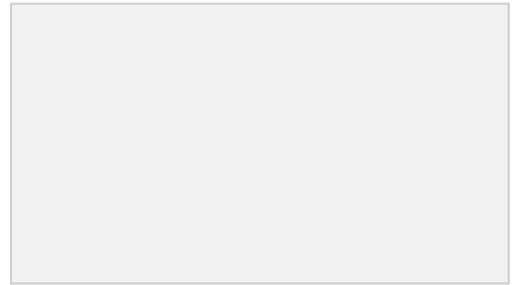
## **9 ACKNOWLEDGMENTS**

I would like to thank Elaine Huang for supporting me through the research project and guiding me on best practices. I would also like to thank Anish Suri and his development team for allowing me to use Bipolar Buddy for this project and working with me regularly to customize the experience, tailoring it for my study. Thank you to all of the participants that took the time to use the application as well as meet with me for interviews. Their willingness to be vulnerable with me, as a stranger, was refreshing and gave me so much insight into their experiences. Thank you to the leaders of the podcasts and Facebook communities that helped me to recruit participants and brainstorm areas in the bipolar space that could use some research. Finally, thank you to my neighbor who came to me and my family in a time of need and shared their process of healing which ultimately inspired me to contribute to research in the mental health space to save some lives and improve others.

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## Consent Form “Bipolar Mood Prediction Study”

### Principal Investigator

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### Supervisors

Prof. Dr. Elaine Huang, Department of Informatics, University of Zurich ([huang@ifi.uzh.ch](mailto:huang@ifi.uzh.ch))

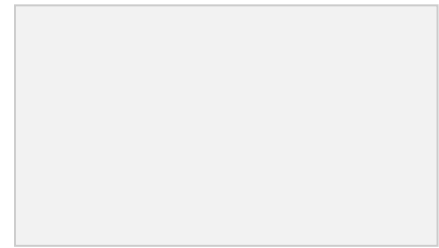
### Purpose

Previous research in the space of mental health technology is rapidly increasing in recent years. However, there is a gap between what is discovered in research about mental health applications and what is used in industry for commercial products such as mood tracking apps. One major challenge for people with bipolar is the unpredictability of their mood swings. This makes it difficult to plan in advance or set realistic expectations for themselves or their peers. The nature of the disorder also causes people to slip into manic or depressive episodes without even knowing it is happening. Mood prediction may be helpful to people with bipolar disorder since they can prepare for upcoming extremes. There are some mood predicting algorithms that have been developed, however there has been no research done around how this prediction should be shown to a user in order to benefit them without eliciting a negative response. I will be using BipolarBuddy as my tracking app which asks for mood ratings, anxiety and motivation levels, sleep information, and offers much more.

### Study Procedure

Overall, the study spans across three weeks and consists of the following five steps:

1. A **15-30 minute introduction** in which I will explain the study procedure, explain the tracking app BipolarBuddy ensuring you can get it installed properly on your phone, and answer any questions you might have. In addition I may ask a few basic questions about how you manage your bipolar currently.
2. In **week 1** you are asked to **use BipolarBuddy** everyday at least once a day for the week without viewing any predictions. This is intended to collect data to train the prediction algorithm to know specifics about the individual and better make mood predictions. All collected data such as mood and sleep entries will be stored on a secure SQL server. The study will use data including (time an entry was made, userID, mood level, anxiety level, motivation level, time you went to sleep, time you woke up, quality of sleep rating, nap duration, additional notes submitted by you).
3. In **week 2** you are asked to **continue using BipolarBuddy** everyday, except now you will have the ability to see mood predictions for the upcoming week. Depending on which study group you are put in, you may see the predictions prominently on your screen after every mood entry, or you may have the choice to view it through a subtle display location.
4. In **week 3** you are asked to **continue using BipolarBuddy** as before, but your group will switch to the other prediction display. The switch is achieved by sending you an updated application build and having you promptly install it (or it will auto update if you are using TestFlight)
5. To wrap-up the study, **I will interview you** in a semi-structured interview which requires no longer than **30 minutes**. The interview is intended to get your feedback on using BipolarBuddy and more specifically to describe how the mood predictions affected you. The interview will be audio-recorded after you give your consent.



### Benefits and Risks

By participating in this study, you will have the chance to learn more about your mood and sleep trends by tracking them everyday. You will also have a quick and easy way to enter them which can be useful for future communicating this data to others such as a health professional. Finally, you can potentially benefit from the mood predictions helping to set your expectations for a potential upcoming mood experience. In the long term, this research may contribute to other bipolar apps in order to optimize the prediction presentation in the most beneficial manner.

The main risk is the loss of time required to participate in the study. I estimate the total amount of time required to participate in the study to be ~1 hour during the course of the 3 weeks (2 minutes per day). I am mitigating this risk by providing constant support in case of difficulty with app usage as well as allowing you to determine a suitable time for the study and interviews. Another risk is that the mood predictions or usage of the app in general may have a negative impact on your mood, perhaps if you are frustrated with something. If this occurs, or in any case, you are free to withdraw from participation at any point during the study, without the need to provide a reason. In the event that your mental stability is impaired beyond reasonable measure, the study leader may remove you from the study and cease further requests until stability is reached again.

### Personal Information

During the project, we will collect personal information about you such as your name, email, gender, age, and job role. Your name as well as other identifying information will strictly be kept separate at all times and will be stored in a different location from any other information you give. In addition, some of the data stored within BipolarBuddy may contain personal information. All of the data stored on the app's server is as follows: time an entry was made, userID, mood level, anxiety level, motivation level, time you went to sleep, time you woke up, quality of sleep rating, nap duration, additional notes submitted by you. I will only use your anonymized data and no identifying information will ever be shared outside of the research group and the confines of this study without your explicit permission. All data collected will be saved in password-protected storages. The identifiable data will only be stored outside of BipolarBuddy for my study for 1 year before either being de-identified or deleted. However, the app data will remain on the servers unless you request otherwise.

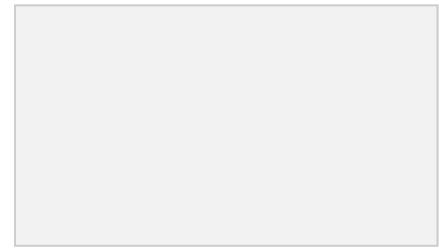
### Data, Storage & Confidentiality

The **application entry data** that BipolarBuddy captures is saved in a SQL database owned by BipolarBuddy. When I extract the data for my study it will be stored in a secure, password protected space and used only by me or my team for the duration of the study. The **final interview** audio recording will be either manually transcribed by the investigators or auto-transcribed by Zoom (as long as you give consent below to do so). After the transcriptions, the audio recording will be deleted.

When your data is transferred to my password-protected device, your data will be associated with a pseudonym and any internal or academic research publication or presentation you will be referred to as such. At no point in time will your peers have access to the captured data. Your obfuscated data will be used and seen only by researchers directly involved with this project. The anonymized, non-identifiable data will be stored for five years, after which it will be permanently deleted.

### Uses of the Study Data

The results of this study will potentially appear in both internal and external academic research presentations and publications, such as academic journals and conference proceedings.



#### Contact for Information about the Study

If you have any questions or desire further information with respect to the study, you may contact Taylor McCants ([taylor.mccants@uzh.ch](mailto:taylor.mccants@uzh.ch)) or Prof. Elaine Huang ([huang@ifi.uzh.ch](mailto:huang@ifi.uzh.ch)).

#### Consent for extended Data Uses

With your explicit consent, you can allow the researchers to transcribe the audio recording of the interview using a professional transcription service:

- ☐ I allow the use of Zoom transcription service to transcribe my interview.

With your explicit consent, you can allow further people access to the data for educational purposes or the application of further scientific methods. Please sign with your initials next to the usage options you agree with:

- ☐ I allow the use of my anonymized data for educational purposes within the scope of classes/lectures offered at the University of Zurich.
- ☐ I allow the use of my anonymized data by external researchers to apply scientific methods.

With your explicit consent you can allow for longer storage of data. Please sign with your initials if you agree:

- ☐ I allow the storage of my anonymized data for longer than 5 years.

#### Consent for Study Participation

Your participation in this study is entirely voluntary. You are free to withdraw your participation at any point during the study, without needing to provide any reason. Any information you contribute up to your withdrawal will be retained and used in this study, unless you request otherwise.

With your signature on this form you confirm the following statements:

- ☐ An investigator explained the study and the listed conditions to me. I had the opportunity to ask questions. I understand the answers and accept them.
- ☐ I am at least 18 years old.
- ☐ I have enough time to make the decision to participate and I agree to the participation.

In no way does this waive your legal rights or release the investigators or involved institutions from their legal or professional responsibilities.

---

Participant's name

---

Location, Date

---

Participant's signature

# Pre Study Interview Notes

Name / Alias: <<NAME>>

Date / Time: <<DATE>>

## Consent Form -

If the users have not already agreed to a consent form of some kind for their answers to be used as data in a study, even if just used within the BipolarBuddy team, this should be made clear and signed off on. This should include any usage data we collect from the users as well as their answers to questions in the interview.

- If possible, it is generally useful to record interviews to be referenced or “coded” afterwards to ensure nothing is missed when taking notes.
- 1. **Before we get started I would like to go through the consent form with you and get your signature to agree to your data being used for the improvement of our application as well as the research study of bipolar app usage.**

- <<Notes taken here>>

## Introductions -

It is important, especially in these cases, to be comfortable with one another before sharing ideas. Introduce the interviewers first.

- 2. **I'll kick it off with an ice breaker question. What is something funny that you did to cope with the COVID pandemic? I'll start, my family decided to do Family Zoom Calls once every couple of weeks.....etc. We always seemed to run out of time while grandma was talking!**

- <<Notes taken here>>

- 3. **I'd like you to tell me a bit about yourself to start, such as where you are from, how old you are, and what it was like getting your diagnosis.**

- <<Notes taken here>>

## Managing Bipolar -

Our priority should be on getting to know what solutions the user currently uses and what the downfalls are in those solutions. That way we can ensure our app addresses the need in the market.

- 4. **Can you tell me about what it's like for you living with Bipolar?**



- <<Notes taken here>>

5. What are some things you use to manage it? How are those strategies working for you? Have you used any apps in the past (including websites or online communities)?

- <<Notes taken here>>

6. What does your support system, if any, look like? (Are you in touch with a professional that provides you support?)

- <<Notes taken here>>

#### Mood Predictions -

One unique thing about our app is that we have an algorithm that can take in your data and predict your mood in advance.

7. Are there strategies you currently use to predict your mood? How well does this work for you? Or have you ever tried to guess what your mood will be?

- <<Notes taken here>>

#### Onboarding -

Go to [SIGN UP LINK](#) and create an account. Then copy the OID line and send it to me in the chat.

8. I am now going to have you do a quick admin task for me to ensure I have your user information to match up with your identity. This will remain anonymous to all except me. At this stage you will create the account that you will be using for BipolarBuddy. In order to do that I will send you a link in the Zoom chat now. Please click on that and select Phone or Email signup, then follow the steps including the verification code. At the end you will see a page with some code jargon at the top and at the bottom there will be a line that begins with OID. That is the value I need. Can you copy and paste that in the chat for me?

- <<Notes taken here>>

9. Since the target for the study begins next Monday, you can expect to see an email from me before that date containing instructions on how to install the app to your device. I will know you did so successfully when I see that you've made your first mood entry. If you run into any issues in this process please let me know.

**10. A: Since you are an ANDROID user, the app updates will be a bit more manual.**

**That being said, what is the best way for me to reach you to notify you when we have an updated release that may address a bug found in the app?**

**B: Since you are an IPHONE user, the TestFlight app will notify you when updates have been made to the app. You will just need to open TestFlight and click "UPDATE".**

- <<Notes taken here>>

#### Closing -

Offer an opportunity for the user to ask questions and gain clarification on anything they don't understand. Then thank the user for their time and give them a forecast of what they can expect next in their testing journey.

**11. Before we close, do you have any questions for us about the app or this process?**

- <<Notes taken here>>

**12. Thank you for your time and input today. I will reach out to you in about 3 weeks for a followup interview after you have some time with the app. Feel free to contact me if you come across anything else you forgot to mention in this interview or have any questions.**

- <<Notes taken here>>

# Post Study Interview Notes

Name / Alias: <<NAME>>

Date / Time: <<DATE>>

## Consent Form -

Remind those who have not yet submitted a signed form.

- <<Notes taken here>>

## Ice Breaker -

It is important, especially in these cases, to be comfortable with one another before sharing ideas. In the event that the participant already shared events going on in the last conversation, it would be most appropriate to follow up on how those events went (i.e. daughter's graduation, surgery, softball games, insurance situation, etc). As a backup, the below topic can be used.

1. **When was the last time you saw fireworks? And does your country have any holiday traditions that include fireworks (perhaps other than new years)**
2. **How was your summer so far? Any holiday trips?**

- <<Notes taken here>>

**Quick Note: I'm sure you may have feedback about the app itself, however if you could hold onto that feedback until I get through my mood prediction specific questions, that would best. After that I would be happy to document and report all feedback you have about the app.**

## General Study Experience -

To help explain any potential anomalies, it's important to understand if anything exceptional happened throughout the study as well as get some subjective data on their app experience.

3. **During this study period, did you face any significant events or unexpected challenges in life?**

- <<Notes taken here>>

4. **Can you describe to me how you integrated Bipolar Buddy into your day? Under what circumstances did you use it? How often did you use it? etc.**

- <<Notes taken here>>

5. **If you feel your usage patterns changed during the study, how did they change?**

- <<Notes taken here>>

6. Did you have any previous experience with using apps similar to this one? If so, what did you use and how does it compare? Both on feature offers and experiences using them. How did they each affect your day to day? Do you feel like you used it differently?

- <<Notes taken here>>

#### Mood Predictions -

One unique thing about our app is that we have an algorithm that can take in your data and predict your mood in advance.

7. What is your general view towards mood predictions overall?

- <<Notes taken here>>

8. How did using the app affect your view on mood predictions?

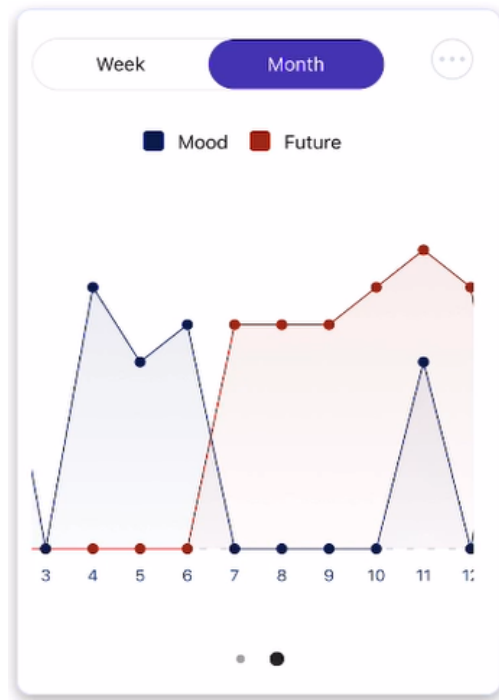
- <<Notes taken here>>

9. Which of the various mood prediction displays did you prefer?

6

You are predicted to feel on average  
**stable** this week.

A:



B:

- <<Notes taken here>>

10. Did you notice when the mood prediction display changed? What did you think about the change?

- <<Notes taken here>>

11. During the study as you were presented with mood predictions, did you sense any changes in your mood, sleep, motivation, or anxiety levels? Do you believe viewing the mood predictions could have an impact?

- <<Notes taken here>>

12. Did any mood predictions cause you to take action in response to the prediction that you wouldn't have otherwise taken?

- <<Notes taken here>>

13. How accurate do you think the mood predictions were for your mood? Did they reflect your actual moods?

- <<Notes taken here>>

14. How would you describe your level of trust for the mood predictions, and what factors contribute to that level of trust? How can the trust be improved?

- <<Notes taken here>>

**15. At any point in the study were you presented with a really low mood prediction, or a really high one? How did this make you feel?**

- <<Notes taken here>>

#### App Impressions -

Start off by asking the users for their overall impression when using the app. You can dive deeper into each factor they mention, but try to focus on functionality over design right now.

**16. Now I'd like to hear about your overall impression of Bipolar Buddy. What did you think overall?**

- <<Notes taken here>>

**17. What were your favorite parts of the app that served most useful to you? And what made it useful?**

- <<Notes taken here>>

**18. What were some of the challenges you faced while using the app?**

- <<Notes taken here>>

**19. If the app suggested recommendations based on your input scores, would that be useful to you?**

- <<Notes taken here>>

**20. What, if anything, would you add or change about the Bipolar Buddy?**

- <<Notes taken here>>

#### Closing -

Offer an opportunity for the user to ask questions and gain clarification on anything they don't understand. Then thank the user for their time and give them a forecast of what they can expect next in their testing journey.

**21. Before we close, do you have any questions or comments for us about the app or this process? Or is there anything else you wanted to tell me that we didn't get to in this interview?**

- **<<Notes taken here>>**

**22. Thank you for your time and input throughout the duration of this study. The data collected here will be used to write my thesis paper and hopefully shared amongst the various Bipolar community groups to educate the creators of future bipolar specific technology. If you have any further questions or concerns you are welcome to reach out to me.**

# Bipolar Mood Prediction Study - User Survey

Thank you again for participating in this study. This survey is meant to collect some quantitative data about your feelings towards mood predictions in the form of ratings. Please answer as best you can, and further explanation can be typed out or explained in our final interview.

If you have not yet scheduled your interview, please do so here: <https://bipolar-mood-prediction-study.youcanbook.me>

1. What is your name?

2. How comfortable are you with using technology and apps in general?

Mark only one oval.

[illegible]

3. What was your overall impression of using Bipolar Buddy?

Mark only one oval.

1 2 3 4 5

---

Terrible ☐ ☐ ☐ ☐ ☐ Fantastic



4. How much do you trust mood prediction technology overall (outside of Bipolar Buddy)?

*Mark only one oval.*

	1	2	3	4	5	
1 - Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	5 - A lot

5. How much do you trust the mood prediction technology used in Bipolar Buddy?

*Mark only one oval.*

	1	2	3	4	5	
1 - Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	5 - A lot

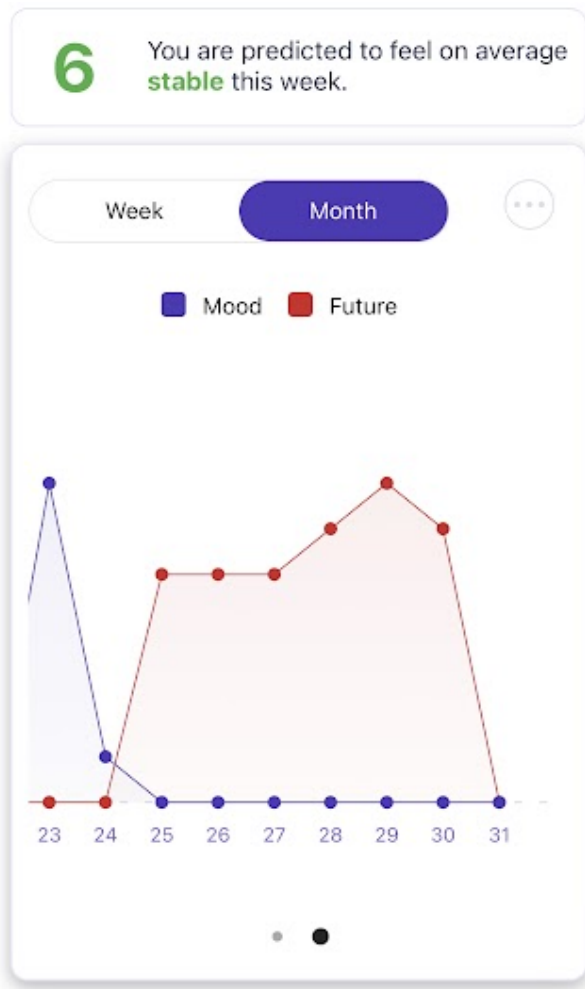
6. What are the main factors that contribute to your trust level in mood predictions?  
(either positive or negative)

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10. How do you feel about the combined view of overall summary score and graph visualization of upcoming week predictions?

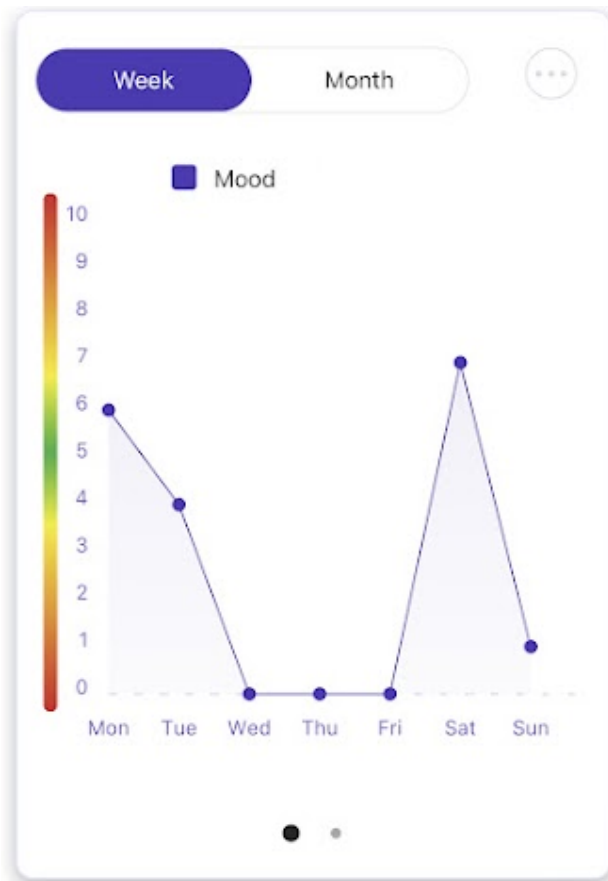


Mark only one oval.

1 2 3 4 5

Really dislike ☐ ☐ ☐ ☐ ☐ Really like

11. How do you feel about seeing no mood predictions at all?



Mark only one oval.

	1	2	3	4	5	
Really dislike	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Really like

12. How much did viewing the mood predictions impact you in the following categories?

Mark only one oval per row.

	1 - Not at all	2	3	4	5 - A lot
<b>Mood</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Sleep</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Motivation</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Anxiety</b>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. What kind of impact, if any, did the mood predictions have on you in the following categories?

Mark only one oval per row.

	1 - Very negative	2	3	4	5 - Very positive	N/A
Mood	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sleep	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Motivation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Anxiety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Time for more Feedback?

14. Do you have a few extra minutes to give feedback on the Bipolar Buddy overall?  
(Click Yes to continue the survey, or No to submit survey)

Mark only one oval.

- ☐ Yes      *Skip to question 15*
- ☐ No      *Skip to question 31*

## Bipolar Buddy Feedback

15. How useful do you think Bipolar Buddy is?

Mark only one oval.

1 2 3 4 5

---

Not useful ☐ ☐ ☐ ☐ ☐ Very useful







24. What are the techniques/tools/products you use to try to manage your symptoms?

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25. What are the biggest challenges you face when you try to manage symptoms yourself?

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26. How good would you say you are at tracking your own mood?

*Mark only one oval.*

☐ Not good at all

☐ Alright

☐ Very good

☐ Other: \_\_\_\_\_

27. When managing your bipolar symptoms, how helpful is it when you track your moods?

*Mark only one oval.*

1

2

3

4

5

Not helpful at all

☐☐☐☐☐

Very helpful

28. What are some obstacles that prevent you from tracking your mood?

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29. How much do you spend on wellness?

E.g - \$100 on a gym membership, \$350 on therapy, etc

---

30. How much would you be willing to spend to use Bipolar Buddy?

E.g - amount / year

---

Thank you for your feedback!

This is the end of the survey.

31. Do you have any additional comments about Bipolar Buddy or the study?

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Google Forms

## Participant IDs - Color mapping



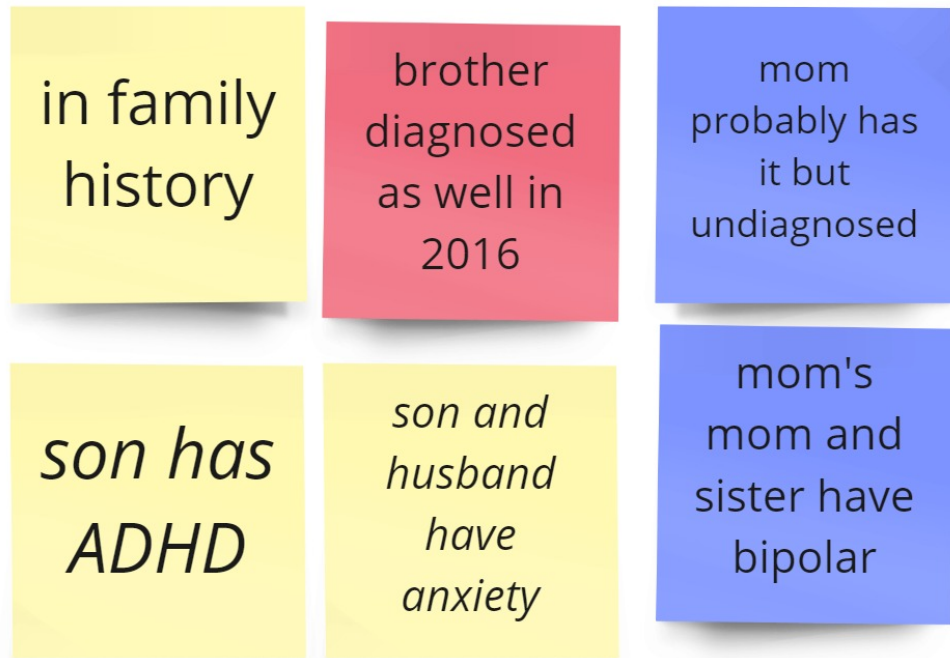
## Careers:



## Bipolar Diagnosis:

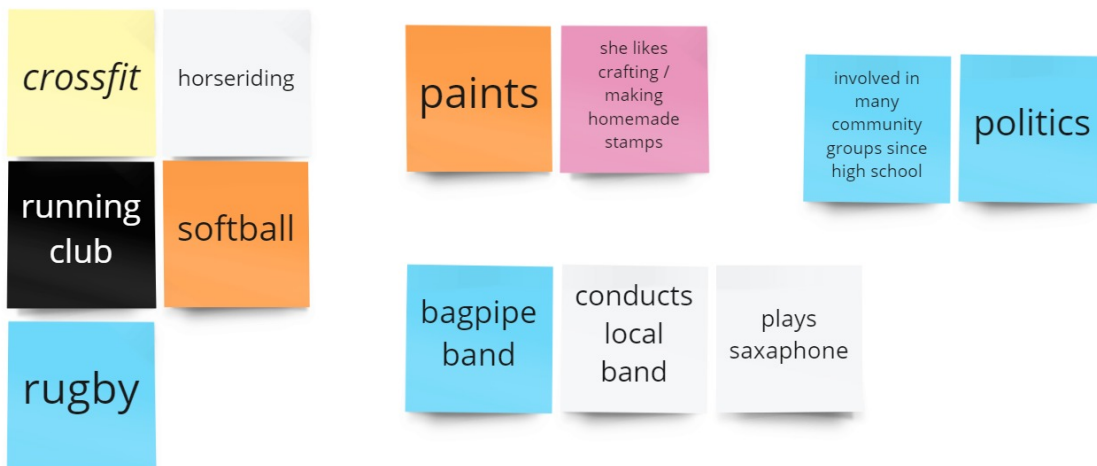


## Bipolar Genetics:



miro

## Hobbies:



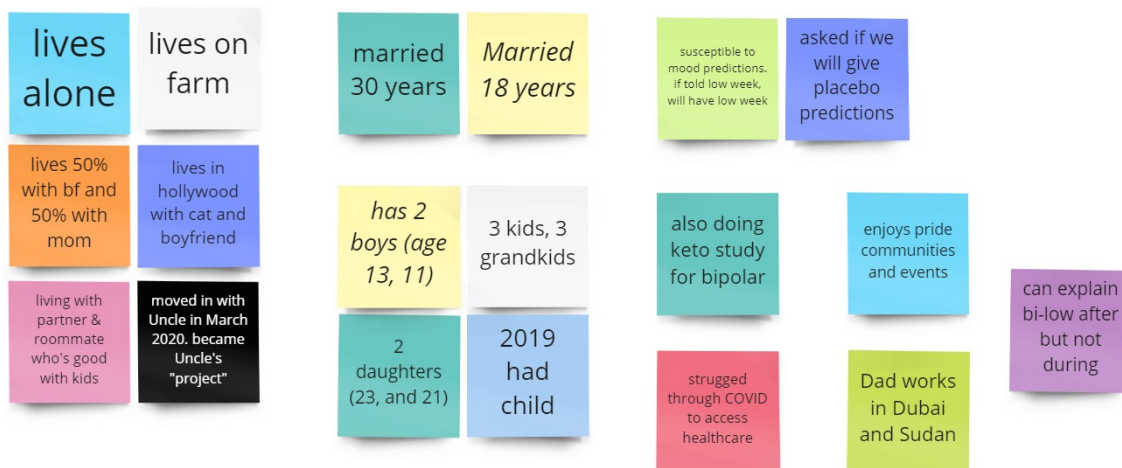
miro

## Nationality / Residency:



miro

## Living Situation / Miscellaneous:



miro

## Personality Traits:

empathetic

used to be  
perfect church  
girl, clean cut,  
perfectionist

really  
organized  
person

hypersexuality

distant  
peers say  
she never  
gets angry

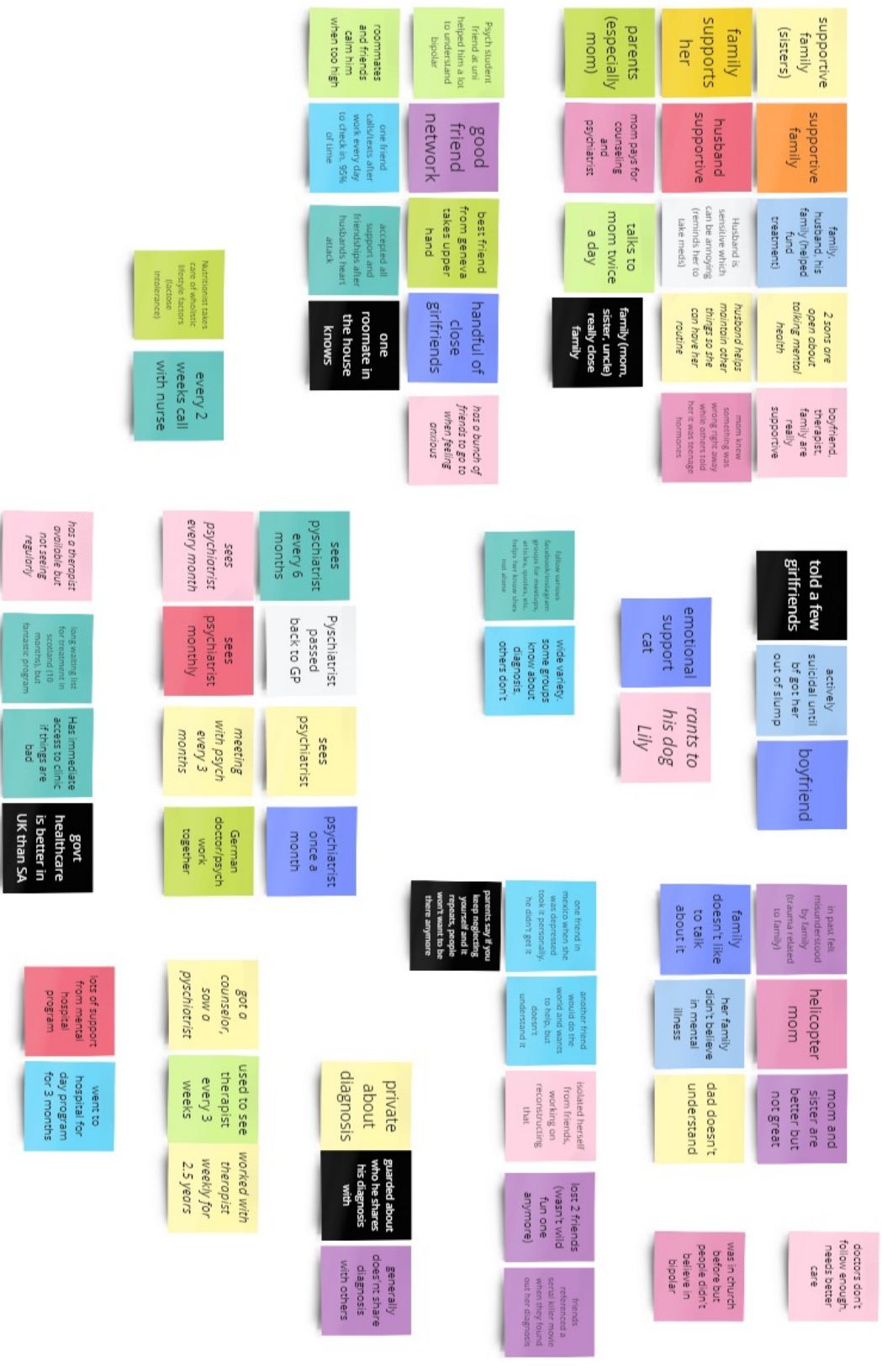


## Strategies for Predicting Moods:





Support System:



## Other Triggering Events:



miro

## Managing Bipolar: Bipolar Experience: Bad Coping Strategies:



Ages:

age 22	age 25	age 31	Age 40	Age 61
Age 23	age 26	age 32	age 48	
Age 24	age 28	age 35	Age 50	
age 24	Age 29	age 35	age 52	

## ▼ Imports and Setup

```
#imports and installations
!pip install pyodbc
from sqlalchemy import create_engine
import urllib
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
from matplotlib.dates import DateFormatter

!curl https://packages.microsoft.com/keys/microsoft.asc | apt-key add -
!curl https://packages.microsoft.com/config/ubuntu/16.04/prod.list > /etc/apt/sources.list
!sudo apt-get update
!sudo ACCEPT_EULA=Y apt-get -q -y install msodbcsql17
```

## ▼ Get Data

```
params = urllib.parse.quote_plus("DRIVER={ODBC Driver 17 for SQL Server};SERVER=tcp:XXXXXX
conn_str = 'mssql+pyodbc:///odbc_connect=' + params
engine_azure = create_engine(conn_str,echo=True)

qry = "SELECT * FROM [dbo].[UserTelemetry] WHERE DATEDIFF(day, UserTelemetry.CreatedTime,
all_data = pd.read_sql_query(qry, engine_azure)
print(len(all_data))

# Add PID column
participant_id_map = {'2625a359-1fc0-4f79-b403-3d51c01798bd'.upper(): 'P1', 'ec58ddc7-ed68
                        '38f95a02-5d81-4b93-b4e0-21bb7cb6973a'.upper(): 'P6', 'e64ab633-cfd5-47
                        '42ba4a0a-852e-42c5-874a-94b062bb0854'.upper(): 'P11', '3581bf5e-7328-4
                        '33cade7c-b890-4bbe-a571-840c9827d863'.upper(): 'P17', 'be657076-60c2-4
                        'e5a00d06-7500-4c34-a79f-768732e2273d'.upper(): 'P23', '83c55623-b19d-4
participant_ids = list(participant_id_map.keys())

all_data["PID"] = all_data["UserId"].map(participant_id_map)
all_data = all_data[all_data['PID'].notna()]
print(len(all_data))

grouped = all_data.groupby(by=['PID'], as_index=False).agg({'CreatedTime': 'count', 'MoodPr
grouped.sort_values(by=['CreatedTime'])
```

## ▼ Mood Entries

```

# get mood data
mood_qry = "SELECT UserTelemetry.UserId, UserTelemetry.CreatedTime, UserTelemetry.Modified
mood_data = pd.read_sql_query(mood_qry, engine_azure)
mood_data["PID"] = mood_data["UserId"].map(participant_id_map)

# convert to proper data types
mood_data = mood_data.astype({'Mood':'int', 'Motivation':'int', 'Anxiety':'int'})
mood_data['CreatedTime'] = mood_data['CreatedTime'].dt.strftime("%d-%m-%Y")
mood_data['ModifiedTime'] = mood_data['ModifiedTime'].dt.strftime("%d-%m-%Y")

# change size of plot
plt.rcParams["figure.figsize"] = (20,3)

mood_data

# create date range
dates = pd.date_range(start="2022-06-27",end="2022-07-25").to_list()

```

## ▼ Plot Participant Mood Data

```

def get_date_to_day_mapping(df: pd.DataFrame, date_col: str, date_format = '%d-%m-%Y') ->
    df = df.copy(deep=True)
    day_col = 'day'
    df[day_col] = pd.to_datetime(df[date_col], format=date_format)
    first_day = df[day_col].min()
    df[day_col] = (df[day_col] - first_day).dt.days + 1
    return dict(zip(df[date_col], df[day_col]))

plt.figure(figsize=(20, 18))
plt.subplots_adjust(hspace=0.5)
plt.suptitle("Participant Mood Data", fontsize=18, y=0.95)

for n, pid in enumerate(participant_ids):
    # add a new subplot iteratively
    ax = plt.subplot(5, 4, n + 1)

    # filter data on pid for the new subplot axis
    p_data = mood_data.loc[mood_data['UserId'] == pid]
    date_to_day_mapping = get_date_to_day_mapping(p_data, 'CreatedTime')

    ax.plot(p_data['CreatedTime'].map(date_to_day_mapping), p_data['Mood'], label='Mood')
    ax.plot(p_data['CreatedTime'].map(date_to_day_mapping), p_data['Motivation'], label='M
    ax.plot(p_data['CreatedTime'].map(date_to_day_mapping), p_data['Anxiety'], label='Anxi

    # chart formatting
    ax.set_title(participant_id_map[pid])
    ax.set_xlabel("Day")
    ax.set_ylabel("Score")
    ax.set_xlim([1, 21])

```

```

ax.set_ylim([0, 10])
ax.set_xticks(range(1, 22, 2))
ax.set_yticks(range(0, 11, 2))

plt.legend(loc='center left', bbox_to_anchor=(3, 0.5))

```

## ▼ Sleep Data

```

# get sleep data
sleep_qry = "SELECT UserTelemetry.UserId, UserTelemetry.CreatedTime, UserTelemetry.Modifie
sleep_data = pd.read_sql_query(sleep_qry, engine_azure)
sleep_data["PID"] = sleep_data["UserId"].map(participant_id_map)
# convert to proper data types
sleep_data = sleep_data.astype({'SleepStart':'datetime64', 'SleepEnd':'datetime64', 'SleepR
sleep_data['CreatedTime'] = sleep_data['CreatedTime'].dt.strftime("%x")

overnight_minutes = (sleep_data['SleepEnd'] - sleep_data['SleepStart']).dt.total_seconds()
overnight_minutes[overnight_minutes < 0] = (24*60) + overnight_minutes
total_sleep = overnight_minutes + sleep_data['Nap']
sleep_data["TotalSleepHours"] = total_sleep / 60
print(sleep_data)

plt.figure(figsize=(20, 18))
plt.subplots_adjust(hspace=0.5)
plt.suptitle("Participant Sleep Data", fontsize=18, y=0.95)

for n, pid in enumerate(participant_ids):
    # add a new subplot iteratively
    ax = plt.subplot(5, 4, n + 1)

    # filter data on pid for the new subplot axis
    p_data = sleep_data.loc[sleep_data['UserId'] == pid]
    date_to_day_mapping = get_date_to_day_mapping(p_data, 'CreatedTime', '%m/%d/%y')

    ax.bar(p_data['CreatedTime'].map(date_to_day_mapping), p_data['TotalSleepHours'], labe

    # chart formatting
    ax.set_title(participant_id_map[pid])
    ax.set_xlabel("Day")
    ax.set_ylabel("Total Sleep (hours)")
    ax.set_xlim([1, 21])
    ax.set_ylim([0, 25])
    ax.set_xticks(range(1, 22, 2))
    ax.set_yticks(range(0, 25, 4))

```

## ▼ Medication

```
# get meds data
meds_qry = "SELECT UserTelemetry.UserId, UserTelemetry.CreatedTime, UserTelemetry.Modified
meds_data = pd.read_sql_query(meds_qry, engine_azure)
meds_data["PID"] = meds_data["UserId"].map(participant_id_map)

# convert to proper data types
meds_data = meds_data.astype({'IsMedicationTaken':'bool', 'MedicationStatus':'int', 'MissMe
meds_data['CreatedTime'] = meds_data['CreatedTime'].dt.strftime("%X")

meds_data['Status'] = 'none'
meds_data.loc[meds_data['IsMedicationTaken'], 'Status'] = 'on-time'
meds_data.loc[meds_data['MedicationStatus'] == 1, 'Status'] = 'late'
meds_data.loc[meds_data['MedicationStatus'] == 2, 'Status'] = 'forgot'

meds_data['Count'] = 1
meds_data = meds_data.groupby(by=['UserId', 'PID', 'Status'], as_index=False).agg({'Count'

pid_sort_order = {f'P{i}': i for i in range(26)}
meds_data = meds_data.sort_values(by=['PID'], key=lambda x: x.map(pid_sort_order))

display(meds_data)

import plotly.express as px

plt.figure(figsize=(20, 25))
plt.subplots_adjust(hspace=0.5)
plt.suptitle("Participant Meds Data", fontsize=18, y=0.95)
colors = {'forgot': '#f15c3f', 'late': '#e5dd54', 'on-time': '#2ac28a'}

fig = px.bar(meds_data, x="PID", y="Count", color="Status",
             color_discrete_map=colors, text_auto=True, title="Medication Compliance")
fig.update_xaxes(categoryorder='array', categoryarray=meds_data['PID'].unique())
fig.update_layout(autosize=False, width=1500, height=750)
fig.show()

for n, pid in enumerate(participant_ids):
    # add a new subplot iteratively
    ax = plt.subplot(5, 4, n + 1)

    # filter data on pid for the new subplot axis
    p_data = meds_data.loc[meds_data['UserId'] == pid]
    date_nums = range(len(p_data))
    print(p_data)
    #ax.bar(p_data, x="CreatedTime", y="Count", color="Status")

    # chart formatting
    ax.set_title(participant_id_map[pid])
    # ax.set_xlabel("")
```

## ▼ Predictions

```
# get meds data
pred_qry = "SELECT * FROM [dbo].[Predictions] WHERE DATEDIFF(day, EntryDate, '2022/06/27')
pred_data = pd.read_sql_query(pred_qry, engine_azure)
pred_data["PID"] = pred_data["UserId"].map(participant_id_map)

# convert to proper data types
pred_data = pred_data.astype({'MoodPred':'int', 'MotivationPred':'int', 'AnxietyPred':'int'
pred_data['EntryDate'] = pred_data['EntryDate'].dt.strftime("%d-%m-%Y")

pred_data

plt.figure(figsize=(20, 18))
plt.subplots_adjust(hspace=0.5)
plt.suptitle("Participant Mood Prediction Data", fontsize=18, y=0.95)

for n, pid in enumerate(participant_ids):
    # add a new subplot iteratively
    ax = plt.subplot(5, 4, n + 1)

    # filter data on pid for the new subplot axis
    p_data = pred_data.loc[pred_data['UserId'] == pid]
    p_data2 = mood_data.loc[mood_data['UserId'] == pid]

    date_to_day_mapping = get_date_to_day_mapping(p_data, 'EntryDate')
    date_nums = range(len(p_data))
    ax.plot(p_data['EntryDate'].map(date_to_day_mapping), p_data['MoodPred'], label='Mood')
    ax.scatter(p_data2['CreatedTime'].map(date_to_day_mapping), p_data2['Mood'], label='Mo')

    # chart formatting
    ax.set_title(participant_id_map[pid])
    ax.set_xlabel("Day")
    ax.set_ylabel("Mood")
    ax.set_xlim([1, 21])
    ax.set_ylim([0, 10])
    ax.set_xticks(range(1, 22, 2))
    ax.set_yticks(range(0, 11, 2))

plt.legend(loc='center left', bbox_to_anchor=(3, 0.5))
```