Exploring Social Activity in Bipolar Disorder Using Automated Smartphone Tracking

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Declarations

Statement of Originality

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library\textsuperscript{1}, being made available for loan and photocopying subject to the provisions of the Copyright Act 1968.

Statement of Collaboration

I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers. I, Nicole Carter, contributed to the design of the research project and recruitment of participants, carried out and interpreted the statistical analyses, and wrote this body of work with editing assistance from my primary supervisor, Dr Tanya Hanstock. I also created the usernames, passwords, and user accounts for each technology platform, set up the IFTTT applets used to track call and SMS data, and monitored the social activity data for technical errors. Dr Tanya Hanstock oversaw all study procedures and along with fellow postgraduate students Madeleine Drew and Catherine King, contributed to research design and implementation. Additionally, they conducted participant assessments during the 6-month data collection period analysed in this thesis. Each students’ thesis is focused on a different aspect of the research project and each student completed separate data analyses for their respective studies. Each individual study contributes to an ongoing research program being undertaken by Dr Tanya Hanstock as part of her Doctor of Philosophy degree. A/Prof. Frances Kay-Lambkin (Chief Investigator and Secondary Supervisor) contributed to the study design and oversaw the progress of the research. Prof. Simon Dennis (Secondary Supervisor) assisted with methodology and

\textsuperscript{1} Unless an Embargo has been approved for a determined period.
technological implementation. Andrew Hide and Ben Stone (Technical Assistants) provided technology support. Megan Valentine and Paul Rippon (Statisticians) assisted with statistical analyses and data interpretation.

**Statement of Authorship**

I hereby certify that the work embodied in this thesis contains a scholarly work of which I am a joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint scholarly work.

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Reference Style Used in This Thesis

This thesis is formatted in accordance with the sixth edition of the *Publication Manual of the American Psychological Association*. The manuscript has been formatted for submission to the British Journal of Psychology, using American Psychological Association (APA) style references. Submission guidelines and checklist are contained in Appendix A.
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Structured Abstract

Scope

Bipolar Disorder (BD) is chronic, lifelong, and associated with high morbidity and mortality. It is characterised by recurrent mood episodes with suboptimal functioning in between, due to residual symptoms and subthreshold mood instability. Mood stability and relapse prevention is integral to effective management. Identification and tracking of early warning signs (EWS) of mood episodes is beneficial in stabilising BD patients. Interpersonal and Social Rhythm Therapy for BD is underpinned by ‘Social Zeitgeber’ theory, which asserts that environmental and social factors strongly influence the development and timing of mood episodes, via their ability to disrupt or entrain circadian rhythms. Though changes in a person’s level of social activity (SA) has been implicated as a potential EWS, it has proven to be a difficult construct to measure, particularly when relying on retrospective, subjective self-report inventories and daily journals. Smartphones enable continuous, automatic monitoring of objective, real-time data.

Purpose

The current study explored the SA levels of people with BD prior to elevated and depressed moods. We aimed to investigate the potential of smartphone technology to objectively track and detect changes in behaviour and symptoms in BD, facilitating early intervention for preventing, or reducing the severity of mood episodes.

Method

Levels of SA among 12 individuals with BD I (n=5) and II (n=7) were monitored over 6-months. Participant symptoms and activity were assessed at baseline, 1-week, 3- and 6-months, and they completed an online weekly mood survey. At each assessment clinicians rated symptoms on the Bipolar Depression Rating Scale (BDRS) and Young Mania Rating Scale (YMRS). Objective SA data was extracted from smartphone sensors (call and SMS, location, and audio). Linear mixed modelling with random intercept was used to validate self-rated mood against clinician rated mood and to explore the relationship between self-rated mood and each objective SA measure.
Results

There was a significant positive relationship between self-reported depressed mood and scores on the BDRS, and between self-reported elevated mood and scores on the YMRS. Self-reported depressed mood was positively correlated with the number of sent and received SMS, while elevated mood was positively correlated with the number of unique contacts and with mobility.

Conclusion

Consistent with previous literature, self-reported mood is a reliable measure of BD symptoms. Though some objective measures of SA in the current study appear to relate to mood, more work is needed before objective SA can be measured reliably. The current study was limited by a small sample size. Factors such as data quality, technical limitations, and study design also influenced results. Future studies may benefit from using individualised computer learning algorithms to detect and predict changes in mood directly, using a combination of sensor data streams and multiple features. In clinical practice, measures of SA should be tailored to the individual, and EWS with the most reliable tracking method should be prioritised to maximise the effectiveness of self-monitoring.

Keywords: Bipolar Disorder, Social Activity, Mood, Automated Monitoring, Mobile Application, Smartphone
Critical Literature Review

Bipolar Disorder (BD) is severe (De Hert et al., 2011), lifelong (Angst, Gamma, Sellaro, Lavori, & Zhang, 2003), and associated with considerable disability (Pini et al., 2005) and high mortality (Crump, Sundquist, Winkleby, & Sundquist, 2013; Kessing, Vradi, McIntyre, & Andersen, 2015). Relapse prevention is integral to effective long-term management of BD (Anderson, Haddad, & Scott, 2012). Psychotherapeutic approaches focussed on lifestyle factors are effective adjunctive treatments to medication (Scott, Colom, & Vieta, 2007). Social Activity (SA) has been implicated as an important lifestyle factor in BD (Frank, Swartz, & Boland, 2007), with changes in SA present in both mania and depression. Diagnostic criteria for mania and hypomania describe being more talkative than usual or pressured speech, and/or an increase in goal directed behaviour. This may manifest as excessive planning and participation in social or community activities. In mania, increased sociability is typical and can include increased calling or contacting friends, acquaintances, or even strangers (American Psychiatric Association [APA], 2013a). In depressive states, social withdrawal is often observed (APA, 2013b) and may involve physically withdrawing inside the home and travelling less. Meanwhile, the increased sociability, social disinhibition, and impulsivity of elevated mood states may lead to increased mobility (Grunerbl, Osmani, et al., 2014). Therefore, changes in social behaviour (and hence SA) may serve as an observable early warning sign (EWS) of mood disturbance in BD and be used to predict mood and prevent relapse. Paper-based tracking of mood and activity have recently been substituted by electronic monitoring and lifelogging – the continuous, automatic recording of objective behavioural data using an electronic device. This literature review will examine the theoretical and therapeutic basis for monitoring lifestyle factors and EWS in BD. Automated methods of tracking SA will be explored and the current literature on the relationship between tracking SA and mood will be described and critiqued.

Bipolar Disorder

Bipolar Disorder I and II affects approximately 1% of the adult population (Merikangas et al., 2011; Pini et al., 2005). People with BD experience recurrent
episodes of hypomania/mania and depression and many also experience chronic mood instability between episodes (Bonsall, Wallace-Hadrill, Geddes, Goodwin, & Holmes, 2012). The risk of recurrence remains high throughout life – twice that of unipolar depression (Angst et al., 2003). Research suggests a clinical progression, with increased number of episodes associated with greater severity (Kessing & Andersen, 2017). Onset in adolescence and early adulthood (Merikangas et al., 2011) can interfere with psycho-social-sexual development, education, and other age dependent developmental tasks with negative consequences for vocational attainment and family relationships (Post, Leverich, Xing, & Weiss, 2001). Multiple incorrect diagnoses are common and 35% wait 10 years or more for a correct diagnosis (Hirschfeld, Lewis, & Vornik, 2003). This increases the risk of comorbidity, particularly substance use (Berk et al., 2009). The majority have at least one other psychiatric disorder, most commonly anxiety (Merikangas et al., 2011). Mortality rates are 2-3 times higher than the general population, due to increased rates of suicide and comorbid medical illnesses (Kessing et al., 2015). Modifiable lifestyle factors, psychotropic medication side effects, and disparities in health care access and provision contribute significantly to the increased morbidity and mortality in BD (De Hert et al., 2011).

BD is likely a polygenetic disease with a complex mode of inheritance (Baum et al., 2008). Modest associations have been found between circadian genes and BD. Several lines of research also indicate that circadian rhythms are disrupted in BD episodes and stabilisation usually occurs with successful treatment (Mansour, Monk, & Nimgaonkar, 2005). Social Zeitgeber theory argues that the development and timing of individual mood episodes are strongly related to life events and social factors via their ability to disrupt circadian rhythms (Ehlers, Kupfer, Frank, & Monk, 1993). “Zeitgebers” are personal relationships, social demands, or activities that entrain biological rhythms. “Zeitstörers” are physical, chemical, or psychosocial life events that disrupt circadian rhythms, leading to mood episodes (Grandin, Alloy, & Abramson, 2006). Mood episodes themselves cause further disruption of circadian rhythms (F. K. Goodwin & Jamison, 1990, 2007). Often, these disruptive influences cannot be
eliminated, however it is possible to limit their impact through self-management of the lifestyle factors that act as zeitgebers, such as sleep and exercise routines, mealtimes, and social interaction.

Interpersonal and Social Rhythm Therapy (IPSRT) for BD asserts that promoting lifestyle regularity through behavioural and lifestyle choices can improve capacity to maintain stable biological rhythms and prevent relapse (Frank et al., 2007). There are lower reported levels of social rhythm regularity in people with BD and this prospectively predicts time to onset of mood episodes (Shen, Alloy, Abramson, & Sylvia, 2008). IPSRT uses the Social Rhythm Metric-II-Five Item Version (SRM II-5) to record daily mood, and chart the timing of daily activities (e.g., sleep/wake, work, meals) against a pre-recorded target time. For each activity, the people involved are also recorded (Frank et al., 2007). Research indicates that whether an activity is social or non-social may be important to how influential it is on circadian rhythms (Grandin et al., 2006; Stetler, 2004).

**Prevention of Relapse**

Psychopharmacology is the main treatment for BD in managing both acute episodes of illness and long-term prevention of recurrence (Anderson et al., 2012). However, there are high rates of medication non-adherence (Sajatovic, Valenstein, Blow, Ganoczy, & Ignacio, 2006, 2007). Many factors contribute to ambivalence about taking medication. One third of people with BD do not experience prophylactic benefits from long-term use of medications such as lithium (F. K. Goodwin, 2002). Side effects are typical, and fluctuate with dosage or may persist indefinitely; As many as 75% of people taking lithium experience some side effects (American Psychiatric Association, 2002). Pharmacotherapy must be carefully managed in situations such as pregnancy, breastfeeding, or comorbid substance use, and rapid withdrawal can trigger relapse (G. M. Goodwin et al., 2016). Many patients are reluctant to take medications that prevent the increased self-esteem, focus, energy, and euphoria of elevated moods (Frank, 2005). Also, lack of insight can be especially pronounced during episodes of mania or hypomania (Depp et al., 2014). This has led to effective adjunctive psychotherapeutic
treatments (such as IPSRT) for the prevention of mood episodes in BD (Miklowitz & Scott, 2009).

A recent meta-analysis demonstrated that adjunctive psychological therapies significantly reduce relapse rates in individuals with BD (Scott et al., 2007). A review by Hollon and Ponniah (2010) rated family-focused therapy as ‘efficacious’ for preventing relapse in BD. Cognitive-behavioural therapy and IPSRT were rated ‘possibly efficacious’ as further randomized controlled trials are needed (Hollon & Ponniah, 2010). Psychological treatment targets include: increasing awareness and understanding of BD; adherence to treatment/medication; reducing substance misuse; stabilising social and sleep rhythms; and self-management (Haynes, Gengler, & Kelly, 2016; Picardi & Gaetano, 2014). These targets are achieved through self-monitoring of behavioural and lifestyle factors, and detection of EWS.

Self-monitoring

There are identifiable and consistent EWS that appear before relapse, and which are idiosyncratic to the individual and type of mood episode. Interventions that include self-monitoring of EWS have been demonstrated to have beneficial effects on relapse rates and hospitalisation (Morriss et al., 2007). Furthermore, independent of clinical treatment, people with BD are using a variety of self-monitoring tools, reporting it facilitates self-awareness, agency and communication with caregivers and clinicians. Sociability was routinely tracked by 21.9% of people with BD independently of clinical treatment (Murnane et al., 2016). Common EWS related to SA include more goal-directed behaviour and increased sociability in mania and a loss of interest in activity or people in depression (Lam, Wong, & Sham, 2001). People with BD are better at reporting EWS of mania, compared to depression (Lam et al., 2001). This is possibly because EWS of mania are predominantly behavioural and easier to gauge and monitor by the patient, family, or close others, whereas EWS of depression are more diverse, and can be difficult to distinguish from residual depressive symptoms. This may explain results that EWS are more effective for preventing manic episodes than bipolar depression (Lam et al., 2001). However, these results also highlight the applicability of
monitoring changes in SA as an observable, objective sign of mood disturbance in BD.

Paper-based self-monitoring using self-report inventories and daily journals are labour-intensive for both patient and clinician, and vulnerable to self-report biases in recall due to memory heuristics or the monotony of repeated measures (Osmani et al., 2013). They may be inconsistently filled out due to interference from symptoms, or because they are easily forgotten leading to missing or retrofitted data (Bardram et al., 2013). Paper logs offer little privacy or security and may not be available when needed (Bopp et al., 2010). With recent advances in computer and hand-held technology, electronic and automated methods are being implemented in order to increase adherence and accuracy, infer changes in mood state, and provide instantaneous feedback in order to increase insight and prevent relapse.

**Electronic Self-monitoring**

Research has found it is feasible to electronically collect daily self-reported mood and symptom data from people with BD. Over 3-months, 80 participants used Chrono Record (Bauer et al., 2006; Whybrow et al., 2003) on a home computer to rate their mood, sleep, medication, and life events for the past 24-hours. User comfort with Chrono Record on a 5-point scale was very high ($M = 4.65$). This eliminates the need to transpose data from paper into electronic format for analysis, which is slow, costly, and error-prone. However, it is still subjective, recorded retrospectively, and lacks momentary access and privacy. In contrast, mobile phones are continuously available; many people carry their mobile phone with them throughout the day and research shows that smartphones are kept within the same room as the user almost 90% of the time (Dey et al., 2011). The daily use of mobile phones, in public and private, is a common, accepted, and widespread practice providing privacy and security for patients to track mood and symptoms electronically (Matthews & Doherty, 2011).

Modern smartphones now allow for email and internet access on the go, as well as dedicated lifelogging applications (apps). MoodChart (Lieberman, Swayze, & Goodwin, 2011) is a fully automated (no clinician contact), free, internet adaptation of Social Rhythm Therapy. It uses a daily reminder email to ask participants to record...
mood and the timing of daily activities for the past 24 hours. During the 90-day pilot adherence was very high ($M = 84$). However, only proven, highly-motivated volunteers were invited to participate as daily self-monitoring for extended periods requires considerable dedication. The Oxford University Symptom Monitoring System (Bopp et al., 2010) assessed mood fluctuations weekly by SMS during outpatient treatment. The study showed high user uptake (87%), and very few incorrectly formatted responses (3.5%) indicating high ease of use. Adherence was 75% over an average of 36 weeks and 83% of responses were within 12 hours of the prompt. The study relied on retrospective recall over the past seven days, with the authors noting that eliminating recall bias with an ecological momentary assessment (EMA; Shiffman, Stone, & Hufford, 2008) approach would come at the cost of a more laborious and intrusive frequency of prompts in order to continue to capture daily or within-daily mood fluctuations.

A dedicated BD smartphone app, MONARCA\(^2\), tracks BD symptoms through daily electronic self-monitoring and automatic tracking of objective behavioural data (e.g., sleep, physical and social activity, and location). A 14-week feasibility study of the self-reported data compared electronically monitored mood (scored from depressed to manic: $-3$ to $+3$) to an equivalent period previously completed on paper by the same 12 participants (Bardram et al., 2013). MONARCA was described as very easy to use, more convenient (as they had it with them), more immediate (they could complete it any time of the day rather than recalling events retrospectively), and perceived as highly useful. MONARCA used a daily alarm that would sound on the smartphone at a self-chosen time during the day. Participants reported the reminder was useful rather than intrusive. Overall, the study found the electronic monitoring on MONARCA had similar adherence rates to the paper monitoring, but with greater validity. While semi-structured follow up interviews revealed significant retrofitting of the paper forms,

\(^2\) MONARCA was a collaboration funded by the European Commission that designed and evaluated a smartphone application to support the treatment and management of BD. Continued development and support of the application is via the commercial arm, Monsenso ApS. For more information see www.monsenso.com.
MONARCA could only be completed for the current day, eliminating the problem of unreliable retrospective completion (Bardram et al., 2013).

Electronic monitoring improves data quality, is more efficient, cost-effective, and accurate, with greater ease of use and adherence compared to paper methods (Bardram et al., 2013; Bauer et al., 2006). It may also empower patients, as fewer appointments may be needed for clinicians to stay informed, reducing travel time and costs for clients. Retrospective recall bias can be minimised with EMA but the frequency of surveys or prompts need to be balanced against user-burden and intrusiveness (Bopp et al., 2010).

**Automated Monitoring**

Ultimately, electronic monitoring still requires burdensome manual data entry by the user and people with BD report the need for automated tracking and analysis, particularly during times of stress and mood episodes (Murnane et al., 2016). Manual data entry limits their uptake, scalability, and suitability for long-term use. Ideally, effective electronic monitoring needs to be automated, unobtrusive, and provide intelligent feedback (Harari et al., 2016; Lane et al., 2011). Modern smartphones are computationally powerful, equipped with a multitude of embedded sensors and have enhanced connectivity for data transfer, which makes them an ideal solution to this problem. Additionally, they routinely record social interactions (e.g., calls, SMS), and location in system logs. Through these sensors and system logs, smartphones are able to passively collect fine-grained, continuous data in real time, infer behaviours, and actively promote wellbeing (Harari et al., 2016; Lane et al., 2011). Several studies have taken advantage of these features to automatically monitor mood, lifestyle choices, and wellbeing using smartphone apps. Notably, these have included the BeWell, MObilyze!, and MONARCA apps.

An Android operating system (OS) smartphone app for the general population, BeWell (Lane et al., 2014; Lane et al., 2011), senses and monitors multiple variables that impact on mental health, including sleep, physical activity, and SA, without needing additional, external devices. Physical activity was inferred by classifying accelerometer data into activity classes (stationary, running, and walking). SA was inferred by
classifying ambient audio from the microphone sensor as non-voicing or voicing. Sleep
duration was inferred using a logistic model based on the duration and frequency of
everyday occurrences that correlate with the user sleeping, such as phone recharging,
periods of near silence, or the phone being stationary. The wellbeing variables tracked
by BeWell are similarly relevant to preventing relapse in BD. The app was well received
by users during a 19-day field trial. Notably, each person used the Nexus One (provided
by the study) as their primary phone, worn at all times in a holster that clips to belt or
clothing. This increases data accuracy by controlling how the phone is carried but
limits real-world applicability. Most people carry their phone in a pocket or bag, or
place it on a surface nearby, which would affect audio data particularly.

The Mobilyze! (Burns et al., 2011) Symbian OS smartphone app for clinically
depressed populations uses machine learning models to recognise user circumstances
and states, and provide ecological momentary interventions (in-the-moment responses
to patient inputs, personalized to their immediate needs). Mobilyze! draws on at least
38 concurrent phone sensor values captured by sensors such as accelerometer,
gyroscope, bluetooth, GPS, cellular network, WiFi, ambient light), as well as system
information (e.g., time/day, calls, SMS, active apps, battery state, volume, lock status).
The companion website provides access to graphical feedback, tools, and weekly
didactic behavioural skills lessons. Adherence was promoted via brief manualised calls
and emails from a clinical coach. An 8-week feasibility study of 8 patients with major
depressive disorder showed, among other things, that accuracy rates of up to 91% were
achieved when predicting categorical contextual states (e.g., location), but that for
states rated on scales, especially mood, predictive capability was poor. The study
showed, however, that patients were satisfied with the phone app and it improved on
their self-reported depressive symptoms.

The MONARCA-I system (Bardram et al., 2013) focussed on self-report data,
though it also gathered accelerometer data and communication logs (Frost, Doryab,
Faurholt-Jepsen, Kessing, & Bardram, 2013). Self-report items included mood, sleep
duration, medicine, subjective activity level, mixed mood, irritability, cognitive
problems, and alcohol consumption. Subjective activity level was ranked highest when correlated with self-rated mood (Frost et al., 2013). Thus, MONARCA-II (Faurholt-Jepsen et al., 2014; Frost et al., 2013) included more automatic monitoring of activity, including physical activity (accelerometer), mobility (cell tower IDs), SA (call and SMS logs), and phone usage (screen and apps). A small trial with 6 users (Frost et al., 2013) found that out of these four objective variables, phone usage and SA correlated highly with self-rated mood. Additionally, two mood estimation models were tested, one using all available data, and another using just objective data. It was found that the objective-only model gave a close estimation of mood, which was only slightly improved by the addition of the subjective variables. This research highlights the feasibility of automated monitoring using smartphones and the role of SA in predicting mood in people with BD.

Social Activity

Social activity is central to BD, yet broad in scope, and difficult to measure. The broad scope of the topic is perhaps one reason it is difficult to define its contribution to relapse in BD. Quality of interpersonal relationships and perceived social support lie in contrast to frequency measures of social interaction. Lower levels of perceived social support are associated with worse outcomes and increased risk of relapse in BD (L. Johnson, Lundstrom, Aberg-Wistedt, & Mathe, 2003; S. Johnson, Winett, Meyer, Greenhouse, & Miller, 1999). Low levels of perceived social support are also associated with depression (George, Blazer, Hughes, & Fowler, 1989). Though the former are important, automated monitoring of BD has had to focus on aspects of SA that are feasibly captured using current smartphone technology, such as the quantity and frequency of various social activities (Lane et al., 2011).

The mobile phone was originally designed for making and receiving phone calls and text messages (SMS). This allows the analysis of social interaction using system data on quantity, duration, and variance of phone calls and SMS. The microphone can also capture audio (using intermittent, short-burst sampling for privacy) and machine learning models can infer SA from the recordings (Gravenhorst et al., 2015). Today,
smartphones are also enabled with location sensors, which can track travel patterns or “mobility” as another indicator of the level of engagement in social routines or activities outside the home.

**Call and SMS.** System logs of call duration, phone numbers, and the quantity of calls and SMS, can approximate a person’s level of SA. Data from the MONARCA-I trial (Faurholt-Jepsen et al., 2015) showed that when adjusted for age and sex, manic symptoms correlated significantly with an increased duration of incoming calls, an increased number of incoming and outgoing phone calls, and an increased number of outgoing SMS, per day. This aligns with the typical increase in SA, talkativeness, and pressured speech of elevated mood. However, increased call duration (in- and outgoing) but not quantity also correlated with higher clinician ratings of depression. Specifically, call duration correlated with a sub-item measuring psychomotor retardation suggesting people with depressive symptoms may take longer to express themselves thus increasing call duration (Faurholt-Jepsen et al., 2015). It has been suggested that people in a mildly depressed state may exhibit greater desire to talk with others about their problems, and friends or relatives may make contact more often, representing an increase in social interaction compared to a nondepressed state. Severe depression, however, may result in very reduced social capacity with even lower call duration than the nondepressed state (Grunerbl et al., 2012). Unfortunately, the target person’s involvement or speaking duration during a call is not able to be inferred from this type of data. Thus, additional sensors and measures are needed to verify these conclusions.

**Audio.** Analysis of speech is a well-established component of assessing bipolar disorder. Gold standard clinical assessment tools incorporate assessment of patient speech (Hamilton, 1967; Young, Biggs, Ziegler, & Meyer, 1978). Depressed patients exhibit reduced speech prosody (emphasis and inflection) and those with psychomotor retardation exhibit changes in speech fluency such as briefer utterances and longer pauses (Alpert, Pouget, & Silva, 2001). Increased speech activity (along with increased motor activity) may predict treatment-emergent (hypo)mania as a result of antidepressant therapy (Frye et al., 2009).
Smartphone microphone sensors can be used for acoustic analyses of low-level features such as pitch, rate and tone, without capturing the content or meaning of spoken words (Gravenhorst et al., 2015). These features were used to continually detect voice in the user’s surroundings using a smartphone application, BeWell (Lane et al., 2011). The results of a 3-user test found that on average BeWell overestimated true social interaction by 14%. This approach is susceptible to errors detected during non-conversational activities such as watching television, or social environments where the target is not participating. However, its strength is that it captures in person interactions as well as phone call audio. Other approaches have captured audio solely during phone calls (Faurholt-Jepsen et al., 2016; Karam et al., 2014; Muaremi, Gravenhorst, Grünerbl, Arnrich, & Tröster, 2014). These studies used open-source software to analyse low-level acoustic features for mood state recognition. Findings indicated that acoustic feature analysis from phone calls was better at classifying: hypomanic (AUC = 0.81) than depressed (AUC = 0.67) states (Karam et al., 2014), and manic or mixed (AUC = 0.89) than depressed (AUC=0.78) states (Faurholt-Jepsen et al., 2016).

A further consideration is whether to use person-dependent models, based on one user’s data, or a single user-independent model for everyone. Based on the phone calls of six patients with BD, a study by Muaremi et al. (2014) found that for mood state recognition acoustic features (e.g., variance and pitch) performed best on average (80%) closely followed by social cues (78%; e.g., speaking length, turn duration, number of short-turn/utterances) and call activity (77%; e.g., timing, number and duration of calls). Combining all three, improved accuracy (83% on average). The study assessed the prediction accuracy of different person-dependent classifiers using 3-fold cross-validation (which splits the data into training and testing subsets). Random forest classifiers performed best (compared to support vector machine, logistic regression, and neuronal network models). It was also able to assess the importance of the variables during the training process. Across all three categories of data, the most important features for mood state recognition varied for each individual, justifying the use of
person-dependent classification models (Muaremi et al., 2014). However, a drawback is
that more time, data, and work is required before the predictive capability of the
system is ready for each person, whereas a user-independent models can be
implemented immediately.

**Mobility.** Mobility has been implicated as a useful marker in BD as travel
patterns tend to change in both depressive and elevated mood states. Depression is
often characterised by immobility and decreased instances of leaving the house
(Faurholt-Jepsen, Frost, et al., 2014; Grunerbl, Muaremi, et al., 2014; Grunerbl,
Osmani, et al., 2014). Indoor activity is performed inside the home, often in solitude,
whereas outdoor activity (i.e., outside the home) often involves a social context, setting
higher demands on communication and self-presentation (Lomranz, Bergman, Eyal, &
Shmotkin, 1988). Depressed patients often limit to indoor activities for these reasons.
Conversely, in mania and hypomania, symptoms such as unwise shopping, talkativeness
and increased SA (APA, 2013a) indicate increased mobility outside of the home and
more erratic travel patterns (Grunerbl, Osmani, et al., 2014).

Mobility can be estimated using smartphone location services which rely on
GPS, WiFi signals, and the cellular network. Precise location accuracy may be
desirable, but is not necessary; All of the above location sensors (alone or combined)
have been found to work sufficiently for detecting patterns of mobility in BD. Although
it is the least accurate of the three technologies for determining precise location, cellular
network location data has been found to correlate negatively with increased depressive
symptoms in BD, indicating depressed patients leave the house less (Faurholt-Jepsen,
Frost, et al., 2014). This was achieved using a coarse time scale of an entire day, and
using data that does not rely on distance (i.e., the number of cell tower ID’s and
number of changes in cell tower ID per day). Another study by Grunerbl et al. (2012)
used the lack of GPS signal indoors to calculate a ratio of time spent outdoors. The
results found that time spent outside (averaged over 10 days) during a depressed state
was approximately 4.12% and increased to 12.88% on average after BD patients’ mood
improved to a euthymic state; An average increase of 200%. The actual increase in time
outside varied greatly between each patient, from 35% to 2,759% emphasising individual differences in behaviour. However, the overall pattern indicates time spent outside is related to mood (Grunerbl et al., 2012).

A combination of GPS data, such as duration outside, number of places visited, distances travelled, and temporal data (e.g., mean time of day outside), was sufficient to train a computer classifier to recognise mood states in BD patients with an average accuracy of 81%, and high overall sensitivity (81.7%) and precision (80.8%; Grunerbl, Osmani, et al., 2014). The authors noted that imperfect recognition is still useful for patients and doctors to view evolving trends and schedule appointments if needed. Imperfection may be a necessary aspect of data from real-world, unconstrained usage of smartphone technology (Grunerbl, Osmani, et al., 2014).

Numerous studies have found that the accuracy and reliability of detecting changes or recognising mood states improves when more than one sensor modality is combined due to the established fact that reliability improves with a larger data set (Faurholt-Jepsen et al., 2016; Grunerbl, Muaremi, et al., 2014). This is particularly true of sensors such as GPS, where data insufficiency (low count per day) and gaps in data (over one day) are common; combining sensors widens the range of days where there is data from at least one sensor to compare with mood ratings (Grunerbl, Osmani, et al., 2014). For these reasons, combining data from various measures should provide the most accurate estimation of SA, rather than relying on one modality alone.

**Accessibility**

Issues of cost, scalability, ease of use, portability, and proximity frequently arise in considering what devices are best suited for automated tracking and electronic self-monitoring in BD. For these reasons, mainstream, off-the-shelf smartphone devices are preferable over highly specialised, dedicated medical devices. Smartphones provide an all-in-one solution to multiple tracking devices or sensors (e.g., Prociow, Wac, & Crowe, 2012). Their data is easily augmented by detailed sleep and activity data from wrist worn commercial activity trackers, such as Fitbit (www.Fitbit.com). Though some approaches have preferred to use a single device (Grunerbl et al., 2012), the advantage
of using both an activity tracker and smartphone is that in the event one device is turned off, charging, or is forgotten when leaving the house, the other device can still provide continuous objective behavioural data.

Android smartphones are more affordable on average, and used by an increasing number of people compared to any other OS. Android has grown from less than five percent of the global smartphone OS market share in 2010 (Bhattacharya, 2016) to 87.5% in the last quarter of 2016; Just 12.1% belongs to Apple’s iOS and 0.3% to other operating systems (Sui, 2016, November 2). Android OS is released on a multitude of new phones every year from partnering brands and as a result there are multiple mid-range or low-priced options on this OS making it more accessible than iOS.

Previous studies have chosen to provide participants with Android smartphones, controlling for the model, computing power, battery life, etc. (Grunerbl et al., 2012; Lane et al., 2011) or allowed participants to choose to either use their own Android smartphone or to loan one free of charge (Faurholt-Jepsen et al., 2016). Though use of private Android smartphones means a greater variability in relevant benchmarks as well as variation in OS version, it has precedent and may even be preferable for some participants, especially over the course of a long study.

The exclusion of iPhones has been noted as a barrier by potential participants in some studies (e.g., Faurholt-Jepsen et al., 2016). However, Android allows apps to run in the background, whereas iOS does not – a significant barrier for automatic, passive, collection of sensor data (del Rosario, Redmond, & Lovell, 2015). Furthermore, Android is a 'true open operating system' where any user can develop an app and deploy it on an Android device, compared to Apple which has determinedly kept its products within a closed, proprietary environment, and all apps must be approved by Apple before users can access it (Hall & Anderson, 2009).

**Conclusion**

Treatment that addresses the prevention of recurrence is paramount for effective management of BD in order to reduce the associated morbidity, mortality, comorbidity, psychological and social impacts, and progressive worsening of the condition.
Smartphones are ubiquitous personal electronic devices, carried on or near the person almost constantly, and as such are ideal for tracking EWS in BD. Research has demonstrated that SA can be tracked using smartphone sensors, and this objective data may relate to mood state in BD. However, more research is needed to determine the methods that most consistently relate to mood and that are both accessible and feasible to implement.
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Exploring Social Activity in Bipolar Disorder Using Automated Smartphone Tracking

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Abstract

Social Activity (SA) is a potential early warning sign of relapse in Bipolar Disorder (BD). Smartphones enable continuous, automatic monitoring of objective, real-time data. The intention of the current study was to explore the relationship between objective measures of SA and mood in people with BD. Levels of SA among 12 individuals with BD I (n=5) and II (n=7) were monitored using smartphone sensors (calls/SMS, location, audio) over 6-months. Participants were assessed by a clinician at baseline, 1-week, 3- and 6-months, and completed an online weekly mood survey.

Results were analysed using linear mixed models with random intercept and likelihood ratio tests. Self-reported depressed mood was positively correlated with the number of sent and received SMS, while elevated mood was positively correlated with the number of people contacted and with mobility. The current study was limited by a small sample size and missing data due to technical challenges. Individual variation in both SA patterns and smartphone use, potentially influenced results. Personalised approaches, combining sensor modalities, and measuring multiple features for each sensor, may assist with effective tracking of objective SA. In clinical practice, SA measures and other early warning signs should be tailored to the individual to maximise the effectiveness of self-monitoring.

Keywords: Bipolar Disorder, Social Activity, Mood, Automated Monitoring, Mobile Application, Smartphone
Exploring Social Activity in Bipolar Disorder Using Automated Smartphone Tracking

Bipolar Disorder (BD) is chronic and lifelong, affecting approximately 1% of the adult population (Merikangas et al., 2011; Pini et al., 2005). It is associated with significant comorbidity, particularly anxiety and substance use (Merikangas et al., 2011) and a mortality rate 2-3 times higher than the general population (Crump, Sundquist, Winkleby, & Sundquist, 2013; Kessing, Vradi, McIntyre, & Andersen, 2015). Clinical guidelines (National Institute of Health and Clinical Excellence, 2014) recommend long-term management using individualised approaches with equal emphasis on pharmacological and psychological intervention.

A key target of psychological interventions for BD is relapse prevention (Miklowitz & Scott, 2009; Picardi & Gaetano, 2014; Scott, Colom, & Vieta, 2007), involving identifying and monitoring early warning signs (EWS) of relapse (Morriss et al., 2007). Interventions using EWS have had beneficial effects on relapse rates and hospitalisation, when delivered in conjunction with treatment as usual (medication and regular outpatient appointments with a psychiatrist; Morriss et al., 2007). Research indicates social activity (SA) is one important indicator of relapse in BD (Faurholt-Jepsen et al., 2014) and it is a focus of psychological treatments aiming to stabilise social and sleep rhythms.

Interpersonal and Social Rhythm Therapy (IPSRT) (Frank, 2005) is underpinned by Social Zeitgeber theory (Ehlers, Frank, & Kupfer, 1988; Ehlers, Kupfer, Frank, & Monk, 1993), which describes the development and timing of mood episodes in BD as strongly related to life events and social factors. This occurs via their ability to disrupt or entrain circadian rhythms. Social ”zeitgebers” or time-givers, are personal relationships, social demands or activities that entrain biological rhythms. “Zeitstörrers” are physical, chemical, or psychosocial life events that can disrupt circadian rhythms and lead to or maintain mood episodes (Frank, Swartz, & Kupfer, 2000; Grandin, Alloy, & Abramson, 2006; Malkoff-Schwartz et al., 1998). IPSRT promotes lifestyle regularity to improve the body’s capacity to maintain stable biological rhythms and prevent the
recurrence of mood episodes. IPSRT uses the Social Rhythm Metric-II-Five Item Version (SRM II-5) to record daily mood and to chart the timing of daily activities against a pre-recorded target time (Frank, Swartz, & Boland, 2007). For each activity, the people involved are also recorded. Research indicates that whether an activity is social or non-social may be important to how influential it is on circadian rhythms (Grandin et al., 2006; Stetler, 2004).

Social activity and other EWS can be monitored on paper or digitally. Paper-based measures, self-report inventories and daily journals are burdensome, easily forgotten causing missing or retrofitted data, and lack privacy and security (Bardram et al., 2013; Bopp et al., 2010; Osmani et al., 2013). Smartphones are an ideal alternative. They provide momentary access as they are kept on the person or within the same room around 90% of the time (Dey et al., 2011). They make self-monitoring inconspicuous, as daily use in public and private is widely accepted (Matthews & Doherty, 2011), and they have inbuilt locking and security features. There is now an online version of the SRM II-5 (Lieberman, Swayze, & Goodwin, 2011) that can be completed on a personal computer or smartphone web browser provided there is access to the daily email reminder and an internet connection.

Electronic monitoring of SA and other EWS improves data quality, is more efficient and accurate, with greater ease of use and adherence compared to paper methods (Bardram et al., 2013; Bauer et al., 2006). It empowers patients, and fewer appointments may be needed for clinicians to stay informed, as well as reducing travel time and costs for clients (Bopp et al., 2010). Retrospective recall bias can be minimised with ecological momentary assessment (EMA; Shiffman, Stone, & Hufford, 2008) but the frequency of surveys needs to be balanced against user-burden and intrusiveness (Bopp et al., 2010).

Independent of clinical treatment, people with BD use electronic self-monitoring tools, but they desire automated forms of digital symptom tracking (Murnane et al., 2016). Electronic self-monitoring methods require manual input of self-ratings. This can limit their uptake, scalability, and suitability for long-term use. Ideally, electronic
monitoring needs to be automated, unobtrusive, and provide intelligent feedback to aid compliance (Harari et al., 2016; Lane et al., 2011). Inbuilt sensors, powerful processors, and the connectivity of smartphones enable people with BD to passively collect fine-grained data on activity and behaviours in real-time (Harari et al., 2016; Lane et al., 2011).

There are three potential measures of SA that are readily captured by smartphone sensors. Being more talkative or sociable when elevated, or withdrawing socially when depressed may be reflected in calls and text messages (SMS), and in audio where voice detection measures the amount of conversation. Location data can also be used to track travel patterns or 'mobility'. Activity inside the home is often performed in solitude, whereas activity outside the home often involves a social context, setting higher demands on communication and self-presentation (Lomranz, Bergman, Eyal, & Shmotkin, 1988). People experiencing depression may have reduced mobility for these reasons, whereas increased sociability and impulsiveness in elevated mood states may lead to increased mobility (APA, 2013; Grunerbl et al., 2014).

Previous research has found a significant relationship between mood or symptoms in BD and phone call data (Faurholt-Jepsen et al., 2015), however the relationship between SMS and mood has not been clearly established. Additional features, such as the quantity of unique phone numbers, have been identified as potentially useful indicators of SA (Muaremi, Gravenhorst, Grünerbl, Arnrich, & Tröster, 2014). Previous studies have recorded audio during the phone calls of people with BD (Faurholt-Jepsen et al., 2016; Muaremi et al., 2014). Another approach was to record ambient audio throughout the day using a wellbeing smartphone application (app) for the general population (Lane et al., 2011; Lin et al., 2012). Both methods were effective; the former ensures it captures audio where the phone user is a speaking participant, whereas the latter also captures in-person communication.

Mobility studies have found that time spent outside the house was lower in a depressed state compared to a euthymic state (Grunerbl et al., 2012), that the number of changes in cell tower ID per day decreased with increased depressive symptoms,
indicating depressed participants left the house less (Faurholt-Jepsen et al., 2014). No relationship between mobility and elevated mood was found, due to low incidence of manic symptoms and the small sample sizes. A larger study used a combination of location parameters to train computer classifier to recognise mood states in BD, using unique models for each person. Average accuracy was 81%, with high overall sensitivity (81.7%) and precision (80.8%; Grunerbl et al., 2014). The authors noted that the data did not need to be perfect to be useful and imperfection may be the price of collecting data from real-world, unconstrained smartphone users. Studies have required participants use the same model phone (e.g., Faurholt-Jepsen et al., 2013), and some have also required it worn in a certain way to increases the reliability and clarity of location and audio data (e.g., Hamm, Stone, Belkin, & Dennis, 2013; Lane et al., 2011). This limits real-world applicability and wide-spread implementation as the model of phone and smartphone habits vary from person to person.

The above studies used smartphone apps that were developed for the Android operating system (OS). Android has a higher global smartphone OS market share (87.5%) than any other OS; Just 12.1% belongs to Apple’s iOS and 0.3% to other operating systems (Sui, 2016, November 2). Android OS is released on a multitude of new phones every year and as a result there are multiple mid-range or low-priced options, making it more accessible than iOS. Furthermore, Android allows apps to run in the background, unlike iOS – a significant barrier for automatic, passive, collection of sensor data (del Rosario, Redmond, & Lovell, 2015). As a "true open operating system" any user can develop an app and deploy it on an Android device, whereas Apple has determinedly kept its products within a closed, proprietary environment, and all apps must be approved by Apple before users can access it (Hall & Anderson, 2009).

In summary, automated monitoring of EWS in BD is an important, desirable, and necessary advancement of existing self-monitoring practices. Smartphone sensors have been used to measure a variety of SA parameters and several of these have been found to relate to mood in BD. This suggests a person’s level of SA can be quantified using objective measures, and this data could be used to predict mood. However,
methods of gathering and utilising complex smartphone data are still evolving, within the highly accessible Android OS environment. The primary aim of the current study was to demonstrate the feasibility of objectively tracking SA using smartphones, and in particular to highlight any technical considerations.

The current study is part of an ongoing project that uses the Fitbit Charge HR and Android smartphone technology to explore lifestyle factors that may serve as EWS in adults with BD. The present study analysed SA as it related to mood, captured by smartphones in the real-world, over the first 6-months of participation of a larger 12-month study. Fitbit data was not used in this study. This study allowed participants to use their own Android smartphone, in order to increase the real-world applicability of the results across a variety of models. Previous research has shown electronically monitored mood to correlate with clinician ratings (Faurholt-Jepsen et al., 2015). Therefore, we hypothesised that self-reported mood would correlate positively with clinician rated symptoms (H1). A number of studies found that various objective measures of SA, including phone call data (Faurholt-Jepsen et al., 2015), audio (Faurholt-Jepsen et al., 2016; Lane et al., 2011; Muaremi et al., 2014), and mobility (Faurholt-Jepsen et al., 2014; Grunerbl et al., 2012; Grunerbl et al., 2014) show promise as predictors of mood. Therefore, we hypothesised that increased SA would be associated with elevated mood (H2) and decreased SA with depressed mood (H3).

Method

Participants

Participants were recruited using a research flyer (Appendix B) displayed in private psychology and psychiatry services, and throughout the university campus. Inclusion criteria required participants 18-50 years of age, with a pre-existing diagnosis of BDI or BDII, currently under the care of a GP/Psychiatrist, stable on medication for BD, without a serious medical condition (e.g., epilepsy or diabetes), that speak English as their first language. Individuals were excluded if they were acutely unwell, psychotic, or suicidal; had a brain injury, IQ delay or learning disorder; or met diagnostic criteria for Cyclothymia.
Ethics approval was granted via the university and local health service human research ethics committees (Appendix C). Interested people contacted the chief investigator for further information and the consent form (Appendix D). Recruitment was staggered. In total, 12 participants were recruited including 2 males and 10 females aged between 23 and 50 years ($M = 33.5$ years, $SD = 7.9$) with BDI ($n = 5$) and BDII ($n = 7$). Table 1 contains further participant demographic information. Two participants did not attend their 3- or 6-month assessments, and subsequently left the study due to work and family commitments. Therefore, they were excluded from some of the analyses.

Measures

**Structured Clinical Interview for the DSM-5, research version (SCID-5-RV).** The BD section of the SCID-5-RV Module D was used to confirm BD diagnosis and subtype (First, Williams, Karg, & Spitzer, 2015). The overall reliability of the SCID as a whole has been determined to be similar to other major diagnostic instruments, with added benefits of high user-friendliness, flexibility, and efficiency (Williams et al., 1992). For BD specifically, previous versions have demonstrated good test-retest reliability (ranging from .64 to .92) for current and lifetime diagnoses of BD in patient samples in an international multi-site trial, and superiority in comparison to other structured, and unstructured interviews (Williams et al., 1992). The SCID has also been found to have high sensitivity and specificity for diagnosing BD (Fennig, Craig, Lavelle, Kovasznay, & Bromet, 1994).

**Bipolar Depression Rating Scale (BDRS).** The BDRS (Berk et al., 2007) is a 20-item clinician-rated scale of the severity of depressive and/or mixed symptoms in the past 48 hours (Appendix E). Studies have reported good validity and excellent internal reliability, Cronbach’s alpha = .92 (Berk et al., 2007). Symptoms are rated on a 4-point scale from 0 (absent) to 3 (severe). The BDRS has a global score of 60, with higher scores indicating greater severity. In the current study, Cronbach’s alpha at baseline was .95.
**Young Mania Rating Scale (YMRS).** The YMRS is an 11-item clinician-rated measure of the severity of manic/hypompanic symptoms in past 48 hours (Appendix F), with good predictive validity (0.66) and excellent interrater reliability, kappa = .93 (Young, Biggs, Ziegler, & Meyer, 1978). Symptoms are rated on a 5-point scale from 0 (absent) to 4 (clinically significant). The YMRS has a global score of 60, with higher scores indicating greater severity. In the current study, Cronbach’s alpha at baseline was .75.

**Weekly Mood Rating.** Self-reported mood (Appendix G) was measured using ecological momentary assessment (EMA) to minimise sources of retrospective bias, including personal heuristics, recency, novelty, or mood-congruent memory effects (Shiffman et al., 2008; Trull & Ebner-Priemer, 2009). Participants rated their mood "today" on 5 dimensions (Depressed, Elevated, Irritable, Anxious, Psychotic) using a 4-point scale (none, mild, moderate, severe). The current study analysed depressed and elevated mood only. The survey was created using the online platform LimeSurvey. Participants completed a paper version of the survey at baseline and the one-week assessment. Subsequently a link to the survey was automatically sent by SMS (https://www.messagemedia.com) at the same time each week for all participants (usually a Wednesday). The frequency was set to weekly to avoid overburdening participants, due to the length of the project (12-months). Rather than allowing for retrospective backfilling of the survey, participants could rate their mood “today” a maximum of once per week, on any day leading up to the next survey.

**Social Activity.** SA was measured objectively using two Android smartphone apps. If This Then That (IFTTT), a free app from the Google Play store, automatically recorded call and SMS data logged by the stock android phone call app and SMS app. This included the duration of calls (in seconds), the number of calls, number of SMS, and people contacted (contacts). Contacts was derived from the number of unique phone numbers across all calls and SMS in a day. Phone number had been coded for privacy in such a way that the same code was used for the same phone number each time. Coded numbers of 4 digits or less were removed as they were likely
to be from or to automated services, such as voicemail or reminders, and not considered to be social interaction.

Unforgettable Me (UM; in beta, 2016/2017; www.unforgettable.me), an Android smartphone app developed by Hamm et al. (2013), continuously recorded location (mobility) and audio (conversation). The data was uploaded over WiFi to a secure cloud storage server whenever the smartphone was connected to WiFi, while also over 90% charged. Location was detected using Android location services. It was used to calculate the distance travelled (in kilometres) for each hour of the day. A threshold of 50m per hour was used to determine if the participant was relatively stationary (low mobility) or involved in movement (high mobility) for each hour. This was used to calculate a proportion for mobility where higher values reflect greater mobility.

In order to estimate the amount of time a participant was engaged in conversation we used the inbuilt microphone to capture intermittent, short-burst audio samples. To protect privacy, audio samples were encoded at approximately 10 minute intervals, were three seconds long and encoded in mel frequency cepstral coefficients (MFCCs). The sparse sampling method means any speech in the audio was incomprehensible (Hamm et al., 2013). Acoustic features extracted from the audio samples were used for speech detection; a person-independent computer algorithm (trained on the QUT-NOSIE-TIMIT database; Dean, Sridharan, Vogt, & Mason, 2007) extrapolated the hours containing voice. This was used to create a percentage of time that contained voice (out of the hours where audio was recorded) as an estimate of the level of engagement in conversation.

Procedure

Participants attended a baseline assessment (Appendix H) with a clinician (clinical or provisional psychologist) at the University of Newcastle’s Psychology Clinic. Eligibility was assessed and diagnosis confirmed using the SCID-5-RV Bipolar Disorder section. Information collected included demographics, medical and psychiatric history. Baseline symptoms were measured with the YMRS and BDRS and a paper version of the weekly mood survey. The Fitbit and smartphone apps were also set up and
demonstrated. One week later participants attended a shorter follow up appointment at the clinic to troubleshoot any technology issues and assess for any changes symptoms and lifestyle factors. Participants attended subsequent assessments at the clinic every 3-months, where symptoms and lifestyle behaviours were reassessed (Appendix I). Participants were able to keep the Fitbit Charge HR device and were compensated for their time with a $20 gift card at the baseline assessment and a $10 gift card at subsequent assessments.

To validate the self-reported mood measure, clinician-rated symptoms at the 1-week, 3-months, and 6-months assessments were compared with the closest available mood survey. This ranged from 2 days before to 5 days after the 3-month assessment, with 8 out of 10 occurring on the same day or within the past 2 days. The range was two days before to six days after for the 6-month assessment with 5 out of 9 on the same day or within the past 2 days. The reference time period for the BDRS was the past 48 hours and for the YMRS was the "last few days". Elevated mood was compared with scores on the YMRS, and depressed mood was compared with scores on the BDRS. Depressed and elevated self-rated mood were analysed as continuous variables.

To compare SA and self-reported mood, each measure (duration, calls, SMS, contacts, conversation, mobility) was compared with depressed and elevated mood. First, the corresponding SA data for each survey had to be determined. It was decided that each survey would be compared with SA data from a period up to 7 days long, leading up to and including the date of the mood survey. This was kept to a maximum of 7 days to ensure the temporal relevance of the data in the event that a participant missed several mood surveys.

For measures based on calls and SMS, the data (duration, calls, SMS, and contacts) was first summed by day, then the mean of the daily data was calculated based on the number of days in the period with valid data. Call and SMS data was only present when an event was successfully recorded. Therefore, it was not possible to determine retrospectively whether an absence of data was true negative or attributable to technical error. Predetermined continuous segments of time where call or SMS data
was missing due to technical difficulties were removed. These segments were noted at the time they occurred and not retrospectively. As a result, some periods had a reduced number of days with valid data, on which the mean was calculated. Each variable was analysed firstly using an unweighted model, and then using a model weighted by the number of days with valid data; periods based on more data were expected to provide a more reliable estimate of SA.

For location and audio, hourly data showed whether the smartphone sensor was recording that type of data, and missing hours indicated the sensor was not recording. Hourly data for each variable was first totalled over the period (not per day), then used to calculate the proportion of voice in the period (conversation) and the proportion of movement (mobility). Each was analysed firstly using an unweighted model, and then using a model weighted by the number of hours in the period where the smartphone sensor was recording either audio or location. This would give less weight to shorter periods or periods with more missing hours of data compared to longer periods with no missing hours.

Statistical Analysis

Cronbach’s alpha analyses were performed using IBM SPSS Statistics for Macintosh, version 23.0 (IBM Corp, 2015). All other analyses were performed with the R 3.4.2 (R Core Team, 2017) within the R Studio environment (RStudio Team, 2016). The lme4 package (Bates, Maechler, Bolker, & Walker, 2015) lmer() function was used to fit linear mixed effects models (LMM). A random effect term was included to account for expected dependencies in the data due to the use of repeated measures. Likelihood ratio tests were used to assess significance ($p < 0.05$) and 95% Wald confidence intervals were calculated for the effect of each explanatory variable.

Results

Sample

Of the twelve participants recruited, ten completed the initial six-month self-monitoring study period (83.33%), with a median participation of 189 days. Two
participants left the study early due to work and family commitments and did not attend the 3- or 6-month assessments. Their data prior to departing the study was retained. Across the twelve participants, the median participation length was 189 days. A third participant did not attend the 6-month assessment, leaving 9 participants that attended all face-to-face assessments (75%). To provide an overview of the level of depressive and manic symptoms throughout the 6-month study, Figures 1 and 2 present each participant’s scores on the BDRS and YMRS respectively. The level of depressive symptoms was higher than elevated symptoms during the study.

Data Availability

Across all twelve participants, there were 43 clinician-ratings on the BDRS and YMRS out of possible 48 (89.58%), and 269 out of 325 (82.77%) completed mood surveys. For the ten participants that completed 6-months in the study the average compliance rate for the mood survey was 86.92% ($SD = 12.81\%$), with individual completion rates ranging from 62% to 100%.

Table 2 contains information for each participant on their duration in the study, the percentage of time where data was available for each measure of SA, and the completion rate for mood surveys. One participant was excluded from all analyses of SA due to insufficient data. A second participant was excluded from analyses of SMS and contacts, as no SMS data was recorded during the study. The percentage of days with at least one phone call, out of total days in the study, for each participant ranged from 18.69% to 86.32% ($M = 62.11\%, SD = 21.25, n = 11$). For SMS, the percentage for each participant ranged from 19.70% to 96.84% ($M = 73.03\%, SD = 27.34\%, n = 10$). Location and Audio data was recorded by the UM app in hourly increments. The percentage of hours where the UM app was running, out of total hours in the study, for each participant ranged from 15.64% to 98.62% ($M = 57.63\%, SD = 27.32\%, n = 11$). The percentage of hours that location was recorded, out of total hours the UM app was running, for each participant ranged from 68.83% to 99.68% ($M = 93.40\%, SD = 9.33\%, n = 11$). The percentage of hours that audio was recorded, out of total hours the UM app was running, for each participant ranged from 87.17% to 100% ($M = 97.81\%, SD = 3.50\%, n = 11$).
Cronbach’s Alpha

The internal reliability of the BDRS and the YMRS was assessed at baseline (N = 12) using Cronbach’s alpha. The 20-item BDRS had excellent reliability (Cronbach’s $\alpha = .95$). The 11-item YMRS had good reliability (Cronbach’s $\alpha = .75$).

Mood

The relationship between depressed mood and the BDRS was statistically significant based on a likelihood ratio test for the fixed effect (depressed mood), $\chi^2 (1) = 31.007, p < .0001$. The model suggests that a 1-point increase on depressed mood corresponds to an increase of 9.7 points on the BDRS (Figure 3). A statistically significant relationship was also detected between elevated mood and the YMRS, $\chi^2 (1) = 10.232, p = 0.001$. The model suggests that a 1-point increase on elevated mood corresponds to an increase of 3.9 points on the YMRS (Figure 4).

Social Activity

SMS and depressed mood was positively and significantly correlated in both the unweighted model ($p < .001$) and the weighted model ($p = .002$). Contact and elevated mood was positively and significantly correlated in the weighted model ($p = .015$), and was not significant in the unweighted model ($p = .128$). Mobility and elevated mood was positively and significantly correlated in the weighted model ($p = .006$), and was borderline significant in the unweighted model ($p = .061$). The remaining contrasts were non-significant ($p < .05$) for both the weighted and unweighted models. Table 3 contains the coefficients, 95% confidence intervals and $p$ values for the weighted and unweighted models for each SA variable.

Discussion

The primary aim of the current study was to demonstrate the feasibility of objectively tracking SA in BD, and in particular to highlight any technical difficulties that would need to be overcome before a study could be conducted in an adequately powered sample. This was done by exploring the relationships between the quantity of SA, measured objectively using smartphone sensors, and mood in BD. For comparison
with SA, mood was measured via a weekly self-report online survey and the mood survey was first validated against clinician-rated symptoms.

**Clinician-Rated and Self-Reported Mood**

It was hypothesised that self-reported mood would correlate positively with clinician rated symptoms (H1). The current findings support this hypothesis. In order to compare objective smartphone data with a validated measure of mood symptoms, past studies have completed clinical ratings fortnightly (Faurholt-Jepsen et al., 2014), every 3-weeks (Grunerbl et al., 2012) or monthly (Faurholt-Jepsen et al., 2015). However, the frequency of clinical mood ratings should be minimised to prevent memory effects from biasing the results. On the other hand, greater frequency enables more comparisons and better utilisation of the continuous smartphone data. Thus, shorter self-report measures have been developed to facilitate completion on a daily basis (Faurholt-Jepsen et al., 2015; Grunerbl et al., 2012). The current study balanced these requirements by using a short, weekly mood survey and compared it with quarterly clinician-rated symptoms. Unlike previous work that used a bidirectional scale for mood, this study used separate scales for depression and elevated mood, and compared these with the BDRS and YMRS respectively. Consistent with previous findings (Faurholt-Jepsen et al., 2015), electronic self-reported mood correlated positively and significantly with clinician rated symptoms. This demonstrated that participants have insight into their current mood, comparable to clinician ratings. As a result, self-reported mood could be used in subsequent analyses to explore the relationship with objective SA measures. Moreover, it represents a more frequent and economical way of monitoring clients – fewer appointments would be needed, while also empowering client involvement through self-monitoring.

**Objective Social Activity**

It was hypothesised that increased levels of objective SA would be associated with elevated mood (H2) and decreased levels with depressed mood (H3). The current findings provide limited support for these hypotheses. An increase in the mean number of SMS per day was significantly related to an increase in depressed mood, but there
was no relationship with elevated mood. An increase in the mean number of daily contacts was related to an increase in elevated mood in the weighted model, as was an increase in mobility, but there was no relationship with depressed mood. No relationship was found between either mood state and duration, calls, or conversation. Though there were some significant correlations with mood, these results should be interpreted with caution given the pilot nature of the study and the small sample size. More importantly, the results demonstrate the feasibility of objectively monitoring SA in BD, and highlight a number of technical considerations.

**Call and SMS.** In contrast to previous studies, we found an increase in the mean number of sent and received SMS was significantly related to an increase in depressed mood. A study of a similar nature and duration, found a significant positive correlation between number of outgoing SMS per day and scores on the YMRS, but no relationship was found for depression Faurholt-Jepsen et al. (2015). The study had a larger number of participants (N = 61) and compared their objective data to clinician rated mood at baseline and six, monthly-intervals, giving them a much larger sample size (over 400 observations) compared to the current study (193 observations). This suggests that if there was a reliable relationship between SMS and mood, it would have been found in a study with a larger sample. However, their sample was also presumably more diverse, with more individuals and fewer mood ratings per person. They also found call duration and number to correlate with depressed and elevated mood, whereas this was not found in the present study. A possible explanation for this, is that it was not possible to find a linear relationship between calls or duration and mood. Some studies have suggested a curvilinear relationship where the number and duration of calls increases in mildly depressed states, and is lower in both non-depressed and more severely depressed states (Grunerbl et al., 2012). Additionally, social media, and internet messaging and calling platforms such as Whatsapp, Twitter, Facetime, and Facebook, are increasingly popular smartphone communication methods. Thus, cellular calls and SMS may represent a very small or restricted subset of social communication. Also, apps such as Facebook messenger have the ability to manage communication from
both internet messaging and SMS, masking SMS activity from the stock app. The use of these apps is very person-specific, and use may vary temporally depending on the person's current situation. This is likely to impact on how comprehensive call and SMS data is as an estimation of SA. With the increasing use of these platforms and internet-based communication, call and SMS data may no longer be a reliable way of capturing phone-based communication. Future studies could address this by aiming to also capture use of social media and internet messaging and calling.

Uniquely, the current study used coded phone numbers to capture the number of people contacted per day (from calls and SMS). This was positively correlated with elevated mood, in line with the argument that people who are elevated are more sociable, and contact more people per day. However, the reverse relationship was not found for depressed mood. This should be interpreted with caution for the same reasons above; phone and SMS, an already limited subset of social interaction (excluding in-person interactions), may be further reduced by the popularity of internet-based social communication.

**Mobility.** Measurements of mobility have varied across studies. It has been measured as a single parameter by Faurholt-Jepsen et al. (2014). They found lowered number of changes in cell tower ID to be correlated with increased depression scores, indicating depressed participants travelled less. In the current study, mobility was measured as a proportion of time, also based on a single parameter (distance travelled per hour). This correlated significantly with elevated mood when weighted to account for missing data and period length. However, no relationship was found with depressed mood. Another approach has been to use a greater number of location parameters, and combine them, to achieve relatively high accuracy, precision, and sensitivity for mood state detection (Grunerbl et al., 2014). Combined, these results may indicate that a single location measure alone is insufficient for predicting mood, and future studies should focus on combining multiple parameters to increase the reliability of this type of SA measure.
**Conversation.** In the current study, ambient audio was recorded to estimate the quantity of conversation a person engaged in. A strength of this approach is that it captures in-person interactions that are usually excluded from studies capturing audio during phone calls only. The audio classifier was trained on an established mixed-speech database, where clean speech samples from a wide variety of speakers (from one database) were mixed with a new collection of background noise representing five different noise scenarios (i.e., car, cafe, home, street, and reverberant), over a wide range of noise levels and active speech proportions. This increases the robustness of the voice detection, even in environments with background noise from televisions or medium to high levels of background speech babble (Dean et al., 2007). Ultimately however, no relationship was found between mood and amount of conversation.

It is possible that the key to utilising voice data successfully is to make direct use of the audio features rather than using it as an estimate of the quantity of SA. Context-sensing approaches have used low level sensor data streams, such as audio features, to infer high-level experiences, such as a person’s location, activity, and social environment (Hamm et al., 2013). This can be useful as a memory aid, and could facilitate recall for people with BD in sessions with their clinician (Murnane et al., 2016). However, a more direct application for detecting mood states in BD has been to use emotion-sensing in audio samples, on an individual basis, to independently recognise and predict depression and (hypo)mania. Emotion features of voice recordings were found on average to be slightly better than social signal features (e.g., short pauses, turn taking, short utterances), and call statistics, though the most useful features varies by person (Muaremi et al., 2014). Current methods of processing audio use all voice detected in the audio, regardless of the identity of the speaker, which can introduce an amount of error into the data when the aim is to quantify or predict using only the target speaker’s voice. In the future, it may be possible for algorithms to differentiate the user’s voice from other speakers, allowing for more accurate predictions of mood.
Strengths

The current study analysed data from a challenging real-world implementation of objective smartphone tracking, over 6-months. The longitudinal design resulted in a considerable amount of data for each participant, and enabled analyses that accounted for individual variation. The study used currently available, accessible smartphone devices, of a variety of models and capabilities. This provided valuable insights into the feasibility of large-scale implementation outside of research settings, where controlling for the model of device is not possible. The UM app also allowed audio to be captured during face to face interactions rather than only during phone calls using a classifier algorithm that was specifically trained to detect voice in noisy environments. Additionally, as this algorithm was person-independent we were able to apply it to the entire data set for each participant, even if they had limited data – a drawback of personalised models. Also, the contacts variable, computed from coded call and SMS phone numbers, showed promise as a relevant measure of SA that has not been used in previous BD research.

Limitations

The current study experienced limitations in a number of areas. Relevant factors included data quality, the technical limitations of the apps, and study design.

Data quality. The current study was limited by the small number of participants. The use of repeated measures increased the overall data set and enabled estimation of the influence of individual differences. However, there were often idiosyncratic, persistent gaps in the data for each individual. Therefore, the small sample size meant that the quality of the overall data set was adversely impacted. For example, SMS activity was not captured for one participant who used Facebook messenger. Additionally, as the data was collected during the every-day life of participants over a long period, participants were using their smartphones as they usually would. This meant that at times sensors would be switched off (by the person or the smartphone) due to low battery power or participants might forget to charge their phone. Also, OS updates would force the app to close, with no recording occurring
until the app was manually restarted, unbeknownst to the participant. This resulted in fewer mood survey periods with data available for analysis than the study duration would suggest. Individuals also vary in the percentage of time they carry their smartphone and where they carry it (e.g., in hand, clothing pocket, wallet or bag), which would impact on the sampling rate and accuracy of audio and location data. In other studies smartphones have been worn on hip holsters (e.g., Lane et al., 2011) or from a lanyard around the neck (e.g., Hamm et al., 2013). However, these methods are increasingly inconvenient with the growing trend for larger screen sizes and smartphones, and are less feasible in long-term studies.

Data quality was also affected by problems with the smartphone apps in interaction with the various smartphone models and OS versions. Participant’s used their own phone during the study and older model smartphones typically experienced greater battery drain, and OS updates introduced new battery optimisation functions that interfered with background data collection processes. Controlling for the model of device may assist in improving data quality for research purposes. For a real world implementation of a smartphone behaviour tracking app, device compatibility is a concern as it is associated with high ongoing IT costs associated with updating and ensuring the functionality of the app across a range of devices.

Applications. There were several technical limitations of the current version of the UM app and the IFTTT app. For the UM app, data was only uploaded when the battery level was at least 90% and simultaneously connected to WiFi. This was by design, to preserve mobile data allocations and battery life. However, in our sample, several participants did not have access to a reliable WiFi connection which caused some problems with their ability to upload data regularly. The UM app was also designed to automatically decrease or suspend location sampling if battery drain was too high. This could also be adjusted by the user within the app settings. As a result, the sampling frequency could vary across participants as a function of their smartphone model and battery life. A low sampling frequency could mean instances of mobility or conversation were missed, affecting the estimation of social interaction.
Another problem was difficulty determining when the app was being switched off by choice, or not running as intended due to software interference. This was also true of the IFTTT app. Collecting additional momentary information on this would reduce missing data by decreasing the time frame for detecting malfunctions and troubleshooting. Using the current IFTTT applets to record call and SMS, it was not possible to distinguish inactivity (true zeros) from missing data. Though some larger segments of missing data had been identified at the time the technical error occurred, and were able to be removed, not all instances of technical malfunction were discovered. It should be noted that there were almost certainly other continuous segments of time where either SMS or calls were missing, or intermittently failing to record. These events were recorded as zero, and remained in the data set, with the effect of lowering the mean level of SA for the period, in the event that there was an underlying technical problem. Due to the relative infrequency of calls compared with SMS, identifying missing data in retrospect is much more difficult for phone calls. With careful scrutiny, this may be possible for SMS, however this was not attempted in the current study as a more effective approach would be to address the root of the problem in future research. Lastly, the original aim for the location data was to create a map of movement to determine time spent at home and spent outside the home (e.g., Grunerbl et al., 2012). Unfortunately this was not available at the time of writing, but may be possible in future.

**Study design.** The design of the current study, to use EMA of mood, and allowing completion any day of the week inadvertently affected the ratio of weekend to week days in each period. This ratio varied as a function of the number of days in the period (e.g., four), and the day of the week the survey was completed (e.g., Friday would mean four weekdays, while Monday would mean only two). This design also limited the current study to moment-in-time correlations and no claims could be made as to shifts in mood states. For example, two successive mood ratings of severe elevated mood, 7 days apart, does not preclude the possibility of a mild or absent elevated mood in between. In this example, the absence of ground truth between ratings precludes the
differentiation between a single manic episode and two hypomanic episodes of shorter duration. Also, the direction of change, would remain unknown for the same reasons. A possibility for future studies with a greater frequency of mood surveys or means of establishing ground truth (e.g., Grunerbl et al., 2012) is to consider the possibility that a change (increase or decrease) in SA levels is associated with mood in BD, and the direction depends on the individual.

The current study was designed to use data from the first 6-months of a 12-month study. The implication of this was a smaller number of participants, and fewer face-to-face assessment time-points. As a result, objective social activity was correlated with weekly self-reported mood in order to increase the number of comparison time-points, and maximise the days of smartphone data that could be used in the analysis. The use of self-reported mood rather than clinician ratings may have influenced the results. Future studies of the full 12-months of data would be better placed to explore the relationship between objective SA and clinician rated mood; there would be an additional two comparison time-points (at 9- and 12-months), and potentially, a larger number of participants, therefore increasing the statistical power of such a study.

**Future Research**

As a matter of practicality, the current study chose not to develop a dedicated smartphone app for BD, instead utilising an existing lifelogging app developed and made available by fellow researchers. One advantage of this was reduced costs and lead in time. However, a downside was the lack of features that may particularly benefit people with BD, such as a feedback mechanism. Data visualisation and exploration was available on the UM web interface. However, participants could also have benefited from quickly accessible, visual feedback directly on their smartphone. Feedback is important to users (Murnane et al., 2016), not only in terms of self-management and behaviour modification, but also for motivation. As a minimum, seeing simple visual feedback of their data daily would reinforce the contribution they were making to the research study. It may also encourage carrying and placement of smartphones in ways
that enhance data quality. For example, if a participant is provided with regular feedback on mobility, they may take extra care to carry their phone on their person to increase accuracy, or keep the microphone unobstructed. It would also give them a means to assess for any problems with the app, such as obviously unlikely data, prompting early troubleshooting of technical issues. Feedback can go beyond simple historical graphs and can provide insight into the factors that impact most on the user’s current mood, or even forecast mood (Frost, Doryab, Faurholt-Jepsen, Kessing, & Bardram, 2013). BeWell, a general wellbeing app, used an ambient display on the lock-screen or wallpaper to display overall scores on sleep, activity, and social interaction. The ambient display used an animation of an aquatic ecosystem to continually represent well-being any time the user interacted with their phone (Lane et al., 2014). Future studies could improve the user experience of the smartphone app, their motivation to continue in the study, and the potential benefits for behavioural modification, by providing features such as these.

The classifier algorithms used in this study were person-independent (the same model used for everyone). This had the advantage that a subset of training data was not needed for each participant, which reduces the study sample size. This also meant that the classifier would still work for participants with limited data. However, in BD research, the most important features for mood state recognition varies by person (Muaremi et al., 2014) justifying the use of person-dependent classification models that are tailored to the individual. A series of studies used supervised and semi-supervised models, using clinician rated mood (every 3-weeks in person, and by phone in between) as the ground truth labels (Maxhuni et al., 2016). Labels were applied to periods 7 days before and 7 days after a mood state examination, based on the assumption that state changes were gradual. Various classifier models were tested, with none outperforming the rest consistently across participants, or between studies of different smartphone sensor data sets (Grunerbl et al., 2014; Maxhuni et al., 2016; Muaremi et al., 2014). However, the Random Forest classification algorithm has been suggested and utilised based on its tendency to perform well on datasets with many features (Faurholt-Jepsen
et al., 2016). These studies typically fuse data from more than one sensor modality, due to the established fact that reliability improves with a larger data set and combining sensors widens the range of days where there is data from at least one sensor to compare with mood ratings. Weighted models based on data availability appear to perform best (Muaremi et al., 2014). Large-scale implementation of person-dependent models requires more work initially, and a training period that creates a delay before the predictive capability of the app is established. However, the increased accuracy, sensitivity, and specificity for detecting and predicting changes in mood state appear to make this investment worthwhile for future research endeavours.

People with BD routinely track a variety of BD-related information independently of clinical treatment, with mood and sleep being the most common (roughly 45% of respondents), followed by sociability (21.9%), exercise (21.5%) and finances (19.3%; Murnane et al., 2016). This could indicate that SA is only a central EWS for one fifth of people with BD, or that SA is too diffuse in its manifestations to easily track. Future research may benefit from personalised approaches or case studies. The difficulty of tracking SA may be especially true using currently available, low- or cost-free methods. In fact, some people have reported using technology-based methods that are non-specific to BD or self-monitoring, such as reviewing chat or phone logs to track sociability (Murnane et al., 2016). Overall, people with BD report that they desire tracking software that automatically and proactively tailors what data it tracks and how often to the individual (Murnane et al., 2016).

Clinical Implications

In clinical practice, it may be more advantageous to focus on EWS that are more reliably measured and more reliably associated with mood across individuals with BD (such as sleep; Bauer et al., 2009) until further advances are made in regard to tracking SA. Clients and clinicians need to be able to easily visualise and review daily data in sessions in an easy to understand graphic format. Ideally clients would use a single app for tracking SA and there would be fewer technical issues. Overall, implementation of SA measures in clinical practice could still be beneficial if person-dependent algorithms
were developed and implemented, and the specific measures able to be tailored to the individual.

Conclusion

Empowering people with BD to improve their recognition and self-management of early signs of depression and manic episodes can potentially delay recurrence of mood episodes and help to avoid preventable adverse outcomes e.g., regarding finances, childcare, and employment (Morriss et al., 2007). The current study presents a novel quantitative approach to measuring SA in BD in a challenging, naturalistic, longitudinal study. Though some objective measures of the quantity of SA correlated significantly with either depressed or elevated mood in the current study, it is clear there is more work needed before SA can be objectively measured reliably. An exploration of the potential reasons and contributing factors has provided insights into the challenges and promising directions for future research. If present, the strength of the relationship between SA and mood may not be strong enough to be a reliable indicator of mood when measured objectively, using person-independent models. More personalised approaches, and potentially fusion of sensor modalities, is warranted in order to automatically and objectively measure SA effectively.


second ACM workshop on mobile systems, applications, and services for healthcare (pp. 31–36). doi:10.1145/2396276.2396280


Table 1

*Participant Demographics*

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<th>BD Med.</th>
<th>MHP</th>
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<td>F</td>
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<td>F</td>
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*Note.* Dx = SCID5 diagnosis; First sym. = Age at first symptoms; Age Dx = Age Diagnosed; BD Med. = Bipolar Disorder Medication; MHP = Mental Health Professional.
Table 1 continued

*Participant Demographics*

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*Note.* Relat. = Relationship status; Employ. = Employment status; Edu. = Highest attained education level; Alc. = Alcohol; THC = Tetrahydrocannabinol/cannabis use; Cig. = Cigarette use.
### Table 2

**Length of Participation and Percentage of Data Availability**

<table>
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<tr>
<th>ID</th>
<th>Days&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Calls</th>
<th>SMS</th>
<th>UM</th>
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</tbody>
</table>

**Note.** Days = days in study; Call = percentage of days with at least one call; SMS = percentage of days with at least one SMS; UM = percentage of hours in the study that the UM app was running; Loc = percentage of hours that the UM app was running where location was recorded; Aud = percentage of hours that the UM app was running that audio was recorded, Mood = number of completed surveys out of possible surveys; NA = not available.<sup>a</sup> Each participant’s duration in the study concluded with either their 6-month review date or the date of the corresponding mood survey; If both were available, the later date was used and if neither were completed, the scheduled 6-month review date was used.<sup>b</sup> Participant left study early and was excluded from SA analyses due to insufficient data. <sup>c</sup> Official departure date was at 6-months, however, participant data mostly ceased after 3-months; Data was retained for analyses.
### Table 3

**Correlations Between Objective Social Activity and Self-Reported Mood**

<table>
<thead>
<tr>
<th></th>
<th>Unweighted</th>
<th></th>
<th></th>
<th>Weighted(^a)</th>
<th></th>
<th></th>
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<tr>
<td></td>
<td>Coeff.</td>
<td>95% CI</td>
<td>(p)</td>
<td>Coeff.</td>
<td>95% CI</td>
<td>(p)</td>
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<tr>
<td><strong>Duration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Depressed</td>
<td>0.004</td>
<td>-0.005 to 0.012</td>
<td>.392</td>
<td>0.004</td>
<td>-0.005 to 0.004</td>
<td>.393</td>
</tr>
<tr>
<td>Elevated</td>
<td>0.002</td>
<td>-0.006 to 0.009</td>
<td>.658</td>
<td>0.001</td>
<td>-0.006 to 0.009</td>
<td>.713</td>
</tr>
<tr>
<td><strong>Calls</strong></td>
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<td></td>
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<tr>
<td>Depressed</td>
<td>0.007</td>
<td>-0.036 to 0.049</td>
<td>.727</td>
<td>-0.004</td>
<td>-0.049 to 0.040</td>
<td>.886</td>
</tr>
<tr>
<td>Elevated</td>
<td>-0.005</td>
<td>-0.042 to 0.032</td>
<td>.801</td>
<td>0.008</td>
<td>-0.029 to 0.044</td>
<td>.661</td>
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<td><strong>SMS</strong></td>
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<tr>
<td>Depressed</td>
<td>0.011</td>
<td>0.004 to 0.017</td>
<td>.002**</td>
<td>0.012</td>
<td>0.005 to 0.018</td>
<td>&lt;.001***</td>
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<td>Elevated</td>
<td>-0.001</td>
<td>-0.007 to 0.005</td>
<td>.840</td>
<td>0.000</td>
<td>-0.007 to 0.006</td>
<td>.989</td>
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<td><strong>Contacts</strong></td>
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<tr>
<td>Depressed</td>
<td>0.009</td>
<td>-0.035 to 0.053</td>
<td>.668</td>
<td>-0.005</td>
<td>-0.053 to 0.043</td>
<td>.867</td>
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<tr>
<td>Elevated</td>
<td>0.029</td>
<td>-0.008 to 0.067</td>
<td>.128</td>
<td>0.050</td>
<td>0.010 to 0.090</td>
<td>.015*</td>
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<td><strong>Convers.</strong></td>
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<tr>
<td>Depressed</td>
<td>-0.041</td>
<td>-0.701 to 0.618</td>
<td>.933</td>
<td>0.369</td>
<td>-0.620 to 1.360</td>
<td>.444</td>
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<tr>
<td>Elevated</td>
<td>-0.157</td>
<td>-0.812 to 0.497</td>
<td>.650</td>
<td>0.086</td>
<td>-0.832 to 1.003</td>
<td>.849</td>
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<tr>
<td><strong>Mobility</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depressed</td>
<td>-0.438</td>
<td>-1.331 to 0.454</td>
<td>.338</td>
<td>-0.424</td>
<td>-1.370 to 0.522</td>
<td>.395</td>
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<tr>
<td>Elevated</td>
<td>0.812</td>
<td>-0.040 to 1.663</td>
<td>.061</td>
<td>1.208</td>
<td>0.360 to 2.056</td>
<td>.006**</td>
</tr>
</tbody>
</table>

*Note.* Averages of the smartphone social activity data were analysed for the period leading up to and including the day of the self-reported mood rating using linear mixed models with random intercept and likelihood ratio tests of the significance. Coeff. = Coefficient. Convers. = Conversation. \(^a\) Duration, Calls, SMS, and Contacts were weighted by the number of days in each period that there was valid data for that type; Conversation and Mobility were weighted by the number of hours in each period that there was data recorded for that type. * \(p < .05\). ** \(p < .01\). *** \(p < .001\).
Figure 1. Each participant’s clinician-rated depression (BDRS) scores collected at baseline 1-week, 3- and 6-month time points.
Figure 2. Each participant’s clinician-rated mania (YMRS) scores collected at baseline, 1-week, 3- and 6-month time points.
Figure 3. Relationship between clinician-rated depression (BDRS) and self-reported depressed mood. Scores were collected at baseline 1-week, 3- and 6-month time points. The bolded line represents the overall average effect. The unbolded lines represent each participant, modelled using a random intercept. Individual data values were plotted using the corresponding participant number.
Figure 4. Relationship between clinician-rated mania (YMRS) and self-reported elevated mood. Scores were collected at baseline 1-week, 3- and 6-month time points. The bolded line represents the overall average effect. The unbolded lines represent each participant, modelled using a random intercept. Individual data values were plotted using the corresponding participant number.
Appendix A

British Journal of Psychology Author Guidelines

The Editorial Board of the British Journal of Psychology is prepared to consider for publication:

(a) reports of empirical studies likely to further our understanding of psychology
(b) critical reviews of the literature
(c) theoretical contributions Papers will be evaluated by the Editorial Board and referees in terms of scientific merit, readability, and interest to a general readership.

All papers published in The British Journal of Psychology are eligible for Panel A: Psychology, Psychiatry and Neuroscience in the Research Excellence Framework (REF).

1. Circulation

The circulation of the Journal is worldwide. Papers are invited and encouraged from authors throughout the world.

2. Length

Papers should normally be no more than 8000 words (excluding the abstract, reference list, tables and figures), although the Editor retains discretion to publish papers beyond this length in cases where the clear and concise expression of the scientific content requires greater length.

3. Submission and reviewing

All manuscripts must be submitted via Editorial Manager. The Journal operates a policy of anonymous (double blind) peer review. We also operate a triage process in which submissions that are out of scope or otherwise inappropriate will be rejected by the editors without external peer review to avoid unnecessary delays. Before submitting, please read the terms and conditions of submission and the declaration of competing interests. You may also like to use the Submission Checklist to help you prepare your paper.
4. Manuscript requirements

- Contributions must be typed in double spacing with wide margins. All sheets must be numbered.
- Manuscripts should be preceded by a title page which includes a full list of authors and their affiliations, as well as the corresponding author’s contact details. You may like to use this template. When entering the author names into Editorial Manager, the corresponding author will be asked to provide a CRediT contributor role to classify the role that each author played in creating the manuscript. Please see the Project CRediT website for a list of roles.
- The main document must be anonymous. Please do not mention the authors’ names or affiliations (including in the Method section) and refer to any previous work in the third person.
- Tables should be typed in double spacing, each on a separate page with a self-explanatory title. Tables should be comprehensible without reference to the text. They should be placed at the end of the manuscript but they must be mentioned in the text.
- Figures can be included at the end of the document or attached as separate files, carefully labelled in initial capital/lower case lettering with symbols in a form consistent with text use. Unnecessary background patterns, lines and shading should be avoided. Captions should be listed on a separate sheet. The resolution of digital images must be at least 300 dpi. All figures must be mentioned in the text.
- All articles should be preceded by an Abstract of between 100 and 200 words, giving a concise statement of the intention, results or conclusions of the article.
- For reference citations, please use APA style. Particular care should be taken to ensure that references are accurate and complete. Give all journal titles in full and provide DOI numbers where possible for journal articles.
- SI units must be used for all measurements, rounded off to practical values if appropriate, with the imperial equivalent in parentheses.
• In normal circumstances, effect size should be incorporated.
• Authors are requested to avoid the use of sexist language.
• Authors are responsible for acquiring written permission to publish lengthy quotations, illustrations, etc. for which they do not own copyright. For guidelines on editorial style, please consult the APA Publication Manual published by the American Psychological Association.
A/Prof Frances Kay Lambkin
Principal Investigator
Lecturer
School of Medicine and Public Health
Old Waratah Post Office
22 Turton Road,
Waratah
NSW, 2298

DO YOU HAVE BIPOLAR DISORDER?

Are you interested in participating in a 12-month study using the Fitbit Charge HR?

A study is being conducted which will track existing patterns of sleep, physical activity, socialisation, and mood in people who have a diagnosis of Bipolar Disorder I or II.

The Fitbit Charge HR will be provided to participants.

Individual face-to-face meetings with a member of our research team will also be required periodically over the course of the study at The Psychology Clinic at UoN.

The assessments including the time frame:

1. Initial assessment (2 hours)
2. A one week check in (1 hour)
3. 3-month assessment (1 hour)
4. 6-month assessment (1 hour)
5. 9-month assessment (1 hour)
6. 12-month assessment (1 hour)
7. 1-month post-study review (1 hour)
8. 3-month post-study review (1 hour)
9. 6-month post-study review (1 hour)

Participants will receive a small reimbursement for each stage of their participation.

Eligible participants will:

• have English as their first language;
• be aged between 18 and 50 years of age;
• currently be under the care of a GP/Psychiatrist;
• not have a serious medical condition (e.g. epilepsy, diabetes);
• have an Android smartphone.

If you would like to participate, or if you would like any additional information, please contact Dr Tanya Hanstock by email at Tanya.Hanstock@newcastle.edu.au or by phone on (02) 4921 5641.

Complaints about this research

This project has been approved by the University’s Human Research Ethics Committee, Approval No. H-2016-006708/08/2016. Should you have concerns about your rights as a participant in this research, or you have a complaint about the manner in which the research is conducted, it may be given to the researcher, or, if an independent person is preferred, to the Senior Human Research Ethics Officer, Research Office, The Chancellery, The University of Newcastle, University Drive, Callaghan NSW 2308, Australia, telephone (02) 49216333, email human-ethics@newcastle.edu.au
Appendix C

University and Health Ethics Approval

HUMAN RESEARCH ETHICS COMMITTEE

Notification of Expedited Approval

To Chief Investigator or Project Supervisor:  
Doctor Frances Kay-Lambkin

Cc Co-investigators / Research Students:  
Doctor Tanya Hanstock
Professor Simon Dennis
Conjoint Associate Professor Rachel Heath
Ms Catherine King
Ms Madeleine Drew
Ms Nicole Carter

Re Protocol:  
Utilising Life Logging and New Technologies to Help Predict Relapse in Bipolar Disorder (Considered in consultation with HNEHREC)

Date:  
12-Aug-2016

Reference No:  
H-2016-0067

Date of Initial Approval:  
08-Aug-2016

Thank you for your Response to Conditional Approval submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under Expedited review by the Chair/Deputy Chair.

I am pleased to advise that the decision on your submission is Approved effective 08-Aug-2016.

In approving this protocol, the Human Research Ethics Committee (HREC) is of the opinion that the project complies with the provisions contained in the National Statement on Ethical Conduct in Human Research, 2007, and the requirements within this University relating to human research.

Approval will remain valid subject to the submission, and satisfactory assessment, of annual progress reports. If the approval of an External HREC has been "noted" the approval period is as determined by that HREC.

The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal Certificate of Approval will be available upon request. Your approval number is H-2016-0067.

If the research requires the use of an Information Statement, ensure this number is inserted at the relevant point in the Complaints paragraph prior to distribution to potential participants. You may then proceed with the research.

**Conditions of Approval**

This approval has been granted subject to you complying with the requirements for Monitoring of Progress, Reporting of Adverse Events, and Variations to the Approved Protocol as detailed below.

**PLEASE NOTE:**

In the case where the HREC has "noted" the approval of an External HREC, progress reports and reports of adverse events are to be submitted to the External HREC only. In the case of Variations to the approved protocol, or a Renewal of approval, you will apply to the External HREC for approval in the first instance and then Register that approval with the University's HREC.
Monitoring of Progress

Other than above, the University is obliged to monitor the progress of research projects involving human participants to ensure that they are conducted according to the protocol as approved by the HREC. A progress report is required on an annual basis. Continuation of your HREC approval for this project is conditional upon receipt, and satisfactory assessment, of annual progress reports. You will be advised when a report is due.

Reporting of Adverse Events

1. It is the responsibility of the person first named on this Approval Advice to report adverse events.
2. Adverse events, however minor, must be recorded by the investigator as observed by the investigator or as volunteered by a participant in the research. Full details are to be documented, whether or not the investigator, or his/her deputies, consider the event to be related to the research substance or procedure.
3. Serious or unforeseen adverse events that occur during the research or within six (6) months of completion of the research, must be reported by the person first named on the Approval Advice to the (HREC) by way of the Adverse Event Report form (via RIMS at https://rims.newcastle.edu.au/login.asp) within 72 hours of the occurrence of the event or the investigator receiving advice of the event.
4. Serious adverse events are defined as:
   - Causing death, life threatening or serious disability.
   - Causing or prolonging hospitalisation.
   - Overdoses, cancers, congenital abnormalities, tissue damage, whether or not they are judged to be caused by the investigational agent or procedure.
   - Causing psycho-social and/or financial harm. This covers everything from perceived invasion of privacy, breach of confidentiality, or the diminution of social reputation, to the creation of psychological fears and trauma.
   - Any other event which might affect the continued ethical acceptability of the project.
5. Reports of adverse events must include:
   - Participant’s study identification number;
   - Date of birth;
   - Date of entry into the study;
   - Treatment arm (if applicable);
   - Date of event;
   - Details of event;
   - The investigator’s opinion as to whether the event is related to the research procedures; and action taken in response to the event.
6. Adverse events which do not fall within the definition of serious or unexpected, including those reported from other sites involved in the research, are to be reported in detail at the time of the annual progress report to the HREC.

Variations to approved protocol

If you wish to change, or deviate from, the approved protocol, you will need to submit an Application for Variation to Approved Human Research (via RIMS at https://rims.newcastle.edu.au/login.asp). Variations may include, but are not limited to, changes or additions to investigators, study design, study population, number of participants, methods of recruitment, or participant information/consent documentation. Variations must be approved by the (HREC) before they are implemented except when Registering an approval of a variation from an external HREC which has been designated the lead HREC, in which case you may proceed as soon as you receive an acknowledgement of your Registration.

Linkage of ethics approval to a new Grant

HREC approvals cannot be assigned to a new grant or award (ie those that were not identified on the application for ethics approval) without confirmation of the approval from the Human Research Ethics Officer on behalf of the HREC.
Best wishes for a successful project.

Professor Allyson Holbrook  
Chair, Human Research Ethics Committee

For communications and enquiries:  
Human Research Ethics Administration

Research Services  
Research Integrity Unit  
NIER, Block C  
The University of Newcastle  
Callaghan NSW 2308  
T +61 2 492 17894  
Human-Ethics@newcastle.edu.au


Linked University of Newcastle administered funding:

<table>
<thead>
<tr>
<th>Funding body</th>
<th>Funding project title</th>
<th>First named investigator</th>
<th>Grant Ref</th>
</tr>
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</table>

SOCIAL ACTIVITY IN BIPOLAR DISORDER
15 August 2016

Dr Tanya Hanstock  
School of Psychology  
Faculty of Science, Information & Technology  
University of Newcastle

Dear Dr Hanstock,

Re: Utilising Life Logging and New Technologies to Help Predict Relapse in Bipolar Disorder (16/03/16/4.05)

HNEHREC Reference No: 16/03/16/4.05  
NSW HREC Reference No: HREC/16/HNE/65

Thank you for submitting the above application for single ethical review. This project was first considered by the Hunter New England Human Research Ethics Committee at its meeting held on 16 March 2016. This Human Research Ethics Committee is constituted and operates in accordance with the National Health and Medical Research Council’s National Statement on Ethical Conduct in Human Research (2007) (National Statement) and the CPMP/ICH Note for Guidance on Good Clinical Practice. Further, this Committee has been accredited by the NSW Department of Health as a lead HREC under the model for single ethical and scientific review. The Committee’s Terms of Reference are available from the Hunter New England Local Health District website.

I am pleased to advise, the Hunter New England Human Research Ethics Committee has determined that the above protocol meets the requirements of the National Statement on Ethical Conduct in Human Research and following acceptance of the requested clarifications and revised study documentation by Dr Nicole Gerrand Manager, Research Ethics & Governance under delegated authority from the Committee, grants ethical approval of the above project.

The following documentation has been reviewed and approved by the Hunter New England Human Research Ethics Committee:

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<th>Document</th>
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<th>Date</th>
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<tr>
<td>NEAF [Submission Code: AU/1/EE6429]</td>
<td></td>
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<tr>
<td>Revised Study Flyer</td>
<td></td>
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<tr>
<td>Participant Information Sheet</td>
<td>Version 3</td>
<td>13 July 2016</td>
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<tr>
<td>Participant Consent Form</td>
<td>Version 2</td>
<td>28 May 2016</td>
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<td>The Bipolar Depression Rating Scale (BDRS)</td>
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<td>Self-Report Stimulation Measures</td>
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<tr>
<td>Young Mania Rating Scale (YMRS)</td>
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Approval has been granted for this study to take place at the following site:

- Hunter New England Mental Health

Approval from the Hunter New England Human Research Ethics Committee for the above protocol is given for a maximum of 5 years from the date of this letter, after which a renewal application will be required if the protocol has not been completed.

The National Statement on Ethical Conduct in Human Research (2007), which the Committee is obliged to adhere to, include the requirement that the committee monitors the research protocols it has approved. In order for the Committee to fulfil this function, it requires:

- A report of the progress of the above protocol be submitted at 12 monthly intervals. Your review date is August 2017. A proforma for the annual report will be sent two weeks prior to the due date.

- A final report must be submitted at the completion of the above protocol, that is, after data analysis has been completed and a final report compiled. A proforma for the final report will be sent two weeks prior to the due date.

- All variations or amendments to this protocol, including amendments to the Information Sheet and Consent Form, must be forwarded to and approved by the Hunter New England Human Research Ethics Committee prior to their implementation.

- The Principal Investigator will immediately report anything which might warrant review of ethical approval of the project in the specified format, including:
  - any serious or unexpected adverse events

  - Adverse events, however minor, must be recorded as observed by the Investigator or as volunteered by a participant in this protocol. Full details will be documented, whether or not the Investigator or his deputies considers the event to be related to the trial substance or procedure. These do not need to be reported to the Hunter New England Human Research Ethics Committee

  - Serious adverse events that occur during the study or within six months of completion of the trial at your site should be reported to the Manager, Research Ethics & Governance Office, of the Hunter New England Human Research Ethics Committee as soon as possible and at the latest within 72 hours.

• Serious adverse events are defined as:
  - Causing death, life threatening or serious disability.
  - Cause or prolong hospitalisation.
  - Overdoses, cancers, congenital abnormalities whether judged to be caused by the investigational agent or new procedure or not.
  - Unforeseen events that might affect continued ethical acceptability of the project.

• If for some reason the above protocol does not commence (for example it does not receive funding); is suspended or discontinued, please inform Dr Nicole Gerrand, as soon as possible.

You are reminded that this letter constitutes ethical approval only. You must not commence this research project at a site until separate authorisation from the Chief Executive or delegate of that site has been obtained.

A copy of this letter must be forwarded to all site investigators for submission to the relevant Research Governance Officer.

Should you have any concerns or questions about your research, please contact Dr Gerrand as per the details at the bottom of the page. The Hunter New England Human Research Ethics Committee wishes you every success in your research.

Please quote 16/03/16/4.05 in all correspondence.

The Hunter New England Human Research Ethics Committee wishes you every success in your research.

Yours faithfully

For: Ms M Hunter
Chair
Hunter New England Human Research Ethics Committee
Appendix D

Participant Consent and Information Form

Information Statement for the Research Project:
Lifelogging and Bipolar Disorder
Document Version 3: 13/07/16

The Research Team:

Associate Professor Frances Kay-Lambkin, School of Medicine & Public Health

Dr Tanya Hanstock: Senior Lecturer, School of Psychology and PhD Candidate in the School of Medicine & Public Health

Nicole Carter, Clinical Psychology Masters Candidate

Madeleine Drew, Clinical Psychology Masters Candidate

Catherine King, Clinical Psychology Masters Candidate

Conjoint Associate Professor Rachel Heath, School of Psychology

Professor Simon Dennis, School of Psychology

You are invited to participate in the research project Lifelogging and Bipolar Disorder, which is being conducted by members of the above Research Team at the University of Newcastle.

The research is part of the studies of three students (Nicole Carter, Madeleine Drew, and Catherine King) in the Master of Clinical Psychology program at the University of Newcastle. It is also part of Dr Tanya Hanstock’s (Senior Lecturer in the School of Psychology) PhD candidature in the School of Medicine and Public Health. These students are being supervised by Professor Simon Dennis (School of Psychology) and Associate Professor Frances Kay-Lambkin (School of Health and Public Medicine) and assisted with data analysis by Conjoint Associate Professor Rachel Heath (School of Psychology).
Why is the research being done?
This research project examines how lifestyle patterns can predict symptom changes in people diagnosed with Bipolar Disorder. We are particularly interested in examining patterns of sleep, physical activity, and social stimulation (how much socialising you do) as shown by people with Bipolar Disorder. Over a 12-month period, we will monitor these lifestyle activities via a Fitbit Charge HR (a fitness tracker), and two free android smartphone applications; Unforgettable Me (designed by researchers at the University of Newcastle), and the IF app which is commercially available. You will also be sent a text message with a link to a short online mood survey, which we will ask you to complete once a week. We hope that this research will help clinicians to predict and potentially prevent relapse in patients diagnosed with Bipolar Disorder.

Who can participate in the research?
You are invited to take part in this study because you responded to an advertisement that described the research project and what would be required of you. This study will be suitable for you if you:

- have a formal diagnosis of Bipolar Disorder Type I or Type II;
- have English as your first language;
- are aged between 18 and 50 years of age;
- are currently under the care of a GP or Psychiatrist;
- are stable on medication; and
- have an Android smartphone.

This study is not suitable for you if you have another serious medical condition (such as epilepsy or diabetes) or if you are acutely unwell, suicidal, have a brain injury, intellectual impairment or learning disorder.

What would you be asked to do?
If you agree to participate, you will be asked to attend the University of Newcastle Psychology Clinic (see attached map and parking information) on a Wednesday for six face-to-face assessments over the course of a 12-month period. These will include an initial assessment, an assessment one-week later to discuss any questions or concerns you might have about the study or the devices we are using to measure your behaviour, as well as assessments at 3, 6, 9, and 12 months after the initial assessment. We will also invite you to attend three follow-up visits; at 1, 3 and 6 months after we have completed the data collection. Each assessment will last for approximately one hour, except for the first visit, which will take up to two hours.

During the first face-to-face assessment, you will be asked to complete a number of questionnaires. These will ask you to provide information about your diagnosis, symptom severity, and lifestyle habits. We will also record your height and weight. At subsequent assessments, we will repeat some of these measures. The measurement devices we are using in this study will also be set up for you at this time.
At the first assessment, you will be provided with a Fitbit Charge HR (a wrist-worn fitness-tracking device), which we would like you wear for the 12 months of the study. The device will record your sleep-wake cycles and levels of physical activity. We will also set up the Android smartphone apps for you, and demonstrate how you can access the weekly online mood-rating questionnaire. Please see below for further information about how we will use these devices.

At this first assessment, you will also be asked for your consent so that the person conducting this assessment (Catherine, Nicole, Madeleine or Tanya) can communicate with the health professional overseeing your mental health care and treatment. This person will be able to verify your diagnosis for our research purposes and ensure that your safety and wellbeing are maintained throughout the study. Please see the consent form for more information about the circumstances under which your health care professional may need to be contacted.

**A Summary of the Assessments, their Durations and Reimbursements:**

1. Start of study (2 hours) $20
2. Week 2 assessment (1 hour) $10
3. 3-month assessment (1 hour) $10
4. 6-month assessment (1 hour) $10
5. 9-month assessment (1 hour) $10
6. 12-month assessment (1 hour) $10
7. 1-month post-study review (1 hour) $10
8. 3-month post-study review (1 hour) $10
9. 6-month post-study review (1 hour) $10

All assessments will occur at The University of Newcastle Psychology Clinic. When you complete the study, your total reimbursement will be $100. We would also like to contact you after the study has been completed to invite you to take part in future studies related to Bipolar Disorder.

**What choice do you have?**

Participation in this research is entirely voluntary. Before you can take part, your informed consent will be required. Whether or not you decide to participate, your decision will not disadvantage you or affect the current treatment you are receiving, nor will it adversely affect your relationship with the University of Newcastle or the researchers.

Even if you do decide to participate in this project, you may withdraw at any time without giving a reason by contacting Associate Professor Kay-Lambkin whose contact details are at the top of this Information Sheet. If this does occur please let us know so we can assist you to deactivate all apps and accounts involved in data collection.

**How much time will it take?**

The data collection for this long-term project will take about 12 months with follow-up interviews occurring up to six months later. We will ask that you wear the Fitbit Charge HR device at all times, where possible, for a period of 12 months and attend six face-to-face assessments during this time. As stated above, the first assessment will take up to two hours, and
each subsequent assessment will take approximately one hour. It should only take you about five minutes each week to complete a brief online mood-rating questionnaire once a week. When the 12-month data collection period has concluded, we will invite you to attend three face-to-face follow-up assessments after one, three and six months, each of these assessments taking approximately one hour.

**What are the risks and benefits of your participating in this project?**

Each participant will receive a Fitbit Charge HR. You will also be given a gift voucher at each face-to-face assessment you attend in order to reimburse you for your time associated with this research.

You may not benefit personally from participating in this research study. However, we hope to use the information you provide to monitor the progress of people diagnosed with Bipolar Disorder and improve our ability to predict relapse. By so doing, we hope to improve the quality of life for people diagnosed with Bipolar Disorder.

Some people experience skin irritation from wearing the Fitbit Charge HR on their wrist. Please contact the researchers if this occurs, as we will suggest other ways you can wear the Fitbit device so that this problem can be avoided.

A clinical psychologist, Dr Tanya Hanstock, will be available should you require psychological support during the face-to-face assessments. We have also provided you with the contact details of appropriate mental health services at the end of this document should you experience any distress while participating in this study.

**How will your privacy be protected?**

Only the members of the research team will have access to your identifiable information while they conduct face-to-face assessments with you, and contact your treating health professional in regards to these appointments. For all other research purposes, you will be given a participant number. In order to protect your confidentiality, this number will be used to identify all the information you provide for this project.

For specific information on how the automatically collected Fitbit and smartphone data will be accessed by the researchers, please read the technology information provided below. Wherever possible, we have indicated how you can examine and then possibly withdraw your data prior to it being accessed by the researchers.

Any information collected by the researchers that might identify you will be stored securely at the University of Newcastle and be accessible only by the researchers, unless you consent otherwise. There are limits to confidentiality, as required by law, and these will be discussed with you in detail in the first face-to-face meeting, prior to beginning the assessment. Data will be retained for at least five years. Your information will only be used for the purpose of this research study and it will only be disclosed without any personal identification with your permission.
How will the information collected be used?
The information collected from this research project will form a substantial component of the Masters theses to be submitted by the student researchers, Nicole Carter, Madeleine Drew and Catherine King. It also forms part of PhD research being conducted by Dr Tanya Hanstock. It is anticipated that the results of this research study will be published and/or presented in a variety of public forums. In any publication and/or presentation, information will be provided in such a way that you will not be able to be identified. Your data without identifiers may also be shared with other research groups to further our knowledge of Bipolar Disorder.

You have a right to receive feedback about the overall results of this study. If you request it, this feedback will be provided via email or post after the study has been completed.

What do you need to do to participate in this research project?
Please read this Information Statement carefully and be sure that you understand its contents before you consent to participate. If there is anything you do not understand, or if you have any questions, please contact Associate Professor Frances Kay-Lambkin, whose contact details are provided below.

If you would like to participate, please complete the attached Consent Form and return it directly to the researchers. Alternatively, you can return it to us via mail, addressed to Associate Professor Kay-Lambkin at the address at the top of this form. Please ensure you keep a copy of this Participant Information Statement for future reference throughout the study. A member of the research team will then contact you to arrange a convenient time for the initial interview.

Further information
If you would like further information about this study, please contact:
Associate Professor Frances Kay-Lambkin
School of Health & Public Medicine
University of Newcastle
University Dr, Callaghan NSW 2308
Phone: (02) 49854309
Email: Frances.Kaylambkin@newcastle.edu.au

Thank you for considering this invitation.
Complaints about the Conduct of this Research Project

This research has been approved by the University of Newcastle’s Human Research Ethics Committee, Reference H-2016-0067.

Should you have concerns about your rights as a participant in this research, or if you have a complaint about the manner in which the research is being conducted, you may contact Associate Professor Kay-Lambkin, or if you would prefer to discuss the matter with an independent person please contact:

The Senior Human Research Ethics Officer
Research Office, The Chancellery,
The University of Newcastle,
University Drive, Callaghan,
NSW, 2308, Australia
Phone: (02) 4921 6333 or
Email: human-ethics@newcastle.edu.au.
INFORMATION ABOUT THE DEVICES AND COMPUTER PROGRAMS WE WILL BE USING IN THIS PROJECT

Fitbit Charge HR

Fitbit Account Set-up and Privacy:
A Fitbit account and password has been set up for you using a free Gmail address and your participant ID instead of your name. This means that the researchers will only be able to see this code and they will not know whether the data belongs to you. Your information will be stored securely and only accessed by necessary members of the research team, using your participant ID, so that your identity will be protected and privacy maintained at all times. No identifiable data will be published. Your name will not appear on any data sets.

At the initial assessment the research team will assist you to install, then log in to the Fitbit app on your Android phone. You will be able to view your Fitbit results on your phone app or on the Fitbit Dashboard, which can be viewed on any web browser. The researchers will securely store these login details for the purposes of remotely accessing and downloading your data for analysis by logging into the Fitbit web interface.

Once your participation in the study has concluded we will assist you to transfer the Fitbit login to your name and to change the password. Once complete the research team will no longer have access to your account or data.

Password Recovery:
The Fitbit app will only require you to login once during set up. However, if your device is reset, or the application is re-installed you will need to re-enter your password. If you forget your password during the study, please contact Dr Tanya Hanstock for assistance. Please do not use the Fitbit password recovery service. Doing so will send a password reset request to the research team.

Setting Up Your Fitbit Charge HR:
In the initial appointment you will be shown how to turn on, calibrate, and sync your Fitbit with your Android smartphone.

How to wear the Fitbit Charge HR:
It is recommended that you wear the Fitbit charge HR on your non-dominant hand, one finger’s width above the wrist bone, and not too tight, as suggested by Fitbit documentation. For better heart rate readings during exercise, it is recommended that you wear the band so that it’s secure, but not too tight, and to wear the band higher on your wrist (about 2-3 finger widths above your wrist bone) and then to lower the band and loosen it after exercise, as suggested by Fitbit documentation.
Please note that the Fitbit Charge HR can cause skin irritation if worn constantly. If this occurs, please remove the device, seek first aid if necessary, and contact the Project Manager.

**When to Wear the Fitbit Charge HR:**
Please be aware that the Fitbit Charge HR is not waterproof. It will need to be removed before showering or partaking in aquatic sports and replaced as soon as possible afterwards. Please wear the Fitbit Charge HR throughout the day and while sleeping, except when showering, partaking in aquatic sports, and during recharging. During sleep recording, please leave the setting as “Normal,” which is indicated as “appropriate for most users” by Fitbit documentation.

**Charging the FitBit Charge HR:**
The Fitbit Charge HR needs to be charged through a USB connection on either a computer or directly using a USB charging device, such as the one you use to recharge your Android smartphone. The battery lasts for up to five days, and it will need to be connected for several hours to recharge. You will receive a warning on the small screen of the Fitbit and in the app when you need to recharge the device. Try to recharge the Fitbit during the day so that the sleep measurements will not be disrupted.

**Syncing Your Data:**
The Fitbit device is automatically synchronized with your smartphone app whenever Bluetooth is enabled. If you are flying, setting your smartphone to airplane mode will not affect the recording of Fitbit data but no data will be transferred to your app during this time. Once you switch off airplane mode, Bluetooth will be enabled and data synchronization will resume. Whenever you attach your Fitbit to a computer via the USB cable, data will be automatically transferred to the application.

Please see https://help.fitbit.com for further information on device compatibility and features.

**Technical Assistance:**
If you have any problems with the technology for this study, please contact Dr Tanya Hanstock via email at Tanya.Hanstock@newcastle.edu.au
Unforgettable Me

What is it?
The Unforgettable Me smartphone application automatically collects information about your physical activity, where you have been and what types of brief sounds you are hearing in your vicinity. No one will be able to detect what you have been saying based on these very short speech samples and your privacy will always be maintained. By tracking where you have been, using wifi and GPS signals, the researchers will be able to evaluate how much travel and how far you travel each day. The researchers will have a rough understanding of where you have been, but not precise locations. You can choose to delete these segments of data and will be shown how to do so.

Account Set-up and Privacy:
Unforgettable Me is an Android smartphone application developed by the University of Newcastle and available for download from the Google Play store. The data collected by the Unforgettable Me app is stored locally on your smartphone for a set number of days of your choosing (up to seven). After this, the data is automatically uploaded to the Unforgettable Me website (http://unforgettable.me), where the research team will be able to remotely access and download your data. This means that the researchers will only be able to access your Unforgettable Me data once it is uploaded by the smartphone application to the website. You are able to access your data from within the app and select any data within the last seven days that you do not wish to share with the research team so that it will be excluded from this upload. You are also able to enter the app at any time and temporarily turn off the data collection for physical activity, location, and sound. These features will be set up and demonstrated to you during the initial assessment.

An Unforgettable Me account and password has been created for you. These login details will enable you to use the Unforgettable Me smartphone application. The researchers will also securely store these login details for the purposes of remotely accessing and downloading your data for analysis.

The account uses your participant ID instead of your name. This means that the researchers will only be able to see this code and they will not know whether the data belongs to you. Your information will be stored securely and only accessed by necessary members of the research team, using your participant ID, so that your identity will be protected and privacy maintained at all times. No identifiable data will be published. Your name will not appear on any data sets.

Password Recovery:
The Unforgettable Me application will only require you to login once during set up. However, if your device is reset, or the application is re-installed you will need to re-enter your password. If you forget your password, please contact Dr Tanya Hanstock for assistance.
Charging Your Smartphone:
The Unforgettable Me application will run in the background on your Android smartphone. Please make sure that your phone is recharged when its battery is low. If you have any problems with keeping your phone charged, please contact Dr Tanya Hanstock for assistance.

Syncing Your Data:
The Unforgettable Me app will upload data to its companion website when your phone is at least 90% charged and connected to Wi Fi so it will keep saving data for as many days as your phone has available space. The Unforgettable Me app will send your data to a secure computer at the University of Newcastle once every seven days by default. At any time before the seven days has expired, you can edit your data within the app. After this time, the data will be deleted from your phone and will only be accessible using the Unforgettable Me website. The researchers will show you how to do this at your initial assessment.

Technical Assistance:
If you have any problems with the technology for this study, please contact Dr Tanya Hanstock via email at Tanya.Hanstock@newcastle.edu.au
IFTTT – If This Then That

What is it?
The IF app (by IFTTT), is available on the Google Play store, and will be used to automatically create a record of answered, missed and dialled phone calls and sent and received SMS, and send it to the Unforgettable Me website where it will be stored and accessed by the researchers. The information collected will include the time of day and duration (for phone calls). Phone numbers will be obscured so that researchers will be able to analyse the quantity and frequency of contact with each obscured phone number. However, the actual phone numbers, names, and the content of SMS will not be recorded on the Unforgettable Me website.

Account Set-up and Privacy:
The IF application works by running an ‘applet’ to automatically collect the required information and send it to the Unforgettable Me website where it will be stored securely. An applet is triggered and executed each time your phone receives or sends an SMS, and each time you answer or miss a phone call or dial a phone number. The research team has already set up the applets for you.

There are five applets (Sent SMS, Received SMS, Calls outgoing, Calls missed, Calls answered). You will be able to temporarily turn off the ‘applets’ that record SMS and phone call data using a toggle from within the app if you want to temporarily stop sharing this data with the research team. Please remember to turn it back on from within the app when you wish to resume sharing this data. Logging out of the IF app will not stop data collection. Uninstalling the IF app will stop data collection until the IF app is reinstalled, at which time data collection will automatically resume. To permanently stop data collection once you have finished participating in the study, please turn off or delete the five applets used in this study or deactivate your IFTTT research account. To ensure your privacy, the research team will deactivate all research IFTTT accounts from the IFTTT website, as each participant finishes their participation in the study. You can continue to use the IF app in future for personal use by creating a new IFTTT account using your personal details.

If you wish to delete your data after it has been recorded you can do so using the Unforgettable Me website and your Unforgettable Me login. You will be shown how to do this in the initial assessment.

Setting Up the IF App:
In the initial appointment you will be assisted to install and set up the IF app on your Android smartphone using a pre-existing username and password.

Charging Your Smartphone:
This application will use a percentage of your smartphone battery charge. You may need to charge your phone slightly more frequently than you are used to. If you are experiencing trouble
with the battery life of your phone and are unable to charge it frequently enough please contact Dr Tanya Hanstock.

**Syncing Your Data:**

The IFTTT app will need to use an Internet connection to send your data to the Unforgettable Me website. It will upload your data automatically whenever it has an Internet connection. The app settings can be used to toggle permission for the app to upload using cellular data or Wi-Fi only (default).

The data collected by IFTTT is automatically sent to the Unforgettable Me website so the research team will not be accessing your account on the IFTTT website during the study. However, the IFTTT app currently creates an activity record within your login that includes actual phone numbers, names, and a short preview of SMS content. This cannot be viewed unless logged into the account. Though the research team will not access this account during the study, you may wish to change your login details for this account. To do this, please log in on the IFTTT website using the login details we have provided to you. Navigate to Settings on the top right drop down menu. Please leave the username the same to protect your identity, but change both the password, and the email address (which is used for password recovery and important updates such as error messages for active applets). If there are any problems or errors with your IFTTT applets in the future we will discuss how to assist you with this while maintaining your privacy. You may need to come to the university if we cannot guide you over the phone.

**Technology Assistance:**

If you have any problems with your technology for this study, please contact Dr Tanya Hanstock via email at Tanya.Hanstock@newcastle.edu.au
Mood Survey

You will be asked to complete a brief, online mood-rating survey each week. A weekly reminder will be sent to your mobile phone prompting you to complete the survey via a web link contained within the SMS message. The survey should take no more than a few minutes to complete. The survey is most effective when completed as close to the time it is received as possible.

The survey asks you to rate how you feel at the moment and gives you a four-choice scale that you can use to rate your feelings. There is also a section for you to add additional comments if you wish. Your data will be sent to the researchers using your participant ID. No one will know that this data comes from you.

Technology Assistance:

If you have any problems with the technology for this study, please contact Dr Tanya Hanstock via email at tanya.hanstock@newcastle.edu.au
Mental Health Services Contact Details

24 Hour Emergency Support:

<table>
<thead>
<tr>
<th>Service</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifeline (free call from mobile)</td>
<td>13 11 14</td>
</tr>
<tr>
<td>Suicide Call Back Service</td>
<td>1300 659 467</td>
</tr>
<tr>
<td>NSW Mental Health Line</td>
<td>1800 011 511</td>
</tr>
<tr>
<td>Men’s Helpline</td>
<td>1300 789 978</td>
</tr>
<tr>
<td>NSW Rural Mental Health Line</td>
<td>1800 656 463</td>
</tr>
</tbody>
</table>

Psychiatric Emergency Care Centre
Mater Mental Health Centre
Edith St Waratah NSW 2298
Phone: 1800 011 511

Lake Macquarie Mental Health
Mater Mental Health Centre
Edith St Waratah NSW 2298
Phone: 4033 5336

Mental Health Substance Use (North)
Edith St Waratah NSW 2298
Phone: 4033 5460
Mental Health Substance Use (South)
Edith St Waratah NSW 2298
Phone: 4033 5440

Newcastle Adult Mental Health and Rehabilitation Team
Barrack Building, James Fletcher Campus
72 Watt St Newcastle NSW 2300
Phone: 4964 7000, 4964 7001

Lake Macquarie Adult Mental Health and Rehabilitation Team
James Fletcher Campus, 72 Watt St
Newcastle NSW 2300
Phone: 4904 9000, 4904 9049

Mental Health and Substance Use
McAuley Building, Mater Campus
Edith St Waratah NSW 2298
Phone: 4033 5600, 4033 5606

Hunter Valley Hospital Inpatient services:

Short Term Acute
Maitland Hospital
550 High St
Maitland NSW 2320
Phone: 4939 2456

Hunter Valley Rehabilitation Team
555 High St
Maitland NSW 2320
Phone: 4939 2940

Adult Mental Health
555 High St
Maitland NSW 2320
Phone: 1800 011 511
Appendix E

Bipolar Depression Rating Scale (BDRS)

The Bipolar Depression Rating Scale (BDRS)
Rater Manual

General Instructions

The BDRS is designed to measure the severity of depressive symptoms in bipolar depression. The BDRS is validated for clinical use by trained raters. The following conventions are designed to standardise scoring of the BDRS. Based on a clinical interview, the BDRS items rate the severity of depressive and/or mixed symptoms expressed by patients currently and during the past few days. If there is a discordance between symptoms currently and the last few days, the rating should reflect current symptoms. The scale contains 20 questions and the maximum score possible is 60. Higher scores indicate greater severity.

Individual items may be either subjective (patient report), objective (clinician rated) or a combination. In those combined items where there is a discrepancy between subjective and objective criteria, the objective should be more heavily weighted. If the rater believes the patient’s score lies between two points of severity, and is unable to clarify with probing where a particular score lies, the more severe rating should be scored. When the operational definitions and suggestions for an item do not fully describe an individual situation, the categories of mild/moderate/severe should guide rating. Do not however ask patients to pick the right answer e.g. mild/moderate/severe.

In individuals with significant symptom lability, for example with ultra rapid or ultradian cycling, the rating should be weighted to the current mental state. When assessing the patient’s current state, assessment should be done if possible without any attribution to environmental variables or medication status, e.g. use of hypnotics in assessing sleep. If a clear medical cause for a symptom is present, e.g. lithium tremor, this should not be rated. Some individuals who have chronic depression or alternate between depression and hypomania, may be unable to recall a period of well being, or be confident of what is normal for them. In items which refer to a person’s usual self, it may be necessary for the interviewer to refer to hypothetical norms for those items.

Beware of central tendency error i.e. avoid assessing at a mid range as a “safe” response. Where examples are given e.g., 5 (3), the experience of one example satisfies the criteria. Is not necessary for any of the specific listed examples to be experienced if in the rater’s judgement this criteria level is met. Do not take these anchor points too literally. The questions listed are a guide rather than a structured interview, and these need to be contextualised to the individual’s clinical situation. Do not assume that because an individual does satisfy a particular anchor point that they will not satisfy the following anchor point. Rater’s should consider both the frequency, duration and severity of the symptom, and when appropriate, associated features such as distress and impairment.

Following the generally agreed protocol in clinical interviewing, questions should move from general to specific. Patients generally are given as few prompts as possible to elicit the information required to obtain a rating. Within each item, questions should move from more open ended to more structured as needed. Raters should be aware of maintaining a balance between minimizing prompting but ensuring sufficient information is elicited to make the rating accurate and representative of the patient’s symptomatology. Particularly unwell patients may generally be expected to need further prompting whereas higher functioning patients may be able to answer questions with less additional input from raters.
Criteria and components of the individual Items:

Before starting, I am going to ask you some questions about some symptoms you may have. When answering please keep in mind that we are focusing only on how you are now and over the last few of days.

**Item 1.** DEPRESSED MOOD

Include self-report and/or observed behaviour.

To score 3 depression should be severe but need not be extreme.

*How has your mood been over the last few days?*
*Have you felt depressed, sad or flat?*
*Do you experience emotions other than depression?*
*Have you had feelings of helplessness or hopelessness?*
*How do you feel about the future?*
*How intense are these feelings?*
*How persistent are these feelings?*

<table>
<thead>
<tr>
<th>1. Depressed Mood (Self reported and/or observed depression as evidenced by gloom, sadness, pessimism, hopelessness, and helplessness)</th>
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<tbody>
<tr>
<td>0</td>
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**Item 2.** SLEEP DISTURBANCE

Score either insomnia 2(a) or hypersomnia 2(b), compared to the person’s normal sleep pattern. Rate sleep quantity independent of medication. Include daytime sleep and “dozing” as well as intermittent sleep when assessing total sleep time.

*How has your sleep been over the last couple of days?*
*How many hours would you usually sleep when you are well?*
*Is your sleep broken?*
*Do you awake feeling refreshed?*
*How many hours in total have you been sleeping over the last couple of nights?*
*Do you nap or doze in the day? For how long?*
*How many hours more or less than usual are you sleeping?*

<table>
<thead>
<tr>
<th>2. Sleep Disturbance: score either A or B (Change in total amount of sleep over a 24 hour cycle, rated independent of the effect of external factors)</th>
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<tbody>
<tr>
<td>A: Insomnia (reduction in total sleep time)</td>
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<tr>
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<td>OR</td>
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<td>B: Hypersomnia (increase in total sleep time, inclusive of daytime sleep)</td>
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Item 3. APPETITE DISTURBANCE

Score either 3(a) or 3(b) compared to their usual eating and appetite pattern.

How is your appetite?
Currently, do you want to eat more or less than usual?
Has your change in appetite altered the amount you actually have been eating?
Has food lost taste?
Do you have to push yourself to eat?
Are you comfort eating or snacking more than usual?
Do you have cravings, which lead to binges?

3. Appetite Disturbance: score either A or B (Change in appetite and food consumption, rated independent of the effect of external factors)

A: Loss of Appetite

0 Nil
1 Mild [no change in food intake, but has to push self to eat or reports that food has lost taste]
2 Moderate [some decrease in food intake]
3 Severe [marked decrease in food intake, hardly eating]

OR

B: Increase in Appetite

0 Nil
1 Mild [no change in food intake, but increased hunger]
2 Moderate [some increase in food intake, e.g., comfort eating]
3 Severe [marked increase in food intake or cravings]

Item 4. REDUCED SOCIAL ENGAGEMENT

Assess any reduction of social and interpersonal interaction the participant experiences due to their avoidance or reluctance to engage in social contact. Rate in the context of what is normal for the individual.

Are you meeting or interacting with other people as usual?
Do you find it easy to be around other people at present?
Are you meeting or seeing the people you would normally meet?
Are you avoiding meeting or making contact with people?
To what extent are you avoiding contact with other people?
Do you avoid answering the phone or seeing visitors?

4. Reduced Social Engagement (Reports reduced social and interpersonal engagement or interactions)

0 Nil [normal]
1 Mild [slight reduction in social engagement with no impairment in social or interpersonal function]
2 Moderate [clear reduction in social engagement with some functional sequelae, e.g., avoids some social engagements or conversations]
3 Severe [marked reduction in social interaction or avoidance of almost all forms of social contact, e.g., refuses to answer the phone or see friends or family]

Item 5. REDUCED ENERGY AND ACTIVITY

Reduced energy and activity should be rated on the basis of subjective reports and consequent reduction in goal directed activity.

Do you find you have as much energy and drive as usual?
Do you feel more tired than usual?
Do you find it takes more energy than usual to do things?
Do your limbs feel very tired or heavy?
Has this led to you reducing your usual activities?
Are there things you no longer do at all because of reduced energy?
Are you spending much more time in bed?

5. Reduced Energy and Activity (Reduced energy, drive and goal directed behaviour)
   0 Nil
   1 Mild [able to engage in usual activities but with increased effort]
   2 Moderate [significant reduction in energy leading to reduction of some role-specific activities]
   3 Severe [leaden paralysis or cessation of almost all role specific activities, e.g., spends excessive time in bed, avoids answering the phone, poor personal hygiene]

Item 6. REDUCED MOTIVATION

Reduced motivation and drive should be rated on the basis of subjective reports and consequent reduction in goal directed activity.

Is your motivation or drive reduced?
Are you less interested in your usual activities?
Do you need to push yourself to do the things you usually do?
Are you doing the things you would usually do?
Have you stopped doing any things you would usually do? Which things?

6. Reduced Motivation (Reports of subjective reduction in drive, motivation, and consequent goal directed activity)
   0 Nil [normal motivation]
   1 Mild [slight reduction in motivation with no reduction in function]
   2 Moderate [reduced motivation or drive with significantly reduced volitional activity or requires substantial effort to maintain usual level of function]
   3 Severe [reduced motivation or drive such that goal directed behaviour or function is markedly reduced]

Item 7. IMPAIRED CONCENTRATION AND MEMORY

This item examines an individual’s concentration, their ability to sustain attention and short-term memory difficulties.

Do you find it hard to concentrate?
Does your attention wander more easily?
Are you more forgetful than usual?
How severe is this?
Do you have any difficulty with reading, driving or watching TV?
Does this affect your ability to function? How much?

7. Impaired Concentration and Memory (Subjective reports of reduced attention, concentration, or memory, and consequent functional impairment)
   0 Nil
   1 Mild [slight impairment of attention, concentration, or memory with no functional impairment]
   2 Moderate [significant impairment of attention, concentration, or forgetfulness with some functional impairment]
   3 Severe [marked impairment of concentration or memory with substantial functional impairment, e.g., unable to read or watch TV]
Item 8. **ANXIETY**

This item assesses both reported levels of cognitive anxiety as well as somatic symptoms. The presence of significant somatic symptoms usually reflects higher anxiety unless these symptoms are due to another medical condition.

*Have you been more anxious or tense than usual over the last few days?*
*Have you found yourself worrying about things that wouldn’t usually bother you?*
*Are you experiencing any physical symptoms such as tremors/palpitations/dizziness/light headedness/pins & needles/sweating/flushes/butterflies in the stomach/diarrhoea?*
*How intense is the anxiety?*
*How persistent is the anxiety?*
*Does it interfere with your ability to function?*

<table>
<thead>
<tr>
<th>Anxiety (Subjective reports of worry, tension, and/or somatic anxiety symptoms e.g., tremor, palpitations, dizziness, light-headedness, pins and needles, sweating, dyspnoea, butterflies in the stomach, or diarrhoea)</th>
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Item 9. **ANHEDONIA**

Assesses person’s reported ability to experience pleasure in usual activities.

*Do you find things as enjoyable as usual?*
*Do you still find any pleasure in the things that you usually enjoy?*
*Which activities still give you pleasure? To what extent?*
*Have you completely lost your ability to experience pleasure?*

<table>
<thead>
<tr>
<th>Anhedonia (Subjectively reduced ability to experience pleasure in usual activities)</th>
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</table>

Item 10. **AFFECTIVE FLATTENING**

This item rates the intensity and range of the individual’s usual emotions. When giving examples to a patient, be aware that an example of feeling “unable to cry” may have gender specific connotations.

*Do you feel your mood is flat or as if your feelings are numbed?*
*Do you have less feelings for significant people in your life?*
*Do you find it harder to get excited, angry or worked up about things?*
*Do you sometimes feel as if you are numb or have no feelings left?*
10. **Affective Flattening (Subjective sense of reduced intensity or range of feelings or emotions)**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nil</td>
</tr>
<tr>
<td>1</td>
<td>Mild [slight constriction of range of affect, or transient reduction in range or intensity of feelings]</td>
</tr>
<tr>
<td>2</td>
<td>Moderate [significant constriction of range or intensity of feelings with preservation of some emotions, e.g., unable to cry]</td>
</tr>
<tr>
<td>3</td>
<td>Severe [marked and pervasive constriction of range of affect or inability to experience usual emotions]</td>
</tr>
</tbody>
</table>

**Item 11. WORTHLESSNESS**

Assesses individual’s feelings of self worth or self-confidence, compared to usual levels of self-esteem.

*How is your sense of self worth or confidence?*

*Do you feel you are as worthy a person as anyone else?*

*Are you still able to see your positive qualities?*

*Do you feel others would be better off without you?*

11. **Worthlessness (Subjective sense, or thoughts, of decreased self-value or self-worth)**

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<thead>
<tr>
<th>Score</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>Nil</td>
</tr>
<tr>
<td>1</td>
<td>Mild [slight decrease in sense of self-worth]</td>
</tr>
<tr>
<td>2</td>
<td>Moderate [some thoughts of worthlessness and decreased self-worth]</td>
</tr>
<tr>
<td>3</td>
<td>Severe [marked, pervasive, or persistent feelings of worthlessness, e.g., feels others better off without them, unable to appreciate positive attributes]</td>
</tr>
</tbody>
</table>

**Item 12. HELPLESSNESS AND HOPELESSNESS**

This item assesses feelings of helplessness or hopelessness, gloom and despondency.

*Do you feel optimistic or pessimistic about the future?*

*Do you feel you will be able to cope with the future?*

*Do you feel helpless or hopeless?*

*Are those feelings constantly there?*

*How intense are those feelings?*

12. **Helplessness and Hopelessness (Subjective sense of pessimism or gloom regarding the future, inability to cope, or sense of loss of control)**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nil</td>
</tr>
<tr>
<td>1</td>
<td>Mild [occasional and mild feelings of not being able to cope as usual; or pessimism]</td>
</tr>
<tr>
<td>2</td>
<td>Moderate [often feels unable to cope, or significant feelings of helplessness or hopelessness which lift at times]</td>
</tr>
<tr>
<td>3</td>
<td>Severe [marked and persistent feelings of pessimism, helplessness, or hopelessness]</td>
</tr>
</tbody>
</table>

**Item 13. SUICIDAL IDEATION**

Assesses reported thoughts of death and suicide.

*Do you feel that life is not worthwhile or meaningless?*

*Do you have thoughts of death or dying?*

*Do you feel that you would be better off dead?*

*Have you thought about ending your own life?*

*Have you had thoughts about harming yourself?*

*Have you made any plans?*
13. Suicidal Ideation (Thoughts or feelings that life is not worthwhile; thoughts of death or suicide)
   0 Nil
   1 Mild [thoughts that life is not worthwhile or is meaningless]
   2 Moderate [thoughts of dying or death, but with no active suicide thoughts or plans]
   3 Severe [thoughts or plans of suicide]

Item 14. GUILT

This item rates guilt, self-blame and remorse for real or past events. Rating varies according to extent to which person feels guilty or deserving of their fate.

Do you find yourself feeling guilty about things that have happened in the past?
Are you self critical about your role in things that have gone wrong?
How intense are these feelings?
Are they there some of the time or all of the time?
Do you think these feelings are excessive?
Do you feel in some ways that having this illness is a punishment?

14. Guilt (Subjective sense of self blame, failure, or remorse for real or imagined past errors)
   0 Nil
   1 Mild [slight decrease in self-esteem or increased self-criticism]
   2 Moderate [significant thoughts of failure, self-criticism, inability to cope, or ruminations regarding past failures and the effect on others; able to recognise as excessive]
   3 Severe [marked, pervasive, or persistent guilt, e.g., feelings of deserving punishment; or does not clearly recognise as excessive]

Item 15. PSYCHOTIC SYMPTOMS

This item rates psychotic symptoms, increasing from over-valued ideas through to overt psychotic symptoms. Rate on the basis of interview and mental status examination. Some of the information for this item will have bee gleaned from previous items.

Do your feelings of guilt affect the things you do?
Are you feeling suspicious?
Have you had unusual experiences such as hearing voices or seeing visions?
Do you believe things other people regard as unusual?

15. Psychotic Symptoms (Presence of overvalued ideas, delusions, or hallucinations)
   0 Nil [absent]
   1 Mild [mild overvalued ideas, e.g., self-criticism or pessimism without clear effect on behaviour]
   2 Moderate [significant overvalued ideas with clear effect on behaviour, e.g., strong guilt feelings, clear thoughts that others would be better off without them]
   3 Severe [clear psychotic symptoms, e.g., delusions or hallucinations]

The Mixed Subscale: Items 16-20

Item 16. IRRITABILITY

This item rates irritability and hostility. It is rated on the basis of subjective reports of irritability as well as observed behaviour.
Do you find things irritate you more than they would have previously?
Do you show that you are irritated or can you keep the feelings inside?
Have you acted ‘out of character’ due to your feelings of irritation?
Have you lost your temper so that you shouted or broke things?

16. Irritability (Reports uncharacteristic subjective irritability, short fuse, easily angered, manifested by verbal or physical outbursts)
   0 Nil
   1 Mild [slight subjective irritability; may not be overtly present]
   2 Moderate [verbal snappiness and irritability that is clearly observable in the interview]
   3 Severe [reports of physical outbursts, e.g., throwing/breaking objects, or markedly abusive verbal outbursts]

Item 17. LABILITY

This item rates both reported and observed mood lability.

Have you experienced mood swings over the last couple of days?
How intense are these mood swings?
How frequently does this happen?

17. Lability (Observed mood lability or reported mood swings)
   0 Nil
   1 Mild [subjective reports of mild increase in mood lability]
   2 Moderate [mood lability clearly observable, moderate in intensity]
   3 Severe [marked and dominant mood lability, frequent or dramatic swings in mood]

Item 18. INCREASED MOTOR DRIVE

This item rates both subjective and observed increases in motor drive and activity. This should include both goal directed and non-specific activity.

Have you been more active than usual over the past few days?
Do you feel you have more energy and drive then usual? How much more?
Have you done more things because of this?

18. Increased Motor Drive (Subjective reports and objective evidence of increased motor drive and motor activity)
   0 Nil [normal motor drive]
   1 Mild [slight increase in drive, not observable in interview]
   2 Moderate [clear and observable increase in energy and drive]
   3 Severe [marked or continuous increase in drive]

Item 19. INCREASED SPEECH

This item scores increased rate and quantity of speech or thought. It is predominantly an observer based rating, although subjective reports are taken into account.

Do you find you want to talk more than you usually would?
Do you find you interrupt people more than you usually would?
Are your thoughts going faster than usual?
Do you find yourself bursting with ideas that you want to tell people?
19. **Increased Speech** *(Observed increase in either the rate or quantity of speech, or observed flight of ideas)*

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<tbody>
<tr>
<td>0</td>
<td>Nil</td>
</tr>
<tr>
<td>1</td>
<td>Mild [slight increase in the rate or quantity of speech]</td>
</tr>
<tr>
<td>2</td>
<td>Moderate [racing thoughts, significantly more talkative, clearly distractible, or some circumstantiality; does not impede interview]</td>
</tr>
<tr>
<td>3</td>
<td>Severe [flight of ideas; interferes with interview]</td>
</tr>
</tbody>
</table>

**Item 20. AGITATION**

This item rates observed restlessness and agitation, although subjective reports are taken into account.

*Do you find you are more restless than usual?*
*Do you feel agitated?*
*Do you find it hard to sit still?*
*How intense are these feelings?*

20. **Agitation** *(Observed restlessness or agitation)*

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<tbody>
<tr>
<td>0</td>
<td>Nil [normal]</td>
</tr>
<tr>
<td>1</td>
<td>Mild [slight restlessness]</td>
</tr>
<tr>
<td>2</td>
<td>Moderate [clear increase in level of agitation]</td>
</tr>
<tr>
<td>3</td>
<td>Severe [marked agitation, e.g., near continuous pacing or wringing hands]</td>
</tr>
</tbody>
</table>
Young Mania Rating Scale (YMRS)

Guide for Scoring Items

The purpose of each item is to rate the severity of that abnormality in the patient. When several keys are given for a particular grade of severity, the presence of only one is required to qualify for that rating. The keys provided are guides. One can ignore the keys if that is necessary to indicate severity, although this should be the exception rather than the rule.

Scoring between the points given (whole or half points) is possible and encouraged after experience with the scale is acquired. This is particularly useful when severity of a particular item in a patient does not follow the progression indicated by the keys.

1. Elevated Mood
   0 Absent
   1 Mildly or possibly increased on questioning
   2 Definite subjective elevation; optimistic, self-confident; cheerful; appropriate to content
   3 Elevated, inappropriate to content; humorous
   4 Euphoric; inappropriate to content; singing

2. Increased Motor Activity – Energy
   0 Absent
   1 Subjectively increased
   2 Animated; gestures increased
   3 Excessive energy; hyperactive at times; restless (can be calmed)
   4 Motor excitement; continuous hyperactivity (cannot be calmed)

3. Sexual Interest
   0 Normal; not increased
   1 Mildly or possibly increased
   2 Definitive subjective increase on questioning
   3 Spontaneous sexual content; elaborates on sexual matters; hypersexual by self-report
   4 Overt sexual acts (towards patients, staff, or interviewer)

4. Sleep
   0 Reports no decrease in sleep
   1 Sleeping less than normal amount by up to one hour
   2 Sleeping less than normal by more than one hour
   3 Reports decreased need for sleep
   4 Denies need for sleep

5. Irritability
   0 Absent
   1 Subjectively increased
   2 Irritable at times during interview; recent episodes of anger or annoyance on ward
   3 Frequently irritable during interview; short, curt throughout
   4 Hostile, uncooperative; interview impossible

6. Speech (Rate and Amount)
   0 No increase
   2 Feels talkative
   4 Increased rate or amount at times, verbose at times
   6 Push; consistently increased rate and amount; difficult to interrupt
   8 Pressured; uninterruptible, continuous speech

7. Language – Thought Disorder
   0 Absent
   1 Circumstantial; mild distractibility; quick thoughts
   2 Distractible; loses goal of thought; changes topics frequently; racing thoughts
   3 Flight of ideas; tangentiality; difficult to follow; rhyming; echolalia
   4 Incoherent; communication impossible

8. Content
   0 Normal
   2 Questionable plans, new interests
   4 Special project(s); hyperreligious
   6 Grandiose or paranoid ideas; ideas of reference
   8 Delusions; hallucinations

9. Disruptive – Aggressive Behavior
   0 Absent; cooperative
   2 Sarcastic; loud at times; guarded
   4 Demanding; threats on ward
   6 Threatens interviewer; shouting; interview difficult
   8 Assaultive; destructive; interview impossible

10. Appearance
    0 Appropriate dress and grooming
    1 Minimally unkempt
    2 Poorly groomed; moderately disheveled; overdressed
    3 Disheveled; partly clothed; garish makeup
    4 Completely unkempt; decorated; bizarre garb

11. Insight
    0 Present; admits illness; agrees with need for treatment
    1 Possibly ill
    2 Admits behavior change, but denies illness
    3 Admits possible change in behavior, but denies illness
    4 Denies any behavior changes

Name: __________________________
Rater: __________________________
Date: ______________
Score: ____________
Appendix G

Weekly Mood Survey

Welcome to the Weekly Mood Rating.

Please click next to start.

There are 2 questions in this survey

**Weekly Mood Rating**

**How do you feel today? * **

Please choose the appropriate response for each item:

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Depressed</td>
<td>Elevated</td>
<td>Irritable</td>
<td>Anxious</td>
</tr>
</tbody>
</table>

Psychotic

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

**Any comments about your mood this week?**

Please write your answer here:

Thanks for filling in this report. You can now close this window.

Submit your survey.
Thank you for completing this survey.
Appendix H

Initial Assessment Interview

Initial Intake of Participants in The Bipolar Study

Hi my name is ______________ and I’m a Clinical Psychologist/Provisional Psychologist and a member of the Bipolar Disorder research team. Thank you for coming in today and taking part in our study. As you may be aware, the study is about monitoring people with bipolar disorder for 12 months to see if we can identify early warning signs for a relapse. Today I’ll be asking you some information about you and your bipolar disorder. This initial assessment will go for 2-3 hours. I just want to check you have our parking voucher on your dashboard and that you have parked in the Psychology Clinic car spaces? Your future review appointments will be much shorter (30mins to 1 hr) as we won’t have to ask a lot of this information again. Are you Ok to start?

(Give information form and go through this and the consent form) – limits to confidentiality

(Ask participant to sign the consent form)

(Date of Initial Assessment):

(Assessing psychologist/title):

(Name of Participant):

(Participant Number):

(Gender):

Demographics

1. How did you hear about the study?

2. What is your date of birth?

3. What is your address?

4. What is your mobile number?

5. What is the best email address to contact you on if needed?

6. Who is your GP?

7. Do you have a treating Psychologist/Clinical Psychologist? (if so, who is this, how long have you been seeing them and how often do you see them?):

8. Do you have a treating Psychiatrist? (if so, who is this, how long have you been seeing them and how often do you see them?):

9. If there was an emergency or if we could not easily contact you, who would be the best contact for you? (Name, relationship and mobile number):
**Background Details**

1. How would you describe your relationship status (e.g., single, married, in a de-facto relationship, divorced)?

2. Do you have any children (if so ages and gender)?

3. What is your current employment/study/financial benefit?

4. What is your highest level of education?

5. What is your current income (0-$18,200, $18,201-$37,000, $37,001-$80,000, $80,001-$180,000, $180,000 and over)

6. What is your current household income? (use above tax brackets)

**History and Symptoms of BD**

7. How old were you when you think you first had any symptoms of Bipolar Disorder?

8. How old were you when you were actually diagnosed (and year)?

9. What are your current diagnoses (include comorbidities)?

10. How many hospital admissions have you had? (at what age/year?)

11. Have you ever attempted suicide (age/year)?

12. Have you ever engaged in self-harm (age/year)?

13. Do you currently use any substances (type, how much and how often)?

14. Do you drink alcohol (type, how much and how often)?
15. Do you currently smoke cigarettes (how much and how often)?

16. What are your current medications?

17. How compliant are you with taking them?

18. Do you have any side effects from your medication?

19. Have you received any psychological help (when, for how long, what type of therapy, what type of psychologist)?

20. Are there any family history of MH Issues (esp. BD)?

21. Has anyone in your family died by suicide?

*Administer the SCID-5 RV (BD section only)*

Clinician Rated Symptoms:

- BDRS
- YMRS (this can be done after if needed)

Physical Health Details

22. Do you have any physical health issues?

23. Are you on any medications for these (which medication for which conditions, dose)?

24. Have you ever used a lifestyle-monitoring device before (if so which one/s, how long, how did you find it)?

25. Have you ever used a Mental Health phone app before (if so which one/s, how long, how did you find it)?
Administer Self-Report Measures:

PSQI

IPAQ-SF

DSSI-10

Personal Network
*Make sure participants have the same amount of time to complete this (15 mins)

Travel

Socialisation

Risk assessment using risk assessment sheet- only if this has been indicated that it is needed in the assessments

Devise safety plan using safety plan sheet – may need to ask their permission to contact the person they live with to let them know the situation and when you write to their treating professional include your assessment of the situation
Fitbit Charge HR

Now I will tell you everything you need about your FitBit Charge HR. Here is the written information sheet as well so it can help you remember this information.

A Fitbit Charge HR Account has been set up for you using a free Gmail address and password that are securely stored by the research team for the purpose of remotely accessing and downloading your data for analysis. The account is registered using your participant ID. Your information will be stored securely and only accessed by necessary members of the research team, using your participant ID, so that your identity will be protected and privacy maintained at all times. No identifiable data will be published. Your name will not appear on any data sets.

Once your participation in the study has concluded we will assist you to transfer the Fitbit login to your name and to change the password. Once complete, the research team will no longer have access to your account or data.

You will be able to view your Fitbit results on the Fitbit phone app, which we will download with you shortly.

Password Recovery:

The Fitbit app will only require you to log in once during set up. However, if your device is reset, or the application is re-installed you will need to re-enter your password. If you forget your password during the study, please contact Dr Tanya Hanstock for assistance. Please do not use the Fitbit password recovery service. Doing so will send a password reset request to the research team.

Setting Up Your Fitbit Charge HR:

*The participant’s phone must not be connected to the university’s Wi-Fi or the university’s guest Wi-Fi because the apps will not download on this. Make sure the participant has their Wi-Fi turned off and this will connect them to their external Wi-Fi or their providers Wi-Fi.

I will now show you how to turn on, calibrate, and sync your Fitbit with your Android smartphone - do this:

1. Go to www.fitbit.com and follow the prompts and this will set up the fitbit web browser.
2. Download app and log in. Select “add device” and follow prompts
3. Use the Fitbit Instructions sheet and go through sections of the fitbit app and fitbit web browser and then read the information below.

How to wear the Fitbit Charge HR:

It is recommended that you wear the Fitbit charge HR on your non-dominant hand, one finger’s width above the wrist bone, and not too tight, as suggested by Fitbit documentation. For better heart rate readings during exercise, it is recommended that you wear the band so that it’s secure, but not too
tight, and to wear the band higher on your wrist (about 2-3 finger widths above your wrist bone) and then to lower the band and loosen it after exercise, as suggested by Fitbit documentation. Please note that the Fitbit Charge HR can cause skin irritation if worn constantly. If this occurs, please remove the device, seek first aid if necessary, and contact the Project Manager.

**When to Wear the Fitbit Charge HR:**

Please be aware that the Fitbit Charge HR is not waterproof. It will need to be removed before showering or partaking in aquatic sports and replaced as soon as possible afterwards. Please wear the Fitbit Charge HR throughout the day and while sleeping, except when showering, partaking in aquatic sports, and during recharging. During sleep recording, please leave the setting as “Normal,” which is indicated as appropriate for most users by Fitbit documentation.

**Charging the Fitbit Charge HR:**

The Fitbit Charge HR needs to be charged through a USB connection on either a computer or directly using a USB charging device, such as the one you use to recharge your Android smartphone. The battery lasts for up to five days, and it will need to be connected for several hours to recharge. You will receive a warning on the small screen of the Fitbit and in the app when you need to recharge the device. Try to recharge the Fitbit during the day so that the sleep measurements will not be disrupted.

**Syncing Your Data:**

The Fitbit device is automatically synchronized with your smartphone app whenever Bluetooth is enabled. If you are flying, setting your smartphone to airplane mode will not affect the recording of Fitbit data but no data will be transferred to your app during this time. Once you switch off airplane mode, Bluetooth will be enabled and data synchronization will resume. Whenever you attach your Fitbit to a computer via the USB cable, data will be automatically transferred to the application.

Please see [https://help.fitbit.com](https://help.fitbit.com) for further information on device compatibility and features.

**Technical Assistance:**

If you have any problems with the technology for this study, please contact Dr Tanya Hanstock via email at Tanya.Hanstock@newcastle.edu.au

**Measure the following for the client:**

- Weight:
- Height:

Calculate BMI (use computer or can download BMI calculator on your phone) (let them know this and give out BMI handout)
Unforgettable Me

The Unforgettable Me smartphone application automatically collects information about your physical activity including where you have been and what types of brief sounds you are hearing in your vicinity. No one will be able to detect what you have been saying based on these very short speech samples and your privacy will always be maintained. By tracking where you have been, using Wi-Fi and GPS signals, the researchers will be able to evaluate how much travel and how far you travel each day. The researchers will have a rough understanding of where you have been, but not precise locations. You can choose to delete these segments of data and will be shown how to do so.

Account Set-up and Privacy:

Unforgettable Me is an Android smartphone application developed by the University of Newcastle and available for download from the Google Play store. The data collected by the Unforgettable Me app is stored locally on your smartphone for a set number of days of your choosing (up to seven). After this, the data is automatically uploaded to the Unforgettable Me website (http://unforgettable.me) where the research team will be able to remotely access and download your data. This means that the researchers will only be able to access your Unforgettable Me data once it is uploaded by the smartphone application to the website. You are able to access your data from within the app, to select and delete any data within the last seven days that you do not wish to share with the research team, so that it will be excluded from this upload. You are also able to enter the app at any time and temporarily turn off the data collection for physical activity, location, and sound.

An Unforgettable Me account and password has been created for you. These login details will enable you to use the Unforgettable Me smartphone application. The researchers will also securely store these login details for the purposes of remotely accessing and downloading your data for analysis.

The account uses your participant ID instead of your name. This means that the researchers will only be able to see this code and they will not know whether the data belongs to you. Your information will be stored securely and only accessed by necessary members of the research team, using your participant ID, so that your identity will be protected and privacy maintained at all times. No identifiable data will be published. Your name will not appear on any data sets.

Password Recovery:

The Unforgettable Me application will only require you to log in once during set up. However, if your device is reset, or the application is re-installed you will need to re-enter your password. **If you forget your password, please contact Dr Tanya Hanstock for assistance.**

Charging Your Smartphone:

The Unforgettable Me application will run in the background on your Android smartphone. Please make sure that your phone is recharged when its battery is low. If you have any problems with keeping your phone charged, please contact Dr Tanya Hanstock for assistance.

Syncing Your Data:

The Unforgettable Me app will upload data to its companion website when your phone is at least 90% charged and connected to WiFi so it will keep saving data for as many days as your phone has available space. The Unforgettable Me app will send your data to a secure computer at the University of Newcastle once every seven days by default. At any time before the seven days has expired, you can edit your data within the app. After this time, the data will be deleted from your phone and will only
be accessible using the Unforgettable Me website (show how to do this by using login 1 example - but download their app first). Remember after deleting the data, you need to go to the trash can and delete the data from there to permanently delete it from the web browser or alternatively there is an option to retrieve the data.

Technical Assistance:
If you have any problems with the technology for this study, please contact Dr Tanya Hanstock via email at Tanya.Hanstock@newcastle.edu.au

Install Application:
We will now download and set up the Unforgettable Me app and UM web browser log in and show you the features we just described.

1. Install app and log in on phone (you will know you are logged in because it will say recording down the bottom of the play screen)
   a. Log in to web browser on a computer (these instructions are on web browser under the "getting started" tab - available if they forget how to use the app
   b. Explain web page logo: Herman Ebbinghouse - memory researcher
2. Explain PLAY screen
   a. Pause button – to stop all recording (remember to press again to turn it back on)
   b. Counts: data points recorded since start of the day or since an upload

Settings: (Navigate to settings screen)

3. Explain audio switch – “this is for the small samples of audio without being able to make out any words, sentences or conversations”. Switch this on - a message should come up and ask the participant to go into settings where the UM app is and give permission for UM app to access the microphone, allow it to do this - if it doesn’t, you will need to manually go in and do this.

4. Explain raw audio switch – “this is for developers to record actual conversations, whereas the noise we capture cannot be reconstructed and listened to”.

5. Switch on GPS.
6. Notifications – leave off “for developers to troubleshoot problems only”
7. Explain that they should not press the button “Copy database” unless they want their raw data copied to their SD card
8. Explain ‘days to review’ switch – max 7 days – default 0 – this is the number of days of data they can review and delete before it is uploaded on the “review page”
9. Troubleshooting: if battery life is poor, adjust rate of sampling intervals to 600 – the default is 500 or about 12 per hour

Review and Delete Data:

10. Explain review panel – for if they want to delete their data
11. Tap on a day which opens each hour for that day and tap the delete button for the hours you want to delete (they won't have any data at this stage but)

12. Won't upload the data until its 90% charged and connected to Wi-Fi so it will keep saving data for as many days as your phone has available space (meaning if they don’t charge and connect to Wi-Fi this could impact on phone storage)

13. Now show them how to delete data by using the Unforgettable Example printout in conjunction with the example login (lifelogbps+750206251@gmail.com; rr5:=+wH) – remember this login only has examples of SMS and CALLS not examples of UM data so just note this to participant. Can search keywords (e.g. SMS, CALL,) join keywords with ‘OR’ in capitals, or use * in the search bar to list all data entries. Delete option is in right hand corner and then trash can option is in the drop down menu to left of search engine. In the trash can, when you hover over the data you can click to restore or to permanently delete data.
**IFTTT – If This Then That**

The IF app by IFTTT, is available on the Google Play store, and will be used to automatically create a record of answered, missed, and dialled phone calls and sent and received SMS, and send it to the Unforgettable Me website where it will be stored and accessed by the researchers. The information collected will include the time of day and duration (for phone calls). Phone numbers will be obscured so that researchers will be able to analyse the quantity and frequency of contact with each obscured phone number. However, the actual phone numbers, names, and the content of SMS will not be recorded on the Unforgettable Me website.

**Account Set-up and Privacy:**

The IF application works by running an ‘applet’ to automatically collect the required information and send it to the Unforgettable Me website where it will be stored securely. The IF app and applets are triggered and executed each time your phone receives or sends an SMS, and each time you answer or miss a phone call or dial a phone number. The research team has already set up the applets for you. There are five applets (Sent SMS, Received SMS, Calls outgoing, Calls missed, Calls answered). You will be able to temporarily turn off the ‘applets’ that record SMS and phone call data using toggles from within the app if you want to temporarily stop sharing this data with the research team. Please remember to turn it back on from within the app when you wish to resume sharing this data. Logging out of the IF app will not stop data collection. Uninstalling the IF app will stop data collection until the IF app is reinstalled, at which time data collection will automatically resume. To permanently stop data collection once you have finished participating in the study, please turn off or delete the five applets used in this study or deactivate your IFTTT research account. To ensure your privacy, the research team will deactivate all research IFTTT accounts from the IFTTT website, as each participant finishes their participation in the study. You can continue to use the IF app in future for personal use by creating a new IFTTT account using your personal details.

If you wish to delete your data after it has been recorded you can do so using the Unforgettable Me website and your Unforgettable Me login - same process as before with the UM data.

**Syncing Your Data:**

The IFTTT app will need to use an Internet connection to send your data to the Unforgettable Me website. It will upload your data automatically whenever is has an Internet connection. The app settings can be used to toggle permission for the app to upload using cellular data or Wi-Fi only (default).

The data collected by IFTTT is automatically sent to the Unforgettable Me website so the research team will not be accessing your account on the IFTTT website during the study. However, the IFTTT app currently creates an activity record within your login that includes actual phone numbers, names, and a short preview of SMS content. This cannot be viewed unless logged into the account. Though the research team will not access this account during the study, you may wish to change your login details for this account.

**Setting Up the IF Browser and App:**

1. We will now install and set up the IF Browser using a pre-existing username and password - check the applets are there.

If you would like to change your login details for the IFTTT we will log in on the IFTTT website using the login details we have provided to you. Navigate to Settings on the top right drop down menu.
Please leave the username the same to protect your identity, but change both the password, and the email address (which is used for password recovery and important updates such as error messages for active applets). Check that the applets are still within the account that has the changed email address and password. If there are any problems or errors with your IFTTT applets in the future we will discuss how to assist you with this while maintaining your privacy. You may need to come to the university if we cannot guide you over the phone.

2. If you do not want to change your login details for IFTTT, we will now install and set up your IFTTT app on your Android smartphone with the account details we have provided for you and check that your applets are there. Or conversely, if you have changed your login details we will download the IFTTT app and you can log in with your new email and password. Either way - a permissions request should come up and ask permission to access your phone contacts – click yes otherwise IFTTT will not begin recording the applets data and will not upload to the UM web browser. You may have to manually go in to settings and set this up if the permission request does not come up automatically.

3. Show the participant how to "toggle" off temporarily if they should wish to do so.

Charging Your Smartphone:

This application will use a percentage of your smartphone battery charge. You may need to charge your phone slightly more frequently than you are used to. If you are experiencing trouble with the battery life of your phone and are unable to charge it frequently enough please contact Dr Tanya Hanstock.

Technology Assistance:

If you have any problems with your technology for this study, please contact Dr Tanya Hanstock via email at Tanya.Hanstock@newcastle.edu.au
Mood Survey

You will be asked to complete a brief, online mood-rating survey each week. A weekly reminder will be sent to your mobile phone prompting you to complete the survey via a web link included in your SMS message. The survey should take no more than a few minutes to complete. The survey is most efficient when completed as close to the time it is received as possible.

The survey asks you to rate how you feel at the moment and gives you a four-choice scale that you can use to rate your feelings. There is also a section for you to add additional comments if you wish. Your data will be sent to the researchers using your participant ID. No one will know that this data comes from you.

We will now ask you to complete the mood survey to check that it works.

Technology Assistance:

If you have any problems with the technology for this study, please contact Dr Tanya Hanstock via email at Tanya.Hanstock@newcastle.edu.au
Write down the username and password for the fitbit app and web browser/IF app/UM app and web browser for the participant – these should be the same for each participant.

Show them the list of health professionals on the PCIF form if they become unwell and need to see a health professional and can’t get into their usual treating professionals.

Here are the dates/time of next follow up session (let them know we can post the parking pass out closer to the date) but if it is straight after the initial, can give them their one week post follow up parking pass then.

Here are the details of who you can contact between now and the follow up appointment if they have any questions or concerns.

Let them know we will be sending a letter to their treating professional stating they are now engaged in the study.

Do you have any questions or concerns re: the study?

Here is your gift voucher for coming today – make sure you mark it off the chart using the specific code

After they leave – do the scoring of each assessment using the spreadsheet if you have time

Send the letter to their treating professional
Appendix I

Subsequent Assessment Interviews

Follow Up Review of Participants in The Bipolar Study

Remind the participant who you are, and that this is a follow up appointment for the Bipolar Study. Explain what number and length of time the follow up is (for example, this is the follow up appointment number and the next appointment will be 3 months from their initial assessment appointment). Explain to them how many more you would like them to attend. Check the dates with them regarding these. Explain that this will take 1hr. Make sure they have a parking pass.

Demographics

(Date of Follow up Assessment):

(Assessing psychologist/title):

(Name of Participant):

(Participant Number):

Ask them if they have any changes to their contact details since they started in the study? For example have they moved, change phone numbers etc?

Have you had any changes as to who is your:

   GP: (if so write the details of the new GP)

   Psychiatrist: (if so write the details of the new Psychiatrist)

Ask them how their BD has been since they entered the study? Write a short narrative

Have they had any episodes of:

   Depression (if so how many and for how long was each one)
   Hypomania-Mania (if so how many and for how long was each one)
   Psychosis? (if so how many and for how long was each one)
   Self-harm? (if so how many and for how long was each one)
   Suicide attempts? (if so how many and for how long was each one)
   Did they have to go to their GP or Psychiatrist for any appointments?
(Check whether these were previously scheduled or if they had any extra appointments)

Have they had to change medication? (if so what are they now on)

Have they had a hospital admission? (if so, where and for how long)

**Physical Health Details**

Have you had any changes in substance use?

Have you had any changes with alcohol intake?

Have you had any changes in smoking?

Have you had any changes in sleep/wake cycle?

Have you had any changes in exercise?

Have you had any changes in socialising?

Weight:

Calculate BMI (let them know this):

**Administer Measures**

Client:

PSQI -

IPAQ-SF

DSSI-10

Personal Network Map

Travel

Socialisation

**Clinician Rated:**

BDRS -

YMRS

**Risk assessment if needed?**
FitBit Information

Remind the client what the study involves again

Ask them how they have been finding the fitbit (record some of the narrative)

What have they enjoyed about it?

Have they had any problems with it?

Have they been looking at their data?

Ask the participant if they think any of their sleep logs may have been when they were lying down still for over an hour (e.g watching t.v). If so, go through their sleep-wake data on the web browser and make a note of these logs here – date and time/duration of sleep log.

Give them their gift voucher for coming today.

Remind them of the dates/time of next follow up session (can give them parking permit on the day they next come in)

Give written details of who the client can contact between now and the follow up appointment if they have any questions or concerns – info on their participant information form

Did the client have any questions or concerns re: the study?

Is the participant still keen to be in the study?

Have they completed this weeks mood survey?

Tell them you will be writing to their treating professional to ask about relapses.

Thank the participant for their time and for taking part in the study.
Background: Bipolar disorder (BD) is a chronic and often relapsing condition. It is ranked as the sixth most debilitating disorder worldwide. It is associated with high rates of hospital admission as well as a high suicide risk. Being able to predict relapse and quickly respond may reduce the number of hospitalisations, improve morbidity and mortality rates for individuals with BD as well as reduce economic costs for public and private health services. Australian researchers (Heath & Murray, in press) have shown that relapse in mania can be detected using activity measurement and have a sensitive methodology for predicting mood-related change using activity data.

Methods: Thirty adults (aged 18 to 50 years) with BD, recruited through public health services as well as in the community, will undertake a 12-month monitoring study of lifestyle and symptom variables to identify early and subtle signs of relapse. Participants will have an initial assessment followed by four three-monthly assessments and one-, three- and six-months post follow-up assessments. BD symptoms and lifestyle variables (including sleep/wake cycles, activity levels and social stimulation) will be measured by a Fitbit Charge HR, a smartphone application that captures audio, accelerometry and GPS information continually and various commonly used psychological measures.

Results: Using machine learning techniques, we aim to be able to predict signs of a relapse at least one week if not two weeks before clients present to health professionals with symptoms. Although each participant may have subtle idiosyncratic signs of relapse, we expect a group outcome of changes in sleep/wake cycles, activity and social stimulation that together will predict relapse.

Conclusion: Helping clients gain better insight into their subtle, idiosyncratic and early warning signs of relapse is a helpful intervention. This may be made possible with new commonly used technologies such as wearable and smartphone devices.

Reference: