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Brief report

Smartphone data as objective measures of bipolar disorder symptoms

Maria Faurholt-Jepsen [a,*], Mads Frost [b], Maj Vinberg [a], Ellen Margrethe Christensen [a], Jakob E. Bardram [b], Lars Vedel Kessing [a]

[a] The Clinic for Affective Disorder, Psychiatric Centre Copenhagen, Blegdamsvej 9, 2100 Copenhagen, Denmark
[b] The Pervasive Interaction Laboratory (PIT Lab.), IT University of Copenhagen, Copenhagen, Denmark

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ABSTRACT

The daily electronic self-monitoring Smartphone software "MONARCA" was used by 17 patients with bipolar disorder for 3 consecutive months. Patients were rated fortnightly using Hamilton Depression rating Scale 17 items (HDRS-17) and Young Mania rating Scale (YMRS) (102 ratings) with blinding for Smartphone data. Objective Smartphone measures such as physical and social activity correlated with clinically rated depressive symptoms. Self-monitored depressive symptoms correlated significantly with HDRS-17 items score.

1. Introduction

Many patients with bipolar disorder experience significant day-to-day or week-to-week mood swings below the criteria of a full-blown episode, but above those experienced by non-affected individuals (Bonsall et al., 2012). This mood instability impairs daily functioning over time (Akiskal et al., 1995) and increases the risk for relapse and/or recurrence, thus indicating that the illness is still active (Judd et al., 2008). However, the longitudinal pattern of mood instability is poorly understood as it is difficult to assess validly (Bonsall et al., 2012). Self-reported subjective measures of depressive and manic symptoms are influenced by decreased illness insight (Depp et al., 2014). Insight varies substantially over time and is decreased when affective symptoms are present, especially when of (hypo-) manic nature (Depp et al., 2014). Thus, there is a need for development of more objectively based measures of illness activity in bipolar disorder. Social activity (Weinstock and Miller 2008), i.e. engaging in relations to others, as well as physical activity (Faurholt-Jepsen et al., 2012; Kuhs and Reschke, 1992; Kupfer et al., 1974) represent central and sensitive aspects of illness activity in bipolar disorder that may be possible to measure objectively. Cell phones have been suggested as an easy and inexpensive way to monitor daily illness activity in bipolar disorder including daily data on social and physical activities (Bardram et al., 2013; Faurholt-Jepsen et al., 2013). As part of this study a software ("MONARCA") for Android Smartphones to monitor subjective and objective activities of bipolar disorder was developed (Bardram et al., 2013; Faurholt-Jepsen et al., 2013).

The aim of this "MONitoring, treAtment and pRediCtion of bipolAr disorder episodes" (MONARCA) pilot study was to investigate possible correlations between clinically rated depressive and manic symptoms of bipolar disorder and subjective and objective Smartphone data, respectively.

2. Methods

The patients were recruited from The Clinic for Affective Disorder, Psychiatric Centre Copenhagen, Denmark from August–October 2012. Inclusion criteria were as follows: 18–60 years of age and bipolar disorder diagnosis according to ICD-10 using Schedules for Clinical assessment of Neuropsychiatry (SCAN) (Wing et al., 1990). Exclusion criteria were as follows: unwillingness to use the study Smartphone as the primary cell phone, inability to learn the necessary technical skills to use the study Smartphone, lack of Danish language skills and pregnancy.

The MONARCA software used to monitor subjective and objective activities of bipolar disorder was developed by the authors (Marcu et al., 2011). Patients were prompted by the software to score the following items every evening for 3 consecutive months: subjective mood score (scored from depressive to manic on a scale from −3 to+3), sleep duration (hours), medicine intake, irritability (yes/no), activity level (scored from a scale from −3 to+3), mixed mood (yes/no), cognitive problems (yes/no), alcohol consumption (numbers of units), stress (yes/no) and individual warning signs (among these subjectively assessed data only analyses of self-rated mood is reported in the present paper). The following objective data were automatically collected every day: speech duration (minutes of speech/24 h), social activity (numbers of outgoing and incoming calls and text messages/24 h), physical activity (measured by an accelerometer every 5 min) and cell tower ID (ID of the cell tower the smartphone was connected to, sampled every 5 min). Further details about the MONARCA software is described elsewhere (Frost et al., 2013).

* Corresponding author. Tel.: +45 38647073; fax: +45 38647077.
E-mail address: maria@faurholt-jepsen.dk (M. Faurholt-Jepsen).

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After inclusion the patients received an Android Smartphone and were instructed to use the software for three consecutive months. Patients were clinically rated fortnightly using the Hamilton Depression Rating Scale-17 items (HDRS-17) (Hamilton, 1967) and the Young Mania Rating Scale (YMRS) (Young et al., 1978). Assessments were carried out by MFJ and ASJ who were not involved in the treatment of the patients and were blinded to Smartphone data.

2.1. Statistical analysis

Mixed effect regression models allowing for random intercept and slope for each participant were used. The results are based on 17 patients rated fortnightly and thus represent a total of 102 clinical ratings. Averages of the data collected from the Smartphones were taken for the days the outcome measures (HDRS-17 and YMRS) were referring to. Data was entered using Epidata®, and STATA (StataCorp LP, Collega Station, TX, USA) version 12.1 was used for analyses. *p*-Values below 0.05 (two-tailed) were considered significant.

2.2. Ethical considerations

The study was approved by the Regional Ethics Committee in The Capital Region of Denmark (H-2-2011-056) and The Danish Data Protection Agency (2013-41-1710). Smartphone data was stored at a secure server at Concern IT, Capital Region, Denmark (I-suite number RHP-2011-03). The Smartphones were loaned to the participating patients free of charge by the study and economic costs due to data traffic were refunded.

3. Results

A total of 21 patients were asked to participate in the study whereof 17 patients (70.6% women, $n=12$) were included. Three patients declined to participate due to a preference of iPhone and one patient never showed up for clinical data collection. No patients dropped out of the trial during the 3-month follow-up period. The mean age was 33.4 (S.D.: 9.5) and 82.4% ($n=14$) suffered from bipolar disorder type I. Of the 17 patients 35.3% ($n=6$) were employed (of these, five full time job and one part-time), 17.6% ($n=3$) were unemployed, 11.8% ($n=2$) were on sick leave, 29.4% ($n=5$) were students and 5.9 ($n=1$) were on disability pension. The adherence rate to make self-assessments in the MONARCA system was 88% and the collection of clinical ratings were complete (100%). The mean HDRS-17 score and YMRS score were 7.3 S.D.: 7.04 (range, 0–29) and 2.7 S.D. 4.28 (range, 0–20) respectively. Table 1 shows the results of mixed effect regression models for Smartphone data versus scores on the HDRS-17 and YMRS. There was a significant correlation between self-rated mood and HDRS-17 in both the unadjusted model and the model adjusted for age and sex. In the adjusted model the estimates were: *B*: −0.051, 95% CI: −0.062; −0.039, $p<0.0001$ indicating that for every 10 points higher score on HDRS the self-rated mood was 0.51 points lower on the mood scale from 0 to −3. The same correlation between self-rated mood and YMRS was not found (*B*: 0.008, 95% CI: −0.011; 0.027, $p=0.4$).

In the unadjusted model there was a significant correlation between lowered number of changes in cell tower ID per day and higher score on HDRS-17 (*B*: −0.48, 95% CI: −0.90; −0.070, $p=0.020$), suggesting that for every 10 points higher score on HDRS-17 patients changed 4.8 times less between cell towers. When the model was adjusted for age and sex the correlation became borderline significant (*B*: −0.43, 95% CI: −0.88; 0.0025, $p=0.064$).

There was no significant correlation between the amount of time the Smartphone screen was on, the number of outgoing text messages and affective symptoms measured with HDRS-17 and YMRS, respectively. In the unadjusted model there was a tendency, although non-significant, towards a lower number of outgoing calls with higher HDRS-17 score (*B*: −0.023, 95% CI: −0.048; 0.0023, $p=0.074$).

4. Discussion

To our knowledge this is the first report on illness activity in bipolar disorder using objective data collected via Smartphones. The results from this study showed that some objective Smartphone data correlated with symptoms of bipolar disorder. The number of cell tower ID changes per day, as an indication of the amount of movement per day, correlated significantly with HDRS-17 score in the unadjusted model and borderline significantly in the adjusted model, thus indicating that increasing depressive symptoms correlated with decreasing amount of movement per day. The number of cell tower ID changes per day is a measure of to what degree the patients in this study leave their home. Patients

Table 1
Mixed-effect linear regression of Smartphone data versus scores on Hamilton depression rating scale and Young mania rating scale in 17 patients with bipolar disorder based on 102 clinical ratings.

	Unadjusted			Adjusted[a]		
	Coefficient	95% Confidence Interval	*p*	Coefficient	95% Confidence interval	*p*
Self-rated mood						
HDRS	−0.043	−0.054;-0.032	<0.0001	−0.051	−0.062;−0.039	<0.0001
YMRS	0.010	−0.0089; 0.30	0.29	0.008	−0.011;0.027	0.41
Change in cell tower ID (number)						
HDRS	−0.48	−0.90;−0.070	0.022	−0.43	−0.88; 0.025	0.064
YMRS	−0.26	−0.84; 0.31	0.38	−0.28	−0.86; 0.29	0.34
Screen on time (seconds pr. day)						
HDRS	8.25	−162.57; 179.08	0.93	16.38	−178.08;210.84	0.87
YMRS	−5.86	−270.30; 258.53	0.97	−6.92	−268.81, 255.00	0.96
	Exp[b]	95% Confidence Interval	*p*	Exp[b]	95% Confidence Interval	*p*
Log outgoing calls (%)						
HDRS	−0.023	−0.048; 0.0023	0.074	−0.020	−0.051; 0.011	0.21
YMRS	−0.014	−0.60; 0.032	0.56	−0.016	−0.061; 0.030	0.48
Log outgoing sms (%)						
HDRS	−0.35	−0.79; 0.0094	0.12	−0.017	−0.064; 0.031	0.50
YMRS	−0.0024	−0.063; 0.058	0.94	−0.0071	−0.065; 0.051	0.81

[a] Adjusted for age and sex.
[b] slope.

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with more depressive symptoms were more at home with less outgoing activities. However, it is a general measure of movement around and is not necessarily a precise measure of daily travelled distances. Additionally there was a tendency, although not significant, for decreasing number of outgoing calls per day with increasing HDRS-17 score. This borderline significant finding was most likely due to the small sample size included in this pilot study, but it cannot be excluded that it may be due to a change in cell phone communicative habits in general. Thus, there is a tendency that electronic communication habits using phone calls and text messages are decreasing whereas communication using social media e.g. Facebook, Instagram and Twitter is increasing. Unfortunately we were unable to collect such data in the present pilot study.

We were not able to identify correlations between the objective Smartphone measures and manic symptoms according to YMRS. These negative findings could most likely be ascribed to the low prevalence of manic symptoms in our sample as the mean YMRS score was 2.7 (S.D. 4.3) reflecting that patients participating in this study were rather mood stable.

Patients were able to score their subjective depressive symptoms using the MONARCA Smartphone software as these correlated significantly with the blinded research based HDRS-17 scores, but there were no significant correlation between subjective manic symptoms and YMRS. Our study is the first to show a significant correlation between electronic self-rated depressive symptoms and HDRS-17 score. The negative finding in relation to self-rated manic symptoms is in accordance with the literature, indicating that patient insight varies substantially over time and is especially decreased when patients suffer from (hypo-) manic symptoms (Depp et al., 2014). However, it cannot be excluded that inclusion of a larger sample followed for a longer time period would have resulted in more significant correlations.

None of the included patients dropped out during the study, but patients who were unwilling to use the study Smartphone were excluded (as mentioned above three patients declined to participate due to a preference to iPhone). Thus, the participating patients could represent a sample of particularly motivated patients not having problems with interacting with Android Smartphones and could introduce a potential bias as described by others (Montes et al., 2012; Spaniel et al., 2008).

5. Conclusion

Data from this pilot study indicate that some measures, such as daily physical and social activity collected via Smartphones in patients with bipolar disorder, correlates with blinded clinically rated depressive affective symptoms. These data suggest that Smartphones may reflect an easy and objective way to record illness activity in bipolar disorder and will be evaluated in larger studies.

Conflict of interests

LVK has within recent three years been a consultant for Lundbeck and Astra Zeneca. MV has been a consultant for Eli Lilly, Lundbeck, Astra Zeneca and Servier. EMC has been a consultant for Eli Lilly, Astra Zeneca, Servier, Bristol- Myers Squibb, Lundbeck and Medilink. MFJ has been a consultant for Eli Lilly. MF and JB have no conflicts of interests.

Contributors

LVK, MV, EMC and MFJ conceived the trial and authored the protocol. MF and JB were the designers of the MONARCA Smartphone system and handled all technical matters. MF recruited the patients. ASJ and MFJ undertook the clinical examinations of participants. MFJ and LVK performed the statistical analyses and MFJ wrote the first draft of the manuscript. All authors contributed to and have approved the final version of the manuscript.

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