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A Bipolar Disorder Monitoring System Based on Wearable Device and Smartphone

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Abstract: The growing aging population and the increasingly healthcare costs demand a new paradigm for the healthcare system, which must focus on patient and emphasize mainly prevention, not only treatment. In this context, and with the wide availability of mobile technology, we here propose a patient monitoring system based on wearable sensors, and connected to a medical datacenter through a mobile device. Patients with bipolar disorder can benefit from this remote monitoring system, as warning signs can be detected early, preventing a hospitalization. Studies have reported that great part of those diagnosed with bipolar disorder do not report recognizing any early warning signs. Thus, to prevent relapses, in our system, predictive information associated with warning signs are sent to the patient's doctor. This paper proposes a continuous monitoring system of the patient's movement amount, including quality of sleep, through a system composed of wearable device, patient's smartphone and a web application.

Keywords: Healthcare, Health Monitoring, Bipolar Disorder, Wearable Devices, Accelerometers.

1. INTRODUCTION

Developed nations face fast growth in elderly combined with falling birth rates. This situation contributes to an exponential increase of healthcare costs, considering that the older portion of the population needs more care than the general population. In addition, in an older population the prevalence of chronic disease increases and the ability of individuals to provide their own safe is reduced (Pavel et al., 2013). The above-cited issues and their implications are the main driving factors to a transformation in the current health system. However, not only the elderly would benefit from that, as each individual suffering from chronic disease, who needs continuous monitoring, or even a healthy person, aiming prevention, could benefit from a dynamic, proactive and preventive health infrastructure.

A new healthcare paradigm must not only focus on treating the disease, but mainly on prevention. Thus, the current hospital-centered system, focused on diagnosis and treatment, is changing its focus to a patient-centered system, with emphasis on detection of risk factors, early diagnosis and treatment (Lymberis, 2003) (Feng et al., 2008). Reaching these goals, it will be possible to reduce treatment costs and offer better quality of life for patients. The development of an information infrastructure, combined with an effective acquisition of behavioural and clinical data, makes it possible to concentrate valuable digital data from individuals and populations. Thus, one can develop approaches to optimize decisions based on proactive evidence and centered on patients (Pavel et al., 2013). On the other hand, to obtain medical or behavioural data, wearable sensors can be used to collect data continuously from patients.

Patients with bipolar disorder can benefit from remote monitoring through mobile technologies, as warning signs can be detected early to prevent a crisis. Bipolar disorder is a mood disorder characterized by alternating episodes of depression, mania or hypomania. The mood instability is associated with a high risk of relapse and hospitalization. The main depression symptoms described by patients are sleeping too much, need to be alone and feeling tired. While for mania the major symptoms are difficult to sleep, not needing much sleep, racing thoughts and more talkative (Lobban et al., 2011).

Evidence shows that teaching patients to recognize early warning signs (EWS) of relapse can increase time to recurrence and decrease hospitalization, as precise and early detection of warning signs is decisive to avoid a crisis (Morriss et al., 2007). The detection of EWS involves helping patients to identify their particular symptoms, which may be unique to them.

Traditionally, the diagnosis of bipolar disorder is based on clinical interviews and evaluations of scores gathered by quantitative psychopathological rating scales that were developed in the early 1960s and other more recent variations of them. These interviews and questionnaires are well established, however, they have their faults. They are executed with irregular frequency, while a change to a potentially alarming state can be produced in between these sessions (Maxhuni et al., 2016). Other approaches are the daily self-reports, but they can be uncertain, because generally depend on current mood of the patients (Sims et al., 1998).

Some of those diagnosed with bipolar disorder do not report recognizing any EWS. When patients often do not recognize their mood changes in a timely manner, it can lead to adverse consequences (Jamison and Akiskal, 1983). In order to prevent relapses, predictive information associated with

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warning signs must be available to doctors, and this information could allow providers to intercede soon after first signs appear.

Recent studies have concluded that mobile computing, with their embedded sensing capability, has great potential to monitor effectively patients' lives for a variety of health behaviors (Maxhuni et al., 2016), including bipolar disorder (Beiwinkel et al., 2016) (Puiatti et al., 2011). However, using a smartphone as a physical activity-monitoring device requires the patient to remain continuously with the phone on hands or in pocket for an efficient control. Furthermore, an important parameter such as the quality of patient sleep, cannot be monitored using only the smartphone's sensors.

This paper proposes a truly continuous monitoring system of the patient's activity level, including the quality of sleep, using a wearable device. In addition, the patient's mood will be evaluated based on a questionnaire answered daily on the smartphone. The complete system consists of a wearable device, equipped with an accelerometer, a smartphone, and a web application for access by the patient's doctor. The main goal of the system is to allow that EWS, undetected by the patient, may be noticed by the doctor.

2. RELATED WORK

Smartphones have been proposed as daily monitoring devices, including patient's self-reported information collected by questionnaires, and patient's activity and social data gathered by embedded sensors (Beiwinkel et al., 2016) (Puiatti et al., 2011) (Festersen and Corradini, 2014). For example, re:Mind (Festersen and Corradini, 2014) is a mobile application in which the patient can insert health-related data, display the data, manage their medicines and prescriptions, and communicate with their doctors. Five patients suffering of bipolar disorder tested the system. Results from this project concludes that switching questionnaires from paper form to mobile application might help 17% of the patients who stated that they always lose their paper form. Preliminary tests with the system demonstrate the usefulness of mobile applications in allowing patients to monitor both their physical and their psychological state, to manage their intake of medicaments, to be informed about their disease, and to keep in touch with their doctor.

A well-known project in this field of study is the Monarca project (Puiatti et al., 2011). The Monarca system consists of two main parts: an Android mobile phone application and a website. Patients can use the mobile phone application, and on the website, there are access areas for the doctor, the patient, and, if allowed by the patient, the family. The mobile application consists of a self-reported questionnaire, data visualization option, actions to take and medicine to take. In background, an application runs as a service to collect the smartphone accelerometer data to monitor physical activity of the patient. In addition, the service application can identify the number of calls made and messages sent, aiming to monitor the patient's social activity. Preliminary feedback from users showed that this system would be very helpful in the daily life of a bipolar disorder patient, and would be a great advantage over the current paper-based forms they use.

The Simba project is the Social Information Monitoring for Patients with Bipolar Affective Disorder (Beiwinkel et al., 2016). This system monitors daily mood, physical activity, and social communication, using a smartphone. The goal of this study was to investigate whether smartphone measurements predicted clinical symptom levels and clinical symptom change. Higher levels of clinical depressive signs were predicted by lower self-reported mood measured by the smartphone. Decline in social communication and in physical activity measured by the smartphone predicted a rise in clinical depressive signs, while lower physical activity on the smartphone and higher social communication predicted higher levels of clinical manic symptoms.

A more complex system is the Psyche (Paradiso et al., 2010), which is a multi-parametric monitoring system based on textile platforms and portable sensing devices for acquisition of data from selected class of patients affected by mood disorders. The objective of the study was measuring heart rate variability from electrocardiogram and respiratory activity, aiming to predict physiological changes that can be an indicator of bipolar disease. Constant feedback and monitoring can be used to manage illness, give patients support, facilitate interaction between patient and physician as well as alert professionals in case of patients relapse and depressive or manic episodes income.

The system proposed in this paper consists of a wearable device, worn on the wrist, the patient's smartphone, a private server and a web application. The system monitors physical activity level, sleep quality and mood of the patient. An Android mobile application running on the patient's smartphone collects data from a wearable device and from a questionnaire answered by the patient once a day. Based on data gathered, the mobile application generates a daily report, which is sent to the cloud, where remains available to the doctor by means of a web application. Fig. 1 shows the general diagram of the proposed system.

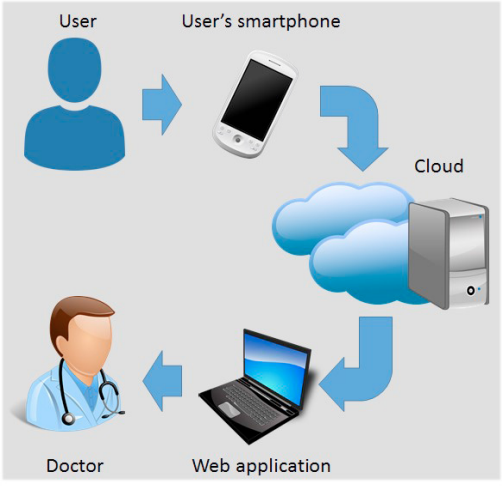

Fig. 1. General structure of the proposed system.