MoodRhythm: Tracking and Supporting Daily Rhythms

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Abstract
Rhythms guide our lives. Our biological clocks tell us when we need to sleep, eat and wake. But our use of technology can interrupt and obstruct these rhythms, making it difficult for our bodies to get what they need to stay healthy and balanced. Our *MoodRhythm* app helps individuals to live a more naturally rhythmic day. The key goals of MoodRhythm are to use patients' smartphones to actively and passively track daily rhythms and to provide affective feedback that can help patients to maintain a regular daily rhythm, while feeding this clinically valuable information back to their physicians.

Author Keywords
MoodRhythm; bipolar disorder; social rhythm; IPSRT

ACM Classification Keywords
H.5.m. [Information interfaces and presentation (e.g., HCI)]: Miscellaneous; J.3. [Computer Applications]: Life and Medical Sciences—Health

Bipolar Disorder
Bipolar Disorder, a common and lifelong illness, is characterized by mood and sleep–wake activity instability. It is associated with poor functional and clinical outcomes [6], high suicide rates [1], and huge societal costs [7]. Absence of regularity in daily routines is associated with an increased risk of new depressive and manic episodes [5]. Daily tracking of

Day of week	Date	Out of bed	First contact (in person or by phone) with another person
	___ / ___ / ___	Time ___:___ AM PM ☐ Did Not Do	Time ___:___ AM PM ☐ Did Not Do
	___ / ___ / ___	Time ___:___ AM PM ☐ Did Not Do	Time ___:___ AM PM ☐ Did Not Do
	___ / ___ / ___	Time ___:___ AM PM ☐ Did Not Do	Time ___:___ AM PM ☐ Did Not Do
	___ / ___ / ___	Time ___:___ AM PM ☐ Did Not Do	Time ___:___ AM PM ☐ Did Not Do

Figure 1. A portion of the original, paper-based Social Rhythm Metric-5 instrument [10].

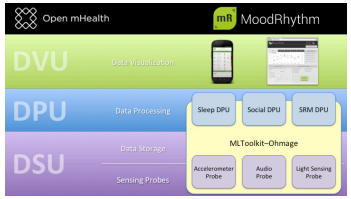

Figure 2. An overview of MoodRhythm's system architecture, based on the Open mHealth framework [3].

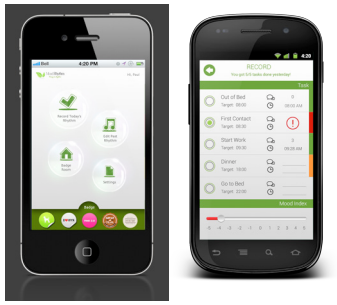

Figure 3. The MoodRhythm user interface. (Left) The app's home screen on iOS. (Right) The Android version's social rhythm data entry screen.

mood and activities helps patients notice how changes in their routines affect how they feel. Clinicians can use this information to help patients stabilize their daily routines, thereby improving their mood and reducing the risk of new episodes of mania and depression.

Interpersonal and Social Rhythm Therapy (IPSRT) is a highly specific behavioral intervention designed to regulate daily routines, which in turn is hypothesized to entrain underlying circadian rhythms [4][5]. IPSRT targets activity patterns as well as sleep timing and duration, factors that have been shown to mediate treatment outcomes. The Social Rhythm Metric-5 (SRM) is a validated, five-item self-report assessment measure of the regularity of daily routines [10]. The SRM helps to record and quantify social routines, and it is used as a both a research and a therapeutic self-monitoring tool in evidence-based psychosocial interventions (Figure 1). Increased regularity of routines, as reflected by SRM scores, has been shown to protect against new episodes of bipolar illness.

Although the SRM has been proven effective for tracking social routines, its paper-and-pencil format has multiple disadvantages, both as a clinical tool and a research instrument. Even well-intentioned patients often forget to complete it or do so inaccurately, particularly if concentration is challenged by mania or depression. The paper format is also not conducive to data summarization, such as creating a graph of trends over time that could be used to enhance patients' self-awareness of their social rhythms and to inform clinicians of prodomal changes in patients' clinical state.

The MoodRhythm System

An interdisciplinary team of students and researchers from Cornell University worked in a participatory design process with clinicians and patients from the University of Pittsburgh Medical Center to create, revise and finalize the implementation of the MoodRhythm system. We consulted standard heuristic guidelines (e.g., Nielsen's 10 heuristics [9] and Android's usability checklist); we also iteratively made improvements based on user feedback.

Our goal with MoodRhythm was to use smartphones to provide a combination of active and passive methods for tracking daily rhythms, for relaying this information to clinicians, and for providing feedback to patients to enable them to improve their moods by establishing more regular daily rhythms. MoodRhythm is a cross-platform mobile app, compatible with both Android and iOS, and a clinical dashboard. Our objectives for this project included adapting the existing paper-based SRM instrument to a digital format, constructing an extensible database schema to represent many patients' SRM data over the long term, and to utilize a smartphone data collection and processing architecture like Open mHealth [3] to enable machine learning of sensed human behavior to automate completion of the SRM to the greatest extent possible and share relevant health information among the patient their close family members, and their clinicians (Figure 2).

Replicating the Paper-Based SRM-5 Instrument: Recording Social Rhythms

MoodRhythm allows patients to track the 5 basic activities used in the prototypical paper version of the SRM, but also to add custom activities that may be more informative based on a particular patient's needs or habits (Figure 3). Patients can set daily targets and to track how closely they meet these target times. Notes can be used to record additional information such as the amount of medication taken or factors that may

Figure 4. MoodRhythm's web dashboard, designed to help clinicians review rhythmicity data together with bipolar patients.

have affected a patient's routine or mood. Ambient feedback and tailored notifications are designed to help patients become more aware of their daily patterns and adhere to their therapeutic goals. The system is designed to provide an at-a-glance summary of the patient's success in meeting their rhythm goals for both the current and preceding day. If the patient completes an activity within a 45-minute window from their target time, then the bar to the left turns green. When the 45-minute window is about to elapse and an event is not yet recorded, the bar appears yellow (a "warning" that a potential rhythm disruption is occurring). If the patient neglects to enter a time for the activity and more than 45 minutes have passed since the target time, the bar becomes red. We are also beginning to experiment with ambient visualizations that depict longer-term trends in adhering to activity targets.

Extending the Paper-Based SRM-5 Instrument: Automatic Rhythm Sensing

In designing MoodRhythm, we have considered how it will be used not only in a patient's daily life, but also over longer periods of time and when a patient is symptomatic; when, according to one clinician, simply remembering to "brush your teeth is a challenge." At these times, self-report can be difficult to maintain.

MoodRhythm uses the onboard sensors on patients' phones to automatically and conveniently track sleep and social activity patterns. The aim is to support patients who find self-tracking challenging but also to eventually make this data collection entirely automatic, thereby increasing the quantity of this clinically valuable daily routine information. This approach is both cost effective and broadly applicable since it targets devices and sensors that patients already own.

MoodRhythm's *Sleep Data Processing Unit* (DPU) uses an empirically validated weighting of inputs from audio, accelerometer, light level, screen unlock, and charging state data sources in order to arrive at an estimation of the time that the user spent sleeping in a given 24-hour period [8]. In MoodRhythm, the output from this module is used to provide a rough estimate of the times that the SRM-5 targets "wake up" and "go to bed" were completed.

The system's *Social DPU* computes the frequency and duration of face-to-face conversations that a phone's owner has over the course of the day based on an analysis of audio data continuously collected using the smartphone's built-in microphone. In MoodRhythm, the output from this module is used to provide a rough estimate of the time that the SRM-5 target "first interaction" is completed. The module is based on code that was previously developed, deployed, and evaluated in the BeWell system for self-reflection on a variety of wellness measures [8].

Supporting Clinician–Patient Communication

We also considered how MoodRhythm could complement and extend clinicians' existing ways of working. During development, one clinician commented:

> *We rely almost entirely on patient memory to make treatment decisions and when a person experiences depression, hypomania and/or anxiety, the memory is often blurry at best.*

MoodRhythm's web dashboard (Figure 4) supports clinical decisions and helps accelerate patients' personal learning. Clinicians can gain a richer picture of a patient's routine and daily sleep and wake environment

in order to inform medical decision-making and guide the patient toward personal insights.

Related Work

The prior work most similar to MoodRhythm from within the HCI and UbiComp research communities is MONARCA, which is designed to serve as a "personal monitoring system for bipolar patients" [2]. While MONARCA is focused on allowing bipolar patients to self-track factors associated with manic–depressive mood swings (e.g., sleep levels, adherence to prescribed medication regimens, and activity levels), MoodRhythm is focused much more intentionally on helping patients maintain consistent circadian and activity rhythms in their day-to-day lives. We anticipate that our system may have broader applicability across a wider variety of mental health disorders; in addition to mood disorders, circadian dysregulation has been implicated in cancer, diabetes, obesity, bulimia nervosa, and Alzheimer's disease. Rhythm entraining interventions offer the potential to help stabilize these disorders, and we hope to use MoodRhythm as a platform for exploring how how a combination of self-report and automated sensing might play an important role in therapy for these patients, as well.

Summary

MoodRhythm is part of an ongoing interdisciplinary project to explore how technologies can support the treatment of a wide range of mental illnesses including mood disorders and schizophrenia. We anticipate the MoodRhythm system will make the following research contributions as we complete ongoing evaluations: (1) it will enable us to identify the role this type of technology can have in supporting clinical interventions; (2) it will facilitate our understanding of how momentary feedback can encourage or reinforce adhering to a daily rhythm; (3) it will enable us to explore how best to combine both passive and self-report measures across different phases of illness; and (4) it will serve as a technology probe for exploring how can technology best support life-long illnesses like bipolar disorder.

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