ARTICLE IN PRESS

Pervasive and Mobile Computing ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Pervasive and Mobile Computing

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

Classification of bipolar disorder episodes based on analysis of voice and motor activity of patients

Alban Maxhuni [a], Angélica Muñoz-Meléndez [b], Venet Osmani [a,*], Humberto Perez [b], Oscar Mayora [a], Eduardo F. Morales [b]

[a] CREATE-NET, Via alla Cascata 56 D, Trento, Italy

[b] INAOE, Luis Enrique Erro No. 1, Sta. Ma. Tonantzintla, Puebla, Mexico

ARTICLE INFO

Article history:
Received 12 January 2015
Received in revised form 15 September 2015
Accepted 8 January 2016
Available online xxxx

Keywords:
Motor activity
Bipolar disorder
Depression
Mental health
Speech emotions
Speech rate
Phone conversation
Personalized monitoring
Mobile computing

ABSTRACT

There is growing amount of scientific evidence that motor activity is the most consistent indicator of bipolar disorder. Motor activity includes several areas such as body movement, motor response time, level of psychomotor activity, and speech related motor activity. Studies of motor activity in bipolar disorder have typically used self-reported questionnaires with clinical observer-rated scales, which are therefore subjective and have often limited effectiveness. Motor activity information can be used to classify episode type in bipolar patients, which is highly relevant, since severe depression and manic states can result in mortality. This paper introduces a system able to classify the state of patients suffering from bipolar disorder using sensed information from smartphones. We collected audio, accelerometer and self-assessment data from five patients over a time-period of 12 weeks during their real-life activities. In this research we evaluated the performance of several classifiers, different sets of features and the role of the questionnaires for classifying bipolar disorder episodes. In particular, we have shown that it is possible to classify with high confidence (≈85%) the course of mood episodes or relapse in bipolar patients. To our knowledge, no research to date has focused on naturalistic observation of day-to-day phone conversation to classify impaired life functioning in individuals with bipolar disorder.

1. Introduction

The worldwide prevalence of many chronic health conditions is steadily increasing, so the management of diseases represents one of the most important challenges for health systems. The World Health Organization (WHO) has ranked mental disorders and mental injuries within the top 20 causes of disability among all medical conditions worldwide in persons aged in the range 14–55 [1]. Like other psychiatric disorder such as schizophrenia and major depression, bipolar disorder is a severe and chronic psychiatric illness that is associated with high rates of medical morbidity and premature mortality [2]. Illness characteristics and neurocognitive deficits certainly influence the quality of life and general functioning in bipolar disorder patients. One of its main characteristics is a repeated relapse of two polar episodes, mania and depression. Patients suffering from the disorder may experience episodes of altered mood states ranging from depression with sadness, hopelessness (including suicidal ideation), loss of energy, and psychomotor retardation, whereas manic episodes are

* Corresponding author.
E-mail addresses: alban.maxhuni@create-net.org (A. Maxhuni), munoz@inaoep.mx (A. Muñoz-Meléndez), venet.osmani@create-net.org (V. Osmani), humbertop@inaoep.mx (H. Perez), oscar.mayora@create-net.org (O. Mayora), emorales@inaoep.mx (E.F. Morales).

http://dx.doi.org/10.1016/j.pmcj.2016.01.008
1574-1192/

characterized by irritability, excessive energy (hyperactivity), reduction in the need of sleep and psychomotor agitation or acceleration.

The diagnosis of bipolar disorder is based on clinical evaluations through interviews and evaluations of scores gathered by quantitative psychopathological rating scales that were developed in the early 1960s (e.g. HAMD, BRAMS scales) and other more recent variations of them (e.g. BSDS). Although these interviews and questionnaires are well established and defined in a specific manual [3], they have their drawbacks, as they are performed on sporadic days, while a change to a potentially dangerous state can be produced in between these sessions. Other approaches include daily self-reports, however, they can be unreliable as they often depend on current mood episode polarity of the patients [4].

Currently, drug therapy is the main treatment, but its effectiveness critically depends on the timing of administration and has to be individually modified according to a patients' state of mind. Therapy can be very effective if administered at the beginning of a patient's transition to a different state but it may be less effective in severe states where the symptoms are present and persisted to a significant degree.

Motor activity is often used as a term to describe a group of symptoms that may range from mild to very severe, and is common feature of bipolar disorder. Assessing the motor activity of the patients with bipolar disorder has always been an essential part of psychiatric evaluations. Clinical measurement of motor activity is largely subjective and derives from caregivers' observations of specific behaviour. Motor functioning manifests itself in different areas such as speech production, facial expressions, gait, gestures, fine motor behaviour and the overall gross motor activity [5]. Furthermore, motor agitation has been shown to be potentially disruptive in patients with bipolar disorder who are experiencing a manic episode, a period when patients have increased activity levels, pressed to incoherent speech, racing thoughts and a decreased need for sleep. Motor activity may also be present during mixed and depressive episodes of bipolar patients, which can be reflected in motor retardation and irritable periods of time [3]. Therefore, monitoring motor activity is relevant for classifying critical state of the disorder. Smartphone is an enabling technology for this purpose due to increasing sensing capabilities.

The advantages of using technology to monitor bipolar disorder have recently been documented in the work carried out in MONARCA project [6–9] and have presented the basic concepts of using smartphones for the management of bipolar disorder. The authors emphasize the importance of state classification of patients by analysing several sensors embedded on a smartphone, such as location patterns from day-to-day activities, social-interaction sensing, level of physical activity, and phone usage and compared them with ground-truth values from psychiatric evaluations. Sensor data acquired from smartphones offers huge potential that through machine learning techniques get valuable insights of behaviour of bipolar disorder patients in their real life. In contrast to previous studies, we show that mood episodes of bipolar patients can be predicted using only information obtained during phone calls.

To our knowledge, no research to date has focused on a naturalistic observation of the day-to-day relationship between motor activities during phone conversation and patients' mood episode in individuals with bipolar disorder. This paper shows that motor activity features extracted from motion readings and speech articulation from smartphone sensors can be used to classify the course of mood episodes of a bipolar disorder patients. This is important because a non invasive and ubiquitous technology, like smartphones, can be used to obtain reliable information for patients during their phone conversations, in contrast to other studies using smartphone over long periods of time that can produce unreliable information when the phones are carried in purses, left at homes or use for playing or text messaging. In total, we analysed 2143 phone calls for a period of 12 weeks from five bipolar disorder patients. We extracted information from accelerometers, audio, and self-assessment questionnaires. We analysed the performance of several classifiers, the use of different sets of features, and the role of the questionnaires in the performance results. We achieved an average classification accuracy of 85.56%, and over 80% for all precision and recall values for each mental state of the different patients. This allows us to give fairly reliable information to clinicians that could take preventive actions on the effectiveness of medication and mitigate worsening of the condition.

The rest of paper is organized as follows: Section 2 summarizes previous research work with smartphones and concerning the monitoring of bipolar disorder patients. Section 3 provides information about the study group and how the data was collected. A detailed description of the attributes that were selected for classifying the episodes of the patients and representative graphs of their values on the training data is given in Section 4. Section 5 presents the experiments and results of our study, and discuss the potential benefits of the approach. Conclusions and future research directions are given in Section 6.

2. Related work

In this section we provide an overview of the most relevant research work on understanding human behaviour through mobile technology advancements.

2.1. Monitoring human behaviour through mobile technology

A number of researchers have demonstrated the potential of monitoring human behaviour using mobile computing and sensing technologies. Smartphones as ubiquitous devices are increasingly complex; they offer powerful computation and sensing capabilities for monitoring people's behaviour. They are often reported as deeply personal devices, regarding them as personal accessory [10]. Alongside these technological advances, there has been also increasing interest from researchers

Please cite this article in press as: A. Maxhuni, et al., Classification of bipolar disorder episodes based on analysis of voice and motor activity of patients, Pervasive and Mobile Computing (2016), http://dx.doi.org/10.1016/j.pmcj.2016.01.008