Experiences of remote mood and activity monitoring in bipolar disorder:

A qualitative study

Kate EA Saunders[1,2], Amy C Bilderbeck[1], Priyanka Panchal[1], Lauren Z Atkinson[1], John Geddes[1,2] and Guy M Goodwin[1,2]

1. Department of Psychiatry, University of Oxford, Warneford Hospital, Oxford OX3 7JX
2. Oxford Health NHS Foundation Trust, Warneford Hospital, Oxford OX3 7JX

Running title: Experiences of mood and activity monitoring in bipolar disorder

Corresponding author: Guy M Goodwin

University Department of Psychiatry, Warneford Hospital, Oxford OX3 7JX,

Tel: +44 (0)1865 226451, Fax: +44 (0)1865 204198

guy.goodwin@psych.ox.ac.uk

Words: 4462 (with quotations); 2549 (without quotations)

Key words: remote monitoring, mood, bipolar disorder, actigraphy, qualitative

ABSTRACT

Background. Mobile technology enables high frequency mood monitoring and automated passive collection of data (e.g. actigraphy) from patients more efficiently and less intrusively than has previously been possible. Such techniques are increasingly being deployed in research and clinical settings however little is known about how such approaches are experienced by patients. Here, we explored the experiences of individuals with bipolar disorder engaging in a study involving mood and activity monitoring with a range of portable and wearable technologies.

Method. Patients were recruited from a wider sample of 50 individuals with Bipolar Disorder taking part in the Automated Monitoring of Symptom Severity (AMoSS) study in Oxford. A sub-set of 21 patients participated in a qualitative interview that followed a semi-structured approach.

Results. Monitoring was associated with benefits including increased illness insight, behavioural change. Concerns were raised about the potential preoccupation with, and paranoia about, monitoring. Patients emphasized the need for personalization, flexibility, and the importance of context, when monitoring mood.

Conclusions. Mobile and electronic health approaches have potential to lend new insights into mental health and transform healthcare. Capitalizing on the perceived utility of these approaches from the patients' perspective while addressing their concerns, will be essential for the promise of new technologies to be realised.

Keywords. Bipolar disorder; Ambulatory monitoring; Activity; Mood monitoring; Wearable devices

1. INTRODUCTION

Symptom assessment in bipolar disorder (BD), like many other mental health disorders, is based upon self-report measures. Self-reported symptoms are highly dependent upon an individual's ability to accurately recall information and communicate complex mood states, aspects of assessment that many patients find difficult [1]. In addition, subjective self-report of manic and depressive symptoms is influenced by decreased illness insight, especially during manic or hypomanic episodes [2]. In recent years, the use of remote mood monitoring for BD has grown dramatically [3]. Reporting symptoms via text and e-mail in response to scheduled prompts overcomes the challenge of patient recall and is an easy and inexpensive way to collect mood data prospectively and longitudinally [4].

Objective monitoring, particularly activity monitoring, also has the potential to indicate clinically important changes in symptoms [5, 6]. Many symptoms of BD manifest in changes of physical [7-9] and social activity [10]. Research exploring objectively monitored activity as an indicator of diagnostic classification and mood changes has benefited from advances in the sophistication and widespread accessibility of portable and wearable technologies. The increasing ubiquity of smart phones with in-built actigraphy, light and other sensors provide a platform for collecting such data remotely, whilst wearable activity monitors are increasingly popular and provide a practical solution to long-term activity monitoring. However, if such approaches are to be successful in the management of BD they need to be acceptable to patients.

A number of studies are currently exploring multi-sensor monitoring in BD to explore whether objective measures can provide clinically meaningful information [11-14]. Although preliminary findings have demonstrated correlations with clinician-rated depressive symptoms [15] and accurate mood state recognition in small samples of BD patients [16] we know very little about the perceived clinical usefulness of monitoring from patients. Few studies have explored patient

experiences of using these technologies [17, 18], and those that have tend to focus on the usefulness and usability of device systems to collect and visualise data. In addition, some studies ~~have reported measures of~~interpret device compliance as an indicator of tolerability [4, 19]. We wanted to explore how patients interpret and use such data in ways that might be clinically useful. We conducted a qualitative study with the aim to explore the experiences of patients with BD who have engaged in remote mood and activity monitoring as part of the Automated Monitoring of Symptom Severity study (AMoSS), in order to understand the personal and clinical benefits to patients using these technologies, and to identify any potential barriers to use. A qualitative approach was employed because it is flexible, grounded in individual experiences, and because we know so little about how tolerable or acceptable automated symptom monitoring is to patients. ~~What can we learn from a qualitative approach tell us that quantitative approach doesn't tell us?~~

2. MATERIAL AND METHODS

Ethical approval for the study was obtained from East of England NHS Research Ethics Committee (13/EE/0288) and practice was informed by the principles manifest in the Declaration of Helsinki.

2.1 Participants

Participants were 21 individuals who were members of the wider AMoSS sample of 50 BD participants. The AMoSS study is a prospective longitudinal study where participants monitor their mood daily using a study-specific smartphone app, complete weekly mood measures using the True Colours system (https://oxfordhealth.truecolours.nhs.uk/www/en/) as well as wearing actigraphs. In addition participants have one week of intensive monitoring where they complete

ten times daily mood ratings and monitor a number of physiological variables. Full study details can be found in the supplementary materials online (see also http://conbrio.psych.ox.ac.uk/the-amoss-study). Recruitment into AMoSS was via outpatient secondary mental health services and advertising in the community. Exclusion criteria were minimal but included lack of capacity to consent and those who had been a psychiatric inpatient in the last month. Informed consent was obtained from all participants. Participants underwent screening by an experienced psychiatrist (KEAS) using the Structured Clinical Interview for DSM-IV (SCID) and met criteria for DSM IV BD. Individuals were invited to interview when they had completed 12 weeks of mood and activity monitoring, or had withdrawn before this time (N=1). Purposive sampling was used to ensure that those who had left the study and those who had submitted incomplete data were also included. No individuals refused to participate in an interview. Once data saturation occurred, no further participants were invited to interview.

2.2 Data gathering

In the majority of cases interviews were conducted in person (N=13, 62%) and the remainder were conducted by phone. Interviews were conducted by one of three members of the research team (KEAS, PP, LA). Participant interviews were conducted using a semi-structured topic schedule and were audio-recorded (for full topic schedule and more information about qualitative interviews see Supplementary Material). Interviews varied in length from 20 to 100 minutes.

Demographic data were gathered from all participants, including age, gender and current medication (see table 1). Quantitative feedback regarding frequency of questionnaire prompting and tolerability of actigraphy devices was collected on feedback forms between weeks 8 and 12 of the study. Participants were asked to indicate, using 7-point Likert scales, the convenience of mood prompting and the convenience and comfort of monitoring devices (1 being not at all uncomfortable/not at all inconvenient and 7 being very uncomfortable/very inconvenient).

Feedback forms also provided an opportunity for participants to give more detailed written feedback regarding how devices were used and worn during the study, whether there were unwanted factors influencing data collection, and any other details of their experience using each device. Feedback forms were filled out by 95% of interviewed patients (N= 20). At the time of the interview just one participant had decided to leave the study following three months of participation.

Table 1 about here

2.3 Data analysis

Qualitative data coding, management and analysis were conducted using NVivo software [20]. Interviews were conducted as part of an on-going and iterative process of data collection and analysis. Audiotaped interviews were transcribed, reviewed, and uploaded to NVivo. Qualitative analysis used a framework technique [21]. The framework technique allows both thematic and case-based analysis (or a combination of both) while retaining a direct link to the data. It has been specifically developed for use in settings where -there are specific questions, a limited time frame, a pre-designed sample (e.g. research participants) and a priori issues (e.g. tolerability and acceptability) that need to be dealt with. Although framework analysis can be used to generate hypotheses its main focus is to describe or interpret what is happening in a particular setting. Two members of the study team, a psychiatrist and research assistant, conducted an initial round of analyses independent of one another. The results of these analyses were then shared and discussed with the wider research team, leading to further refinement of the thematic framework. To reduce researcher bias, we discussed and maintained an awareness of preconceptions (facilitated by interviewer note-keeping and memos) and constantly linked the emerging thematic framework to the participant-derived data. Data gathering ceased when no further advance was being made in understanding the participants' experiences of monitoring.

Quantitative data were summarised using standard statistical approaches. Data were not normally distributed, with a pronounced positive skew evident in the distribution of both convenience and comfort scores, and negative skew in the distribution of compliance scores. Therefore non-parametric tests were used to make statistical comparisons.

3. RESULTS

3.1 Qualitative interview findings

Six themes emerged from the interviews which provided greater understanding as to how patients interpreted, reflected upon, and in turn utilised mood and activity monitoring within the context of managing BD.

3.1.1 Insight

The majority (N=16, 76%) of participants described how the use of mood and activity monitoring enhanced their understanding of their illness.

> *"I thought it was interesting because you're doing it so often noticing how quickly your mood can change within a day".* Participant 3-F

> *"It's really apparent to me that the more I do, like my mood's quite good today because I went to the gym yesterday… … if my mood's a bit low I might ea, eat unhealth-, make unhealthy food choices … … I definitely recognised that I do feel better if I'm more active."* Participant 1-F

> *"It's probably made me more aware of ... in that when I do think to look at the [True Colours] graph I can say if my depression's dipping ... or going up even that I'll go*

right I'll go for a walk at lunchtime, you know so I suppose it gives me a little sense of control." Participant 2-F

~~*"I thought it was interesting because you're doing it so often noticing how quickly your mood can change within a day".* Participant 3-F~~

Commented [l1]: This could potentially also fit in the behaviour change theme? I could find a more suitable quote if you think it would make the themes more seperate

Half the participants highlighted how monitoring their mood had been useful in enabling them to identify how they were feeling and that this in itself led to an improvement.

"My difficulty there was I recognised the pattern of behaviour and couldn't name it and once I named it I was fine I brought my mood right down again... you see my anxiety starting to go up and then it goes like that and then it comes right down like that as soon as I'd named it and identified it." Participant 5-F

"Having to sort of reflect on my mood, on my how I was feeling actually helped, helped me to sort of temper it and control It … … sometimes if I was feeling you know particularly stressed or whatever, I would, I would, I would get out the phone and I'd do it [Mood Zoom] and that, and just that act would, would, would be helpful to me" Participant 6-M

The relationship between mood states and sleep was noted by a number of participants (N=6, 29%).

"Because everyone has bad days and I think when you've got bipolar it's kind of you're always on the verge of thinking oh is this when I'm going to really crash. Just having a look at the graph and thinking actually no it might be just because I didn't sleep well last night". Participant 7-F

3.1.2 Behavioural change

In over half of participants, mood and activity monitoring was associated with a change in behaviour. The majority of change related to activity, with most finding that they had increased their exercise levels as a result of taking part in the study.

> *"I think it encourages you to do more exercise if you come to the end of the day and you have a choice of walking to the pub or driving I'm more likely to walk".*
> Participant 11-F

> *"Makes you think about the amount of exercise that you're doing…it has made me move more and I will try, I do try and get more exercise in during the day. But yeah, I think it has actually changed my behaviour for the better."* Participant 8-M

Others commented on improving their sleep hygiene.

> *"I thought mmm I'd, I would like to get a bit more sleep and I'll go to bed a bit earlier, because I do notice, that, my bi-, one of my ….. ways of managing bipolar is to get a good amount of sleep"* Participant 1-F

3.1.3 Context

A majority (N=14, 66%) of participants spoke about the importance of context when monitoring mood. Concerns were raised that reactive mood changes might be misinterpreted as representing illness relapse. They emphasised that mood changes were to be expected in many instances. In some cases participants expressed the desire to be able to record context in order to be able to reflect on possible patterns and triggers to their mood episodes.

> *"Had I done a workout and then filled in my AMoSS, the scores would've been really high, but then again there would be no way to say I've just done a workout"*
> Participant 4-F

"I started a new job in January and 3 days before then I really was incredibly anxious and you know yes it's reflected in the score but there wasn't anything that actually provided the context of why I might have been anxious at that time which I think would have been very very useful with this information because obviously if you're anxious for no particular reason or you're anxious for a trivial reason then that's actually something that's quite informative" Participant 8-M

3.1.4 Concerns

~~Three participants raised concerns about the sensitivity of the daily Mood Zoom questions having noticed that their responses rarely changed.~~

> ~~*"I almost answer the same things everyday like you know so I don't, so I don't feel like it was maybe accurately measuring me well enough"* Participant 10-M~~

~~One participant acknowledged that this might simply have reflected their current mood state.~~

> ~~*"On the mood zoom I'd say I rarely went beyond the half way and I know as I scientist you use the full range but I suppose it was a reflection of my mood as well."* Participant 11-F~~

Four participants spoke about the potential for monitoring to become preoccupying and thus unhelpful.

> *"I was thinking with all this self-monitoring you can go insane, you can go completely over board. In addition to the alcohol monitoring I also started doing budget monitoring and this is how you can go nuts …I realised I was spending an hour and a half or 2 hours a day just calculating what I was doing and I said "this is out of control, I need a life".* Participant 12-F

"Just sort of thought I think that generally you can examine your own navel too much and if you're wondering if you've got a little bit of anxiety or those are normal things aren't they and I didn't want to sound abnormal". Participant 13-F

A few (N=3, 14%) expressed a desire to receive feedback or interpretation of their data.

"Just putting the data out into the ether suddenly felt quite, haven't really, felt a bit alone with it all, is it actually, what are you getting out of it, I don't think I'm getting out of it very much anymore. Um, needed a bit more reciprocal perhaps." Participant 14-M

"Having some kind of reassurance about that or explanation I think would have been very very useful" Participant 8-M

Two participants raised concerns as to how they might misinterpret monitoring when unwell and many others highlighted the need for such devices to look normal and not draw attention from the general public.

"It would freak me out if I had to do that while being paranoid… I think my main concern was with the paranoia and with having lots of equipment" Participant 7-F

"It's so ugly and it's so noticeable and people will say or people will tease you about your watch or something else and so it brings into focus it's something different" Participant 11-F

"They'll see the number, they might see the number on the front and that just looks like I expect a sort of serial prison number or something. Or it could be a tag" Participant 6-M

3.1.5 Semantics and mood monitoring

~~A number of different improvements to the study devices were suggested by participants.~~

Three participants raised concerns about the sensitivity of the daily Mood Zoom questions having noticed that their responses rarely changed.

"I almost answer the same things everyday like you know so I don't, so I don't feel like it was maybe accurately measuring me well enough" Participant 10-M

One participant acknowledged that this might simply have reflected their current mood state.

"On the mood zoom I'd say I rarely went beyond the half way and I know as I scientist you use the full range but I suppose it was a reflection of my mood as well." Participant 11-F

Some queried the mood descriptors we had used in the questionnaires as they felt that others may have been more relevant to them.

> *"Energetic, because sometimes, it's, how sluggish do you feel? …I would like to take a few out like how I know for me have never changed from the whole time when you look at it, so that's not monitoring a change for me."* Participant 15-F

> *"Sad and elated I think should be low and high because you can feel low and depressed but not feel sad if that makes sense. Equally, you can be high and full of ideas and running around like a mad thing but not necessarily feel elated…"* Participant 8-M

Others (N=6, 29%) raised semantic concerns stating that they would have preferred to have had greater explanation as to the meaning of the mood descriptors that were used.

> *"Elated… can mean happy but it can also mean manic and it can, you know and it's, it's kind of am I elated or do I just kind of feel normal and alright and positive and actually well then that's not a zero on the scale, that's probably you know and just sort working out the semantics of it"* Participant 13-F

"So what does 7 on the energetic scale feel like without any sort of measure of what that should be it's kind of difficult to pick a number on that" Participant 4-F

3.1.6 Enhancing clinical care

Eighteen participants (86%) thought that prospective mood and activity monitoring would be beneficial to enhance clinical decision making during routine clinical care, and make time spent with psychiatrists more efficient.

"I think they'd be able to make, … make objective decisions about medication changes … and frequency of interaction and yeah freq- …, yeah, yeah, … it's, it's … having, …, having … a little of our data about our moods, just health professionals would be able to make much better decisions I think" Participant 6-M

"I think if you've got an appointment with the psychiatrist and you've got like a 20 minute appointment or something … … they could look at that data before they see you to get an overview whereas they're assessing you on like how you are today." Participant 1-F

Comments were made about how difficult it is to recall mood states and how monitoring can assist with this.

"I think it's a really good thing to be looking at because I do find that if I'm not feeling well and then you don't get an appointment for a week it's so difficult to describe how you were feeling before and I think even with physical pain like as well as mood." Participant 9-F

"If they could see at least I've been moving around and doing stuff during the week I think it would be useful for them. They have to take my word for it at the moment and although I won't lie there are some days I say I'm sorry I haven't got a clue what I did. I think it would be useful for them to get connected, involved in some sort of way.

You might give them insight into why people react to what they're doing." Participant 16-M

Just one participant said that they didn't want others to be able to access their data as they felt this may take some control away from them and they feared burdening others.

"I've never wanted anyone, I think if I, it might be useful but I don't want it. If my mood is low or high I don't want anyone to know until I'm ready to let them know and I know I should but I don't want to put the pressure or the burden on to anyone else or friends…. I'll choose when to seek help." Participant 11-F

3.~~2.11.7~~ Tolerability and usability

Questionnaire responses revealed that once daily mood monitoring via the daily Mood Zoom questionnaires was found to be of little or no inconvenience (Mdn 1.5; see Table 2). This contrasted with mood monitoring when mood samples were collected ten times daily during the 'high-intensity' phase of the study, where median reported convenience was 'somewhat inconvenient' (Mdn 3), a difference that was statistically significant (z = -2.31, p = 0.02, r = -0.39).

Table 2 about here

In addition, the majority of participants tolerated the study devices well. The GeneActiv watch (worn on the wrist and used to measure actigraphy, body temperature and light levels) and the Fitbit activity tracker were reported to be similarly tolerable (z = -0.57 p = 0.57). Free text questionnaire responses, provided further support for device usability and tolerability, although some participants commented on problems remembering to wear their technology or apply appropriate button-presses to activate certain functions. ~~Some participants noted that trackers did not capture all of their activities and thus the data may not have been be entirely accurate (N= 6, 29%).~~

'Unobtrusive- soon forgot I was wearing it'' – Participant 104 – F

'Sometimes forgot to attach it to arm after shower before bed. Sometimes forgot to attach it to body in morning.' – Participant 21 – M

Some participants noted that trackers did not capture all of their activities and thus the data may not have been be entirely accurate (N= 6, 29%).

Formatted: Indent: Left: 0 cm, First line: 0 cm

'It doesn't register in certain circumstances- swimming (have to remove it), yoga, biking' – Participant 108 – F

Despite this, very few technical difficulties were reported with the devices over the study period.

3.2.2 Compliance

Compliance with both Mood Zoom daily questionnaires and True Colours weekly questionnaires was high (see Table 3).

As reflected in the qualitative interviews and feedback questionnaires, compliance with activity monitoring devices was found to be relatively high throughout the 12 week study period. The GeneActiv watch was worn by participants for 96% of the time required. One participant lost their Fitbit within the first 2 weeks of the study. Of those that remained, 16 (80%) showed compliance of over 90% (defined as the percentage of days where at least 200 steps were recorded); remaining participants showed compliance levels at 72%, 56%, 34% and 28%.

Table 3 about here

4. DISCUSSION

4.1 Principal findings

Mood monitoring and actigraphy was well accepted and tolerated by individuals with BD. Monitoring was reported by participants as having assisted them in the recognition of mood states. This awareness enabled them to link their mood with sleep, alcohol intake and exercise. In this way, insight appeared to be directly linked to behaviour change or behaviour reinforcement in many participants. Compliance with daily and weekly prompts to submit mood ratings was high (median 86% for Mood Zoom and 100% for True Colours). These findings are comparable to other studies that show compliance rates to remote mood and activity monitoring ranging from 75% [4] to 88% [15].

An increasing body of work suggests that interventions based on mobile or electronic health platforms are acceptable to patients [22]. However, the majority of previous studies have estimated acceptability from the frequency of use of the platform/intervention; study retention; response rates; and proportion of devices returned. We know of only four prior studies that have used qualitative methods to explore bipolar disorder patients' experiences of mobile health technologies, despite the potential richness of data that this approach can contribute to the understanding of factors influencing patient engagement, including perceived utility. Two studies by Bardram et al [17] and Frost et al [18] reported that patients with BD had found the MONARCA system – a mobile application for personal monitoring in bipolar disorder – both usable and useful in disease management. However, no systematic qualitative analysis of patients' experiences was conducted, and feedback was primarily relevant to the development of this specific application; there was little exploration of the broader influence of monitoring technologies on patients' lives or disease management. Wenze, Armey and Miller [23] found that participants with BD (N=14) who received automated feedback via a personal digital assistant for 2 weeks reported increased insight into mood patterns and behavioural changes (greater regularity in daily routines; more physical exercise) whilst Naslund et al [24] found, working with patients with schizophrenia or BD (total N=28) and using technology similar to the present study, that commercial wearable mobile health technologies were perceived as

Formatted: Indent: Left: 0 cm

effective in supporting weight loss. However, these studies focussed on medication adherence and weight loss, respectively, and did not explore the impact of mobile monitoring on other aspects of illness management.

Our findings highlight important patient preferences for mood monitoring to be sufficiently flexible, comprehensive, and contextualized. Some individuals stressed that ~~that~~ there was little opportunity to explain the context of individual mood ratings and that as a result some ratings might be misinterpreted as evidence of relapse. Feeling enabled to view and make sense of data was also clearly important to participants. In addition, patients largely preferred "low-friction" solutions to longitudinal monitoring of activity and sleep, where data collection required minimal input. A small number of participants expressed some unease about accessing and interpreting the data, and how monitoring might feed paranoia during episodes of illness. Additionally, the potential for individuals to become overly preoccupied with monitored data was raised as a challenge. Given the relapsing and remitting nature of most major mental illness this is an area which warrants further exploration. The use of monitoring may also be deemed to add to stigma of mental illness by drawing attention to the user particularly if it requires the use of novel devices. More generally there also needs to be consideration of the nature of personal data stored on such devices and the security of its storage.

Despite the~~se~~ concerns raised by participants, there was wide recognition of the potential for monitoring to facilitate earlier identification of mood changes or relapse, and enhance clinical care. At present psychiatric assessment relies heavily on an anamnestic approach which is prone to recall bias and dominated by current mood state. The ability for patients to prospectively monitor symptoms in real time presents an exciting opportunity to gain a more accurate and individualised insight into psychiatric illness. It also raises the possibility of more dynamic and flexible service provision and monitoring of treatment outcomes.

Commented [KS2]: Possibility for individualised treatment responses too

Commented [I3]: Yes I think this is a good point to add, especially in light of the work Andrea is doing.

TNotably, the forms of monitoring employed in our study were not generally seen to be inconvenient, although patients did indicate that completing our short (7-item) mood questionnaire at a rate of ten times a day could be intrusive. This raises questions about the frequency over which multi-day mood samples could tolerably be collected, particularly in longitudinal studies or interventions.

This is the first study to explore the tolerability of mood monitoring and actigraphy in people with BD. While mood monitoring apps for BD are widely available, few have been systematically assessed and download numbers have largely been used as a metric for tolerability [25]. The ubiquity of mobile technology makes it an attractive platform for the delivery of mood monitoring questionnaires while the sensors housed within smart phones and other portable or wearable devices are a further source of objective data. However, for these approaches to be successful in clinical research and practice, it is important to understand patients' experience of using new technologies in this context as they need to be acceptable and tolerable to patients.

The influence of current mood state on self-report was raised by participants; however they viewed frequent monitoring as assisting in reducing this potential bias, particularly in the recollection of previous mood states during clinical interactions. The possibility for monitoring to exacerbate underlying psychopathology is of concern and was raised by a couple of participants. We were unable to explore this objectively as none of the participants experienced a psychotic episode during the first three months of the study.

The study duration was relatively short, and the longer term acceptability of monitoring could not be explored. However, all participants were given the option to continue in the study for up to a year and 18/21 of them chose to do so, suggesting that approaches such as this may be tolerable for at least medium- to long-term data collection. The study involved a number of different devices and procedures and it is likely that those participants who chose to take part

were more motivated to use these forms of monitoring, and as such may not be representative of ~~the~~ bipolar patients more generally. However, our purposive sampling allowed exploration of the experiences of participants who had withdrawn from the study or demonstrated low compliance with monitoring. Finally, our analysis team were of varied (both medical and non-medical) backgrounds, with different levels of involvement with participants during the study period, bringing varying perspectives to the analysis and reducing potential bias.

5. Conclusions

Mood and activity monitoring is well tolerated by individuals with BD; is associated with greater understanding of the illness; and facilitates more informed mood management. The ubiquity of mobile technology means that high frequency mood monitoring can be delivered more efficiently and less intrusively than has previously been possible. It is a powerful tool for self-management and the enhancement of clinical care. The increasing evidence base for other markers of mood such as geolocation, activity and vocal prosody in combination with machine learning approaches have the potential to transform the way in which mood is monitored, however, this will only be clinically useful if patients are prepared to tolerate it and perceive it to be helpful.

Acknowledgements

We thank Lucy Curtin for her assistance in transcribing the interviews and Rita Silva for her input into the discussion of the findings.

Funding: This work was supported by a Wellcome Trust Strategic Award (CONBRIO: Collaborative Oxford Network for Bipolar Research to Improve Outcomes, 102,616/Z).

References

1. Bilderbeck, A.C., et al., *Psychiatric assessment of mood instability: qualitative study of patient experience.* British Journal of Psychiatry, 2014. **204**(3): p. 236-241.
2. Depp, C.A., et al., *A prospective study of the trajectories of clinical insight, affective symptoms, and cognitive ability in bipolar disorder.* J Affect Disord, 2014. **152-154**: p. 250-5.
3. Malik, A., G.M. Goodwin, and E.A. Holmes, *Contemporary approaches to frequent mood monitoring in bipolar disorder.* Journal of Experimental Psychopathology, 2012. **.3**(4): p. pp.
4. Bopp, J.M., et al., *The longitudinal course of bipolar disorder as revealed through weekly text messaging: a feasibility study.* Bipolar Disord, 2010. **12**(3): p. 327-34.
5. Parker, G. and H. Brotchie, *Psychomotor Change as a Feature of Depressive-Disorders - an Historical Overview.* Australian and New Zealand Journal of Psychiatry, 1992. **26**(2): p. 146-155.
6. Teicher, M.H., *Actigraphy and motion analysis: new tools for psychiatry.* Harv Rev Psychiatry, 1995. **3**(1): p. 18-35.
7. Kupfer, D.J., et al., *PSychomotor activity in affective states.* Archives of General Psychiatry, 1974. **30**(6): p. 765-768.
8. Kuhs, H. and D. Reschke, *Psychomotor Activity in Unipolar and Bipolar Depressive Patients.* Psychopathology, 1992. **25**(2): p. 109-116.
9. Faurholt-Jepsen, M., et al., *Differences in psychomotor activity in patients suffering from unipolar and bipolar affective disorder in the remitted or mild/moderate depressive state.* Journal of Affective Disorders, 2012. **141**(2–3): p. 457-463.
10. Weinstock, L.M. and I.W. Miller, *Functional impairment as a predictor of short-term symptom course in bipolar I disorder.* Bipolar Disord, 2008. **10**(3): p. 437-42.
11. Valenza, G., et al., *Mood recognition in bipolar patients through the PSYCHE platform: Preliminary evaluations and perspectives.* Artificial Intelligence in Medicine, 2013. **57**(1): p. 49-58.
12. Faurholt-Jepsen, M., et al., *Daily electronic monitoring of subjective and objective measures of illness activity in bipolar disorder using smartphones--the MONARCA II trial protocol: a randomized controlled single-blind parallel-group trial.* BMC Psychiatry, 2014. **14**: p. 309.

13. Beiwinkel, T., et al., *Using Smartphones to Monitor Bipolar Disorder Symptoms: A Pilot Study.* JMIR Ment Health, 2016. **3**(1): p. e2.
14. Faurholt-Jepsen, M., et al., *Daily electronic self-monitoring of subjective and objective symptoms in bipolar disorder--the MONARCA trial protocol (MONitoring, treAtment and pRediCtion of bipolAr disorder episodes): a randomised controlled single-blind trial.* BMJ Open, 2013. **3**(7).
15. Faurholt-Jepsen, M., et al., *Smartphone data as objective measures of bipolar disorder symptoms.* Psychiatry Res, 2014. **217**(1-2): p. 124-7.
16. Grunerbl, A., et al., *Smartphone-based recognition of states and state changes in bipolar disorder patients.* IEEE J Biomed Health Inform, 2015. **19**(1): p. 140-8.
17. Bardram, J.E., et al., *Designing mobile health technology for bipolar disorder: a field trial of the monarca system*, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2013, ACM: Paris, France. p. 2627-2636.
18. Frost, M., et al., *Supporting disease insight through data analysis: refinements of the monarca self-assessment system*, in *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*. 2013, ACM: Zurich, Switzerland. p. 133-142.
19. Faurholt-Jepsen, M., et al., *Daily electronic self-monitoring in bipolar disorder using smartphones – the MONARCA I trial: a randomized, placebo-controlled, single-blind, parallel group trial.* Psychological Medicine, 2015. **45**(13): p. 2691-2704.
20. QSR International Pty Ltd, *NVivo qualitative data analysis software*. 2010.
21. Ritchie, J. and L. Spencer, *Qualitative data analysis for applied policy research.*, in *Analyzing Qualitative Data*, A. Bryman and R. Burgess, Editors. 1994, Routlage. p. 173–94.
22. Naslund, J.A., et al., *Emerging mHealth and eHealth interventions for serious mental illness: a review of the literature.* J Ment Health, 2015. **24**(5): p. 321-32.
23. Wenze, S.J., M.F. Armey, and I.W. Miller, *Feasibility and Acceptability of a Mobile Intervention to Improve Treatment Adherence in Bipolar Disorder: A Pilot Study.* Behav Modif, 2014. **38**(4): p. 497-515.
24. Naslund, J.A., et al., *Feasibility of Popular m-Health Technologies for Activity Tracking Among Individuals with Serious Mental Illness.* Telemedicine and e-Health, 2014. **21**(3): p. 213-216.
25. Nicholas, J., et al., *Mobile Apps for Bipolar Disorder: A Systematic Review of Features and Content Quality.* Journal of Medical Internet Research, 2015. **17**(8).

Table 1. Demographic and clinical characteristics of participants.

Values are numbers of cases (percentages in brackets) unless otherwise specified.

	Total N=21		
	Diagnosis		**Overall**
	BDI (N=14)	**BDII (N=7)**	
Mean age at study start (SEM, range), years	43.43 (3.2, 26-63)	46.29 (4.08, 33-63)	44.38 (2.49, 26-63)
Female gender	9 (64.3%)	5 (71.4%)	14 (66.7%)
Current medications*			
Lithium	6 (42.9%)	2 (28.6%)	8 (38.1%)
Anticonvulsant	6 (42.9%)	2 (28.6%)	8 (38.1%)
Antipsychotic	6 (42.9%)	5 (71.4%)	11 (52.4%)
Antidepressant	5 (35.7%)	3 (42.9%)	8 (38.1%)
Anxiolytic	1 (7.1%)	0 (0.0%)	1 (4.8%)
Hypnotic	1 (7.1%)	0 (0.0%)	1 (4.8%)
None (drug free)	3 (21.4%)	0 (0.0%)	3 (14.3%)
Mean weeks depressed† at 3 months (SEM, range), percentage	15.83 (7.55, 0-100)	22.86 (14.59, 0-100)	18.17 (6.82, 0-100)
Mean weeks manic‡ at 3 months (SEM, range), percentage	15.23 (6.7, 0-70)	8.44 (7.04, 0-50)	12.97 (4.99, 0-70)
Employment status			
Employed full-time	5 (35.7%)	5 (71.4%)	10 (47.6%)
Employed part-time	5 (35.7%)	2 (28.6%)	7 (33.3%)
Student	1 (7.1%)	0 (0.0%)	1 (4.8%)
Unemployed	3 (21.4%)	0 (0.0%)	3 (14.3%)
Education level			
O-level/GCSE	1 (7.1%)	0 (0.0%)	1 (4.8%)
AS/A-level/HND/BTEC	2 (14.3%)	1 (14.3%)	3 (14.3%)
Degree (includes NVQ level 5)	7 (50.0%)	3 (42.9%)	10 (47.6%)
Post graduate degree	3 (21.4%)	3 (42.9%)	6 (28.6%)
Missing data	1 (7.1%)	0 (0.0%)	1 (4.8%)

†Defined as QIDS>10

‡Defined as ARSM>5

SEM = Standard Error of the Mean

Table 2. Acceptability and tolerability of AMoSS study devices.

	Median	IQR
AMoSS study app – Mood Zoom questionnaire		
Convenience - once per day	1.50	1.00-2.00
Convenience – 10 x per day	3.00	2.00-5.25
GeneActiv watch		
Comfort	2.00	1.00-3.00
Convenience	1.00	1.00-2.00
Fitbit		
Comfort	1.00	1.00-2.00
Convenience	2.00	1.00-4.00

**Answers were given on a 1-7 scale, with 1 indicating either "Not at all uncomfortable" or "Not at all inconvenient" and 7 indicating either "Very uncomfortable" or "Very inconvenient".*

Table 3. Questionnaire Compliance at 12 weeks.

	Median	IQR
Mood Zoom daily questionnaire	86.67%	75.56-93.33%
True Colours weekly questionnaire	100%	91.67-100%

**Compliance is expressed as a % of mood responses completed during 12 weeks. Maximum possible number of Mood Zoom responses was 90/90 and maximum possible number of True Colours responses was 12/12.*