# Smartphone-based monitoring and treatment of unipolar and bipolar disorder:
## Supervised learning augmented by unlabeled data

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## INTRODUCTION

Bipolar and unipolar disorder (depression) are a common mental diseases imposing high societal costs in terms of productivity, suffering and premature mortality. The RADMIS project aims to design, develop, and provide clinical evidence for the use of a smartphone-based monitoring and intervention technology, which has the potential to improve health outcome, quality of life, and empowerment for patients with bipolar disorder and depression. The ultimate goal of the project is to reduce readmission of patients by 50%.

Specifically, the PhD project is part of the data analysis and processing work package, which aims at establishing methods and machine learning algorithms for efficient and scalable analysis of behavioral data for pattern recognition and prediction of recurring manic and depressive episodes.

## SMARTPHONE DATA

Self-monitoring and automatically generated data is collected from patients with bipolar disorder via smartphones and transmitted to a secure server. An overview of the system is presented in Figure 1 and the platform architecture can be seen in Figure 2. The collected data can be divided into three main categories:

- ***Self-monitoring data***
- ***Phone usage data***
- ***Sensor data***

The self-monitoring data include: mood, sleep, medicine adherence, physical activity, irritability, mixed mood, cognitive problems, alcohol consumption, and stress. The phone usage data consist of: call-logs, SMS-logs, screen on/off and voice features extracted from phone calls. The sensor data include: location, step detector, proximity, and light. An example of data collected from one individual is presented in Figure 3.


**Figure 1:** The Monsenso solution. Individual users employ a smartphone to collect data, which is transmitted to a secure server where it is stored and analyzed. Healthcare providers use a web portal to monitor patients on a continuous basis and offer proactive treatment.

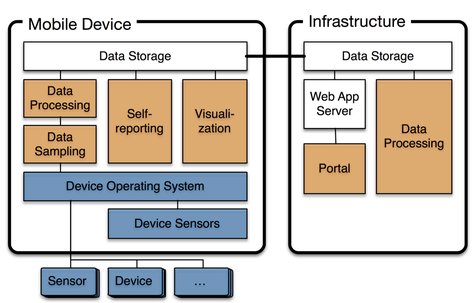


**Figure 2:** Architechture of the Monsenso platform [1]. The blue components are device-specific operating system and sensors; the white components are generic components for mobile data management and synchronization; and the orange components are components designed specifically for the personal health platform.

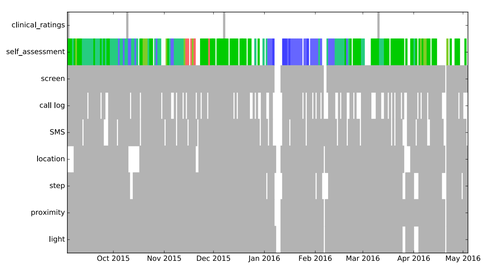


**Figure 3:** Example of data collected from one individual. Self-monitoring and sensor data is collected continuously while the clinical labels are only observed periodically. Semisupervied learning can be applied to label unlabeled data with clinical ratings in order to learn a more accurate model.

## CLINICAL RATINGS

In addition to the collection of smartphone data, the users are invited to attend clinical evaluations where their symptoms are scored on clinical rating scales for depression and mania. These ratings are numerical and said to be valid on the day they are observed as well as the three preceding days. The clinical ratings provide ground truth labels and are ultimately what we want to predict in order to enable early intervention.

## BENEFITS FROM SEMISUPERVISED LEARNING

Acquiring the clinical ratings is costly, requiring the patient to go to the clinic as well as a trained clinician to perform the interview and evaluation, while obtaining data from the smartphones is relatively cheap. Consequently, a semisupervised learning approach is of interest, since we have far more unlabeled data than data labelled with the clinically rated symptom scores.

***By utilizing semisupervised learning we hope to achieve more accurate prediction of symptom scores by taking into account the unlabeled data.***

For a semisupervised learning approach to be feasible, the unlabeled data has to carry information relevant to the objective. Previous work has shown that daily electronic self-monitoring and automatically generated smartphone data correlate with clinically rated symptoms of bipolar disorder [2], indicating that the data contains valuable information which can be utilized as objective state markers of mania and depression.

## REFERENCES

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