Journal of Affective Disorders 205 (2016) 225–233

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research paper

Daily longitudinal self-monitoring of mood variability in bipolar disorder and borderline personality disorder

A. Tsanas [a,b,c,*], K.E.A. Saunders [d], A.C. Bilderbeck [d], N. Palmius [a], M. Osipov [a], G.D. Clifford [e,f], G.M. Goodwin [d], M. De Vos [a,c]

[a] Institute of Biomedical Engineering, Department of Engineering Science, University of Oxford, UK
[b] Oxford Centre for Industrial and Applied Mathematics, Mathematical Institute, University of Oxford, UK
[c] Sleep and Circadian Neuroscience Institute, Nuffield Department of Clinical Neurosciences, UK
[d] Department of Psychiatry, University of Oxford, UK
[e] Department of Biomedical Informatics, Emory University, Atlanta, GA, USA
[f] Department of Biomedical Engineering, Georgia Institute of Technology, USA

ARTICLE INFO

Article history:
Received 10 May 2016
Received in revised form
21 June 2016
Accepted 26 June 2016
Available online 2 July 2016

Keywords:
Bipolar disorder
Borderline personality disorder
Digital health
Mood assessment
Mood monitoring
Patient reported outcome measures

ABSTRACT

Background: Traditionally, assessment of psychiatric symptoms has been relying on their retrospective report to a trained interviewer. The emergence of smartphones facilitates passive sensor-based monitoring and active real-time monitoring through time-stamped prompts; however there are few validated self-report measures designed for this purpose.

Methods: We introduce a novel, compact questionnaire, Mood Zoom (MZ), embedded in a customised smart-phone application. MZ asks participants to rate anxiety, elation, sadness, anger, irritability and energy on a 7-point Likert scale. For comparison, we used four standard clinical questionnaires administered to participants weekly to quantify mania (ASRM), depression (QIDS), anxiety (GAD-7), and quality of life (EQ-5D). We monitored 48 Bipolar Disorder (BD), 31 Borderline Personality Disorders (BPD) and 51 Healthy control (HC) participants to study longitudinal (median $\pm$ iqr: 313 $\pm$ 194 days) variation and differences of mood traits by exploring the data using diverse time-series tools.

Results: MZ correlated well ($|R|>0.5$, $p < 0.0001$) with QIDS, GAD-7, and EQ-5D. We found statistically strong ($|R|>0.3$, $p < 0.0001$) differences in variability in all questionnaires for the three cohorts. Compared to HC, BD and BPD participants exhibit different trends and variability, and on average had higher self-reported scores in mania, depression, and anxiety, and lower quality of life. In particular, analysis of MZ variability can differentiate BD and BPD which was not hitherto possible using the weekly questionnaires.

Limitations: All reported scores rely on self-assessment; there is a lack of ongoing clinical assessment by experts to validate the findings.

Conclusions: MZ could be used for efficient, long-term, effective daily monitoring of mood instability in clinical psychiatric practice.

1. Introduction

The potential benefits of reliable monitoring of symptom severity is acknowledged in many chronic conditions (Steventon et al., 2012; Tsanas, 2012), but particularly for mental health (American Psychiatric Association, 2013; Holmes et al., 2016; Lanata et al., 2015; Solomon et al., 2010). Residual symptoms are important in psychiatric disorders because they directly impair social and economic activity and increase the risk of new episodes. Capture and monitoring of symptom variability and progression prospectively (Slade, 2002; Solomon et al., 2010) is accordingly widely encouraged in treatment guidelines.

Monitoring of mood states is often used in the assessment and management of mood disorders. Traditionally, self-monitoring of mood using Patient Reported Outcome Measures (PROMs) was achieved using paper-based and more recently computer-based questionnaires (Bopp, 2010, Malik, 2012) but in recent years the ubiquity of mobile networks and the rapid evolution of smartphone technology have led to an increasing focus on the use of mobile applications (Faurholt-Jepsen et al., 2015; Schärer et al.,

* Corresponding author. Present address: Institute of Biomedical Engineering, Department of Engineering Science, University of Oxford, Old Road Campus Research Building, Headington, Oxford OX3 7DQ, UK.
E-mail addresses: athanasios.tsanas@eng.ox.ac.uk, tsanas@maths.ox.ac.uk, tsanasthanasis@gmail.com (A. Tsanas).

http://dx.doi.org/10.1016/j.jad.2016.06.065

2015; Schwartz et al., 2016). This approach has advantages because mood states can be reported in real time without the inconvenience of logging to a computer and thus self-ratings should be less prone to recall bias (Proudfoot et al., 2010). However, the optimal temporal frequency of mood monitoring remains the source of some uncertainty (Moore et al., 2014). Here, we describe the validation of a smartphone-based application for the delivery of daily mood monitoring in two patient groups where mood instability is a common. Bipolar Disorder (BD) and Borderline Personality Disorder (BPD) affect around 2% of the population respectively. Traditional descriptions of BD comprising clear episodes of elated or depressed mood interspersed with periods of euthymia mask the true course of the disorder which is characterised by chronic mood instability and poor inter-episode function. The duration of these periods may vary considerably from weeks to months, with depression typically dominating the longitudinal course of the disorder (Anderson et al., 2012). Borderline personality disorder is a pervasive disorder where mood instability is accompanied by impulsivity, interpersonal dysfunction, repeated suicidal gestures, an uncertain sense of self, inappropriate anger and a fear of abandonment. Mood instability in BPD is thought to differ from other disorders in its nature (Koenigsberg et al., 2002) and relate to an inability to modulate emotional responses (Gratz et al., 2006; Linehan, 1993) although few direct comparisons with BD have been made. BD and BPD can be clearly distinguished using laboratory measures of social cooperation and reward learning (Saunders et al., 2015) but in clinical practice their distinction can be far more challenging. Correct diagnosis is essential given their divergent treatment approaches; BD requires a long term medication (Goodwin et al., 2016) whereas there are no licensed medications for BPD and psychological interventions are recommended (NICE, 2009). We stress that this study focuses on mood variability and not emotional dysregulation. The latter refers to short-term (from seconds to a few hours) behavioural outbursts, and is the result of poor regulation of emotional responses. Mood is less specific than emotions and refers to an internal psychological state which can last from hours to months; mood variability aims to characterize long-term mood disturbances.

The aims of the study were to: (a) introduce and validate a novel clinical questionnaire used for *daily* mood monitoring as part of a smartphone application, (b) explore the longitudinal variation in mood characteristics of BD, BPD, and Healthy Control (HC) participants extracted from this new questionnaire as compared to four established psychiatric questionnaires quantifying mood on a *weekly* basis and (c) to test the hypothesis that mood variability might discriminate BD and BPD groups from HC and more critically from each other. We present results from a relatively large number of participants in the context of longitudinal mood monitoring, tracking their mood variation for *multiple months*, as opposed to other studies that were confined to a *few weeks* (e.g. Holmes et al., 2016; Schwartz et al., 2016), and using multiple questionnaires (most previous studies focus on a single questionnaire to investigate symptom variation, e.g. depression, for example Bonsall et al., 2012; Moore et al., 2014; Bonsall et al., 2015; Holmes et al., 2016). Moreover, most other studies focus solely on a single disorder (e.g. BD, Bonsall et al., 2015; Faurholt-Jepsen et al., 2015; Holmes et al., 2016; Lanata et al., 2015), whereas we have also recruited people diagnosed with BPD, and compared findings against HC.

2. Data

The data were collected as part of the Automated Monitoring of Symptom Severity (AMoSS) study exploring mood, activity and physiological variables (Palmius et al., 2014). The study was observational, and independent from the clinical care the participants received. We recruited 139 participants: 53 diagnosed with BD, 33 diagnosed with BPD and 53 age-matched HC. BD and HC were also gender-matched; the BPD group were predominantly female. The participants were recruited for an initial three-month study period, with an option to remain in the study for 12 months or longer. We excluded data from participants who either withdrew consent (one participant), or completed participation without providing at least two months of data. We processed data from 130 participants, 120 of whom had provided data for at least three months, and 61 participants provided data for at least 12 months. All participants gave written informed consent to participate in the study. All patient participants were screened by an experienced psychiatrist (KEAS) using the Structured Clinical Interview for DSM IV and the borderline items of the International Personality Disorder Examination (IPDE) (Loranger et al., 1994). The study was approved by the NRES Committee East of England – Norfolk (13/EE/0288) and the Research and Development department of Oxford Health NHS Foundation Trust. The demographic details of the participants are summarised in Table 1.

We used the Wilcoxon statistical hypothesis test to assess whether there are statistically significant differences conducting pairwise comparisons between the three cohorts. We found no statistically significant differences ($p > 0.01$) when comparing the days into the study, and the ages of the participants for the three cohorts. Similarly, there was no statistically significant difference in terms of gender between HC and BD, but gender was statistically significantly different between HC and BPD ($p = 0.003$), and also between BD and BPD ($p = 0.006$).

2.1. Established questionnaires

The participants completed the following standardized questionnaires on a *weekly* basis using the True Colours (TC) system (www.truecolours.nhs.uk) online: (i) Altman Self-rating Mania scale (ASRM) (Altman et al., 1997) to assess mania, (ii) Quick Inventory of Depressive Symptomatology Self-Report (QIDS) (Rush et al., 2003) to assess depression, (iii) Generalised Anxiety Disorder (GAD-7) (Spitzer et al., 2006) to assess anxiety, and (iv) EQ-5D (EuroQoL) assessing quality of life.

ASRM is a five-item scale requesting participants to report on (1) mood, (2) self-confidence, (3) sleep disturbance, (4) speech, and (5) activity level over the past week. Items are scored on a 0

Table 1
Summary of the AMoSS study details for the three groups.

	Bipolar Disorders (BD)	Borderline Personality Disorders (BPD)	Healthy Controls (HC)
Originally recruited	53	33	53
Processed data from	48	31	51
Days in study	353 ± 261	313 ± 107	276 ± 253
Age (years)	38 ± 21	34 ± 15	37 ± 20
Gender (males)	16	2	18
Any psychotropic medication	47	23	0
Lithium	19	0	0
Anticonvulsant	19	1	0
Antipsychotic	33	6	0
Antidepressants	17	23	0
Hypnotics	3	2	0

Of the 139 recruited participants, nine participants were excluded from further analysis who withdrew consent or failed to provide at least two months of data. The details provided refer to the 130 participants whose data was further processed. Where appropriate, we summarised the distributions in the form median $\pm$ iqr range.