**Automatic Detection of Social Rhythms in Bipolar Disorder via Smartphone**

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**Abstract**

Substantial evidence indicates that greater regularity of daily routines is associated with improved outcomes in bipolar disorder. Indeed, stability of social rhythms is central to several forms of empirically-supported psychosocial treatment for bipolar disorders, including interpersonal and social rhythm therapy (IPSRT), family-focused treatment (FFT) and various cognitive-behavioral approaches. However, there is limited information about rhythm distortion and its potential relation to greater symptom burden and severity of illness. In this study, we aim to develop an objective and automated assessment of social rhythms in patients with bipolar disorder.

**Methods**

Patients with bipolar disorder used smartphones for 4 weeks that collected sensor data including accelerometer, microphone, location and communication information to infer behavioral and contextual patterns. Participants simultaneously completed SRM entries via the MoodRhythm app.

**Results**

We found that automated sensing can be used to infer SRM scores. Using location, distance traveled, conversation frequency, and non-stationary durations as inputs, our generalized model achieves root mean square error (RMSE) of 1.40, a reasonable performance given the theoretical SRM score range of -7 to 7. Personalized models further improve performance with a mean RMSE of 3.2. Classifiers using sensor streams can predict stable (≥3.5) vs. unstable (<3.5) states with high accuracy (precision=0.85; recall=0.86).

**Conclusion**

Automatic sensing is a feasible approach to inferring rhythmicity, a key marker of wellbeing in bipolar disorder. Automated sensor-free smartphone data provide an excellent proxy for self-reported data on regularity of daily routines, offering novel opportunities for clinical intervention when it is most needed.

**Table 1. Demographic and clinical characteristics of study participants.**

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>Female</td>
<td>BP-I</td>
</tr>
<tr>
<td>35</td>
<td>Female</td>
<td>BP-II</td>
</tr>
<tr>
<td>35</td>
<td>Male</td>
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<td>BP-II</td>
</tr>
<tr>
<td>35</td>
<td>Male</td>
<td>BP-II</td>
</tr>
</tbody>
</table>

**Table 2. Correlation between sensor stream and reported mood trajectories over 7 days.**

<table>
<thead>
<tr>
<th>Number of Location Clusters</th>
<th>Distance Traveled</th>
<th>Conversation Frequency</th>
<th>Non-stationary Duration</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.31***</td>
<td>0.23**</td>
<td>0.25**</td>
<td>1.35**</td>
<td>1.55</td>
</tr>
</tbody>
</table>

**Table 3. Ranking of feature importance for social rhythm stability using recursive feature elimination (RFE) and weights assigned to feature in a support vector machine using linear kernel.**

**Study Limitations**

- Small study population
- Data collected over only four weeks
- Sensor data accuracy dependent on participants carrying the phone
- Participants used study phones rather than their own devices

**Summary**

We investigated the feasibility of automated assessment of SRM score — a clinically validated marker of stability in patients with bipolar disorder — using sensor data streams from MoodRhythm, a smartphone app. Employing statistical learning techniques, we found that smart sensor data can be used to distinguish between stable and unstable states. We believe that automatically assessing rhythmicity without requiring active user engagement could have considerable clinical utility. In particular, this approach could help to overcome issues with existing paper-and-pencil based clinical tools by substantially lowering user burden associated with manual tracking and by providing data when patients are in clinical states least likely to be associated with adherence to self-report data collection.

Because automatic sensing can result in much more granular and wide-ranging data than manual tracking, this approach could be extended to an early warning system for relapse detection. Such a system could open up novel ways to provide interventions — enabling preemptive care at the right moment and the right place based on subtle, but crucial clues to inform clinical decisions on individualized treatment.

**References**