Mobile App and Website for Major Depression Monitoring

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Abstract: One of the challenges for the patients diagnosed with major depression is not to experience relapse or reoccurrence which are very common characteristics of major depression. Providing constant monitoring of these patients during their daily life for the first year of their depression can have a significant impact on preventing these patients to experience reoccurrence and relapse. In this paper we describe an intelligent remote monitoring system that is in the process of development and present the new research done centered on the interaction between the system and the actors involved, i.e. patients, psychiatrists and primary care physicians. This interaction is done through an android application for mobile telephones and a Website. The specification and design of the information requested and submitted to system actors through both platforms is performed by the communication module, which is also described in this research.

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1 INTRODUCTION

Depression is a common mental disorder that according to World Health Organization is affecting 121 million people worldwide (WHO, 2012). Compared with other medical diagnoses, depression is very common. It is twice as frequent in women comparing to men and it can begin at any age, but its average age of onset is in the middle of the 20s. Lifetime prevalence estimates for major depressive disorder in the community range from 15% to 17%, one year prevalence range from 6% to 7% (Ebmeier et al., 2006). A crucial aspect of the epidemiology of major depression is the increased mortality associated with this condition. A recent meta-analysis of 25 studies with 1.3 to 16 years´ follow-up of over 100,000 individual reported an overall relative risk of dying between 1.58 and 2.07 compared with people who are not depressed. According to studies, a sixth of people in the community will have major depressive disorder during their lifetime (Ebmeier et al., 2006).

Major depression is traditionally considered a treatable mental disorder. Nevertheless up to 50% of such patients may not have a satisfactory response in spite of adequate trials of antidepressant drugs (Fava, 2003). Even if they respond to medication still there is a high risk of relapse or recurrence. Naturalistic studies have found that most patients will eventually experience either a relapse (another depressive episode within 6 months after response) or recurrence (another depressive episode after 6 month elapsed) if followed for a long enough period without sustained treatment. After 15 years, almost 90% of the patients could be expected to become depressed again after experiencing an acute depressive episode (Nierenberg et al., 2003). One widely accepted method for preventing relapse or recurrence is long-term pharmacotherapy. Depression is ranked as third among disorders that cause global disease, with all the concomitant economic costs to society and will rank as first in high-income countries by 2030 (Waraich et al., 2004). Even beyond the assessment of global and national costs, the personal cost of depression is enormous. Half of the people suffering a first episode of depression will develop chronic or recurrent disorder and spent more than 20% of their life in a depression condition (Cuijpers et al., 2012).

On the other hand due to the large epidemic character of major depression it becomes impossible that psychiatrists can carry out a continuous supervision of the patient in the short time during the healing process and a long term observation after the full recovery.

Moreover, once diagnosed and prescribed by a psychiatrist, the follow-up of patients is usually done by primary care physicians, which give follow-up appointments to the patients every 3 months to analyze their evolution and make changes in the medication if required.

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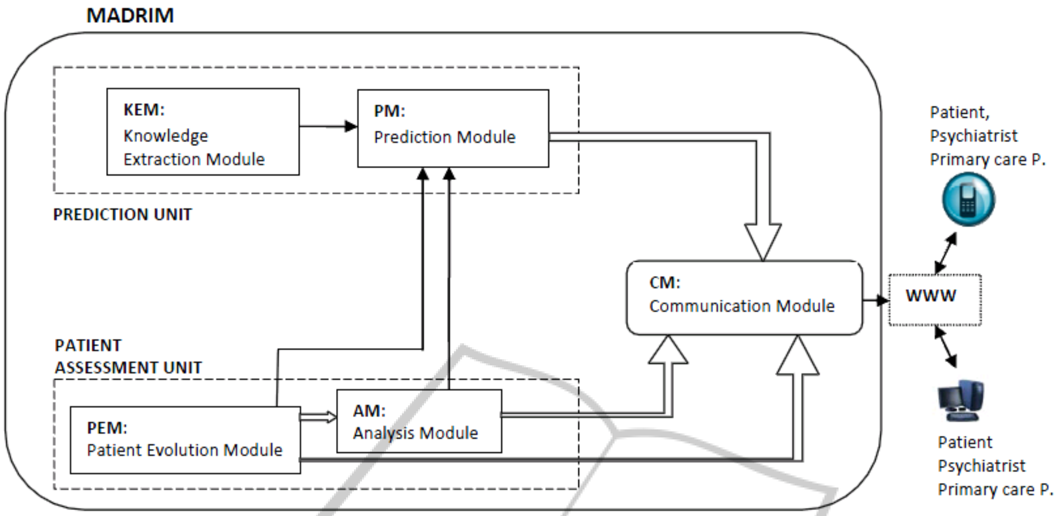

Figure 1: Architecture of the MADRIM remote intelligent monitoring and prediction system.

Therefore, in the major depression disorder there is a clear gap of supervision and continuous attention to the patients, when in reality this type of patient needs greater oversight in order to ensure, as much as possible, to take the pills.

Automatic monitoring is a tool which can prove vital to mitigate these problems and give greater attention to the patient. In addition, advances in telecommunication and sensors technologies make the task of developing ubiquitous monitoring feasible and of great usefulness. Moreover, the widespread use of mobile phones and computers make continuous remote follow-up of the patient completely feasible and practical.

Our recent work is focused on the development of an intelligent remote monitoring and prediction system, called MADRIM, for MAjor Depression Remote Intelligent Monitor, to help physicians in the process of supervision and give continuous attention to the patients. We think that a monitoring system that provides clear and concise information to both patients and physicians, keeps them informed of the evolution of patients in a short term basis and alerts them in the case of necessity is a valuable contribution if the goal is to offer monitoring to a massive number of patients. Moreover, predictions of the evolution of the patient in the near future and prediction of relapse and reoccurrence would be of great interest to psychiatrist if included in the system.

This paper is centered on the part of this system that interacts with the actors, which are patients, psychiatrists and primary care physicians. A mobile App and Website are developed and presented in this research allowing the continuous interaction with all the actors involved in the intelligent remote monitoring system, each one with its specific role.

The first part of the paper presents the whole intelligent monitor architecture and describes shortly the developments already performed. The second part of the paper presents the new developments centered on the interaction between the system and the actors involved in the major depression disease. Finally the conclusions are presented and the future work is outlined.

2 INTELLIGENT REMOTE MONITORING SYSTEM

The architecture of MADRIM is presented in Fig. 1. MADRIM is composed of two units: the patient assessment unit and the prediction unit.

The goal of the patient assessment unit is to follow the evolution of the patient during his/her recovery in order to understand its behavior and provide support to patients, psychiatrist and primary care physicians. The prediction module has the goal of going a step further and forecast the evolution of the patients some time in advance taking into account the patient assessment at this time and the knowledge obtained from data mining of registered major depression data.

The patient assessment unit is already developed and it is based on rule-based models derived from experience and expert knowledge (Mugica et al., 2012). The prediction unit is still being developed and it is based on knowledge extracted from real data by means of the Fuzzy Inductive Reasoning

(FIR) data mining technique (Escobet et al., 2008). MADRIM is implemented in java.

The communication module has the function of transmitting the results of the patient assessment unit and the prediction unit to those actors involved in the healing process, i.e. psychiatrists, physicians and patient. To this end the interaction with the patient, psychiatrist and primary care physicians is done by means of a Website and a mobile App under android platform.

2.1 Patient Assessment Unit

The idea behind the patient assessment unit is to develop a multi-factor monitor that allows following the evolution of the patient during his/her recovery in order to understand its behavior and also to provide support that helps to preventing the relapse of depression. It receives the following information (input data): the clinical data of the patient (personal information and clinical history); patient's mood and life events that are obtained from patient's responses to specific questionnaires (e.g. PHQ-9, Brugha, etc.) and physiological data streaming from sensors as for example weight, sleep and movement. Although the patient assessment module is designed in a generic form, i.e. it works with any of the available psychiatric questionnaires, in the description presented here the PHQ-9, Brugha and M.I.N.I questionnaires are used to describe the design and development of the different modules and to validate its functioning. The PHQ-9 is a depression assessment tool, which scores each of the 9 diagnostic criteria of mental disorders. The questionnaire is designed to assess the patient's mood over the last 2 weeks (The Macarthur, 2013). It is important to notice that the PHQ-9 is an extensively used questionnaire that has been validated in several studies and that is useful not only for major depression diagnosis but also for patient's evaluation. It has also been proved that this kind of questionnaires can also be applied through the telephone obtaining reliable results (Pinto-Meza et al., 2009). The Brugha questionnaire is a self-report questionnaire that examines the incidence of 12 categories of negative life events over the previous 6 months (Brugha et al., 1985). The questionnaire assesses life stressors involving moderate or long-term threat such as illness or injury, death of a close friend or relative, unemployment, financial loss and loss of important relationships. The use of this questionnaire in our system is not to support the initial diagnosis, but to help to understand certain variations in patient evolution that would be inexplicable without this information.

The Mini-International Neuropsychiatric Interview (M.I.N.I.) is a short structured diagnostic interview, developed jointly by psychiatrists and clinicians in the United States and Europe, designed to meet the need for a short but accurate structured psychiatric interview for multi-center clinical trials and epidemiology studies and to be used as a first step in outcome tracking in non research clinical settings (Sheehan et al., 1997). Although it has several modules, in this research we only use the suicidal risk questionnaire, in order to detect suicidal intentions. In the case that the question 9 of the PHQ-9 takes its highest value, more information is needed to distinguish between thoughts of death (relatively common in patients with depression, that do not necessarily imply thoughts of suicide) and the real thoughts of suicide. In this case the M.I.N.I questionnaire is presented to the patient in order to get more information related to the suicidal risk.

The patient assessment unit is composed of the Patient Evolution Module (PEM), inspired on a qualitative reasoning and the Analysis Module (AM), based on expert knowledge and pattern recognition models.

The PEM allows tracing the progress of the patients in a short time basis (15 days) in order to characterize their re-establishment to the mental health pattern. The PEM is centered on the overall rate of PHQ-9 questionnaire that is responded by the patients every two weeks.

The AM receives the short-term patient evolution status, which is the output of the PEM. From this knowledge and together with the input data described before, it defines a framework for assessing both the process of healing and the patient's risk/hazard level for each stage of treatment. The word risk is used here in the sense of defining the level of patient's enhancement, so it has nothing to do with the risk of not taking the pills. The AM is designed as a rule base model that processes a set of heterogeneous information related to the patient with the goal of monitoring and assessing the process of healing of the patient. Once diagnosed and prescribed by a psychiatrist, the follow-up of patients is usually done by primary care physicians. The objective of the system is to provide expert information to both physicians and patients that allow them to know the effectiveness of the prescribed treatment, at any time. From this point of view the results of the analysis module must be quickly and easily interpretable. The set of heterogeneous information that the analysis module requires during the reasoning process is the following:

- evolution of the patient state (i.e. the inferred rules obtained by PEM),
- incidence of new major stressful life events (e.g. Brugha questionnaire change),
- significant variations in the physiological data (e.g. sleep, weight and movement sensors),
- preexistence of alarms in the past weeks,
- number of weeks passed from the beginning of medication,
- clinical history of patients regarding to prior suicide attempt or prior recurrence or relapse,
- continuous high risk response to persistent suicidal thoughts (i.e. question 9 of PHQ9 questionnaire and section C of the MINI international neuropsychiatric interview).

The rule system of the AM processes this set of inputs in order to establish the patient treatment efficiency. AM produces two levels of conclusions. At one side, it provides a classification that in a very synthetic way warns if the treatment progresses successfully, if the evolution is not satisfactory or if the treatment is failing or if it has a high risk of failure. On the other side, it stores information about the rules that have been shot in the reasoning process and that allow to explain the above classification.

The AM is robust because it is able to deal with incomplete data, i.e. the patient is not answering the questionnaires temporally, the system could not save the data that was generated, etc. In these cases the analysis module is still capable of performing the classification and reasoning process.

2.2 Prediction Unit

This unit is composed of the Knowledge Extraction Module (KEM) and the Prediction Module (PM).

The KEM has as main goal extracting knowledge from real data that will be used for predicting patient's future behavior, especially possible reoccurrences or relapses. The process starts from data steaming form the patients. The data available for real patients are usually: personal data (i.e. age, gender, marital status, number of children, is working now?, level of studies, etc.), clinical data (i.e. previous diagnosis of major depression, has or not other diseases such are asthma, cancer, hypertension, neurological, lung, etc., the patient smokes or drinks), questionnaires (i.e. PHQ9, Hamilton, SCID depression, SCSR, etc.), treatment received (i.e. type of antidepressant, frequency and doses, type of anxiolytic, frequency and doses, type of hypnotic, frequency and doses, etc.), treatment effects (i.e. is the patient taking the medication?, has the patient side effects? which ones?, etc.). These data is usually registered at the beginning of the treatment, when the patient is diagnosed, and after 3 and 6 months of the treatment.

The Fuzzy Inductive Reasoning (FIR) methodology is then used to perform variable selection and to determine a prediction model that defines the causal and temporal relations between the relevant variables and a set of rules. With these kind of data it usually happens that the quality of the models obtained are not as good as desired, i.e. the entropy associated to the model is high. That is why we think that argumentation can be an interesting solution. The idea behind working with learning examples accompanied by arguments is to come up with machine learning techniques more efficient through mechanisms of argumentation (Bratko and Mozina, 2004); (Bratko et al., 2006). The usual task of machine learning from examples is: given a set of examples find a theory that is consistent with the examples. In the case of argument based machine learning, given a set of examples and supporting arguments for some of the examples the idea is to find a theory that explains the examples using given arguments. The motivation for using arguments in learning is twofold, 1) arguments impose constrains over the space of possible hypotheses, thus reducing search complexity and 2) a model conclusion should make more sense to an expert as it has to be consistent with given arguments. It is also important to take into account that the knowledge that experts have is usually implicit and they find it extremely difficult to elicit in the form of a set of rules. However, experts can rather easy discuss a certain case, instead of giving a general theory. The experts should give arguments to some specific examples for all possible outcomes. The arguments are then given to an argumentation engine that can use these, possible contradictive, arguments to make predictions for new examples. The prediction unit is now under development, and it is expected to have it working properly in the near future.

3 INTERACTION WITH SYSTEM'S ACTORS

The interaction with system's actors involves two main tasks. The first one is the specification and design of the information that should be gathered from the patients and that the system should offer to the stockholders. The communication module (CM) is the responsible for this task. The second one corresponds to the physical means by which the stakeholders have access to the monitoring process. In this case a mobile App and a Website. In this section both crucial developments are described in detail.

3.1 Communication Module

The CM is the responsible to sort out the risk data that is derived from the AM and to provide the adequate information to the different actors involved in the treatment process, i.e. patient, primary care physicians and psychiatrists.

While the patient needs positive encouragement messages to continue with the treatment, the primary care physician requires a tool to observe if the patient is progressing adequately. This tool should present the information in an intuitive way that does not require too much time of interpretation. If the patient does not have a good progress, the primary care practitioner redirects the patient to the psychiatric unit. The CM is designed so as to provide, on the one hand, synthesized visual information and, on the other hand, relevant and detailed information of the AM reasoning or analysis process. The first information is very helpful to the doctor and the patient, while the second is essential to facilitate psychiatrist decision making.

Every two weeks the information of the patient is actualized and a short term analysis of the state of the patient is performed by the AM. The results of the analysis are sent to the communication module, which prepares the appropriate messages and alarms to the involved actors.

The CM provides four hierarchies of communication: semaphore, alerts, reports and alarms. The highest level of the hierarchy, i.e. the semaphore, is visible for all the actors involved in the system in each time instant. A green light means that the patient is progressing adequately saying to the physicians that no action is needed. A yellow light represents an alert. This means that the patient is doing well but that there is the possibility that in the near future the progress of the patient suffers a recess. Therefore, the patient should be closely observed by the virtual assistant and/or the primary care physician. An example of yellow light could be when the PEM gives as output that the patient is improving quickly but a terrible life event, captured by the Brugha questionnaire, has occurred recently. In this case the AM concludes that a yellow light is the adequate alert level and sends this information plus the reasoning performed by the model to the CM. Finally a red light represents an alarm. An alarm means that the patient is not doing well and that physicians need to take actions, i.e. have a personal interview with the patient to asses him/her more deeply, change the medication, increase the dosage, etc. The format of the following hierarchical levels, i.e. alerts, reports and alarms are presented as a set of text messages that explain the reasoning process carried out by the AM but with different language, priority and detail depending on the level and type of the actor to whom is sent. The different messages to a particular actor can be inhibited or activated depending on the system requirements specified by psychiatrists and primary care physician. Alerts are activated each time the patient is responding to the questionnaires. Associated to the light color, the alerts show synthetically important information that must be present to interpret the light properly and, are specific to each actor in the system. Reports explain in an extensive and detailed way the inference performed by the rule base system defined in the AM, adapting the set of messages to each recipient. The reports are available upon request. Alarms inform of critical states that require taking specific actions and are transmitted by means of rapid ways like sms, e-mails, etc.

3.2 App and Website

In this research two platforms have been designed to allow the interaction with the patients and the doctors, i.e. an android mobile application (App) and a Website. The idea is that the actors can use the platform that is available to them at each time.

The architecture of the interaction between MADRIM and system actors is synthesized in Fig. 2. Both platforms cooperate with a web server that has implemented the MADRIM reasoning process described in Fig 1. The MADRIM App and Website interact, previous actor identification, with the patient, the primary care physician or the psychiatrist. The application is responsible of capturing the data of the different questionnaires administered to patients. These data is used by MADRIM reasoning process as described in the previous sections and a conclusion of the evolution of the patient is obtained. This evolution is display through a graphical semaphore representation and a set of alerts in the form of messages, to the actors that has requested it. If required the system sends also reports and alarms to psychiatrists or primary care physicians.

Both the App and the Website have an identification functionality, since each actor has different functionalities and the interaction with the

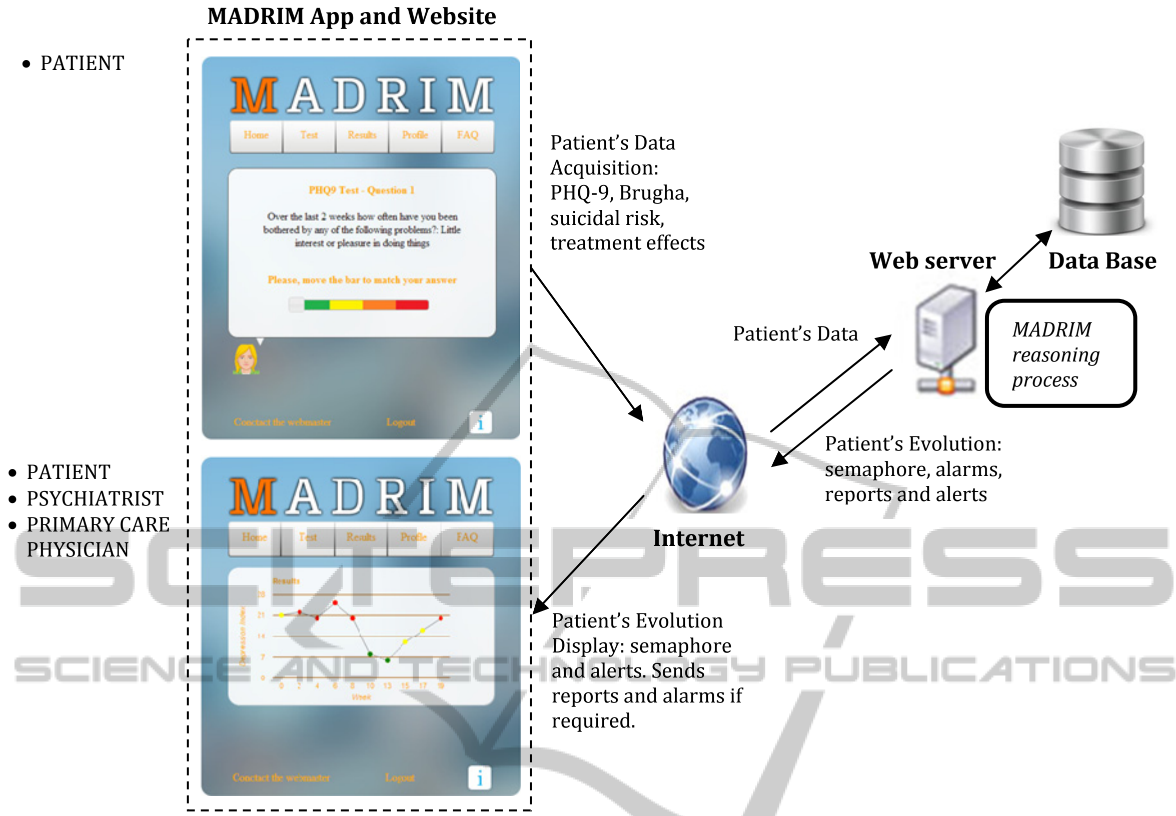

Figure 2: Architecture of the interaction between MADRIM and system actors.

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system differ from one actor to another. Moreover, both use a secure shell protocol that allows having access to patient's data in a secure manner.

The MADRIM main functionalities available for each actor are summarized next.

3.2.1 The Patient

There are three main functionalities for the patient in both platforms (App and Website). The first one allows the definition of the virtual assistant profile. The second one allows the patient's data acquisition, i.e. presents to the patient the different questionnaires that should answer. The third functionality presents the evolution of the patient graphically and gives the right messages to the patient at all times.

With respect the virtual assistant profile functionality, the patient can personalize a specific profile for his/her virtual assistant, i.e. can choose a face for the assistant, different colours for the App or Website and chose between different languages.

With respect patient's data acquisition, the most relevant actions involved in this functionality are:

- Presentation of the PHQ-9 questionnaire to the patient in a user-friendly manner every two weeks and acquisition of the patient responses.
- If the patient answered PHQ-9 question #9: *Thoughts that you would be better off dead, or of hurting yourself*, with a value of 3 (maximum value), then the M.I.N.I. suicidal risk questionnaire is presented to the patient. Patient responses are then saved.
- The system asks to the patient if he/she has had a critical event in the last month. If the answer is *yes* then the system presents the Brugha questionnaire to the patient in a user-friendly manner and acquires his/her responses
- Presentation of additional questions to the patient related to the treatment effects, i.e. is the patient taking the medication?, has the patient side effects? are they supportable? Patient responses are then saved.

There are a number of logistical issues that the mobile App must manage and resolve to make the platform dynamic and flexible to the patient's timing, when presenting the different questionnaires.

For example, how the mobile App should act when the patient is not answering the questionnaires on time? Different action protocols have been

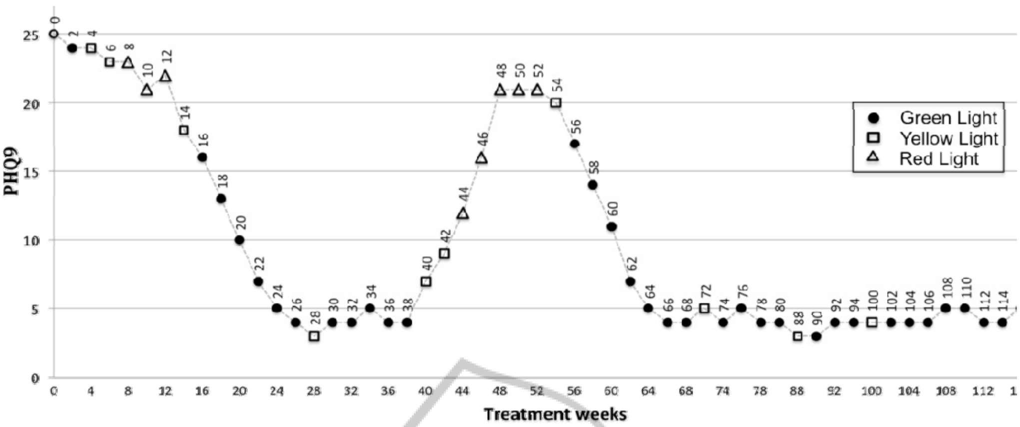

Figure 3: Graphical representation of the evolution of a patient during treatment at home. The symbols represents the different lights of the semaphore (a black dote corresponds to a green light, a square to a yellow light and a triangle to a red light), and the numbers near the symbols are the accumulated weeks of treatment.

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defined to deal with each of the possible adverse situations derived from the patient interaction.

For instance, in the case that the patient is not answering the PHQ9 every two weeks the App detects that the patient did not respond the questionnaire the day fifteen and since then, each day sends a recall SMS message indicating in a friendly manner that she/he needs to respond the questionnaire in order that he/she can see graphically its own evolution and that the doctors can follow also his/her recovery. Each day the message is a little different getting less polite day by day. If the patient does not answer the questionnaire the next time he/she should respond (i.e. a month has been passed since the last PHQ-9 data registered), then the App sends an alarm message to the primary care physician alerting of a possible reoccurrence of the depression. The doctor decides if it is necessary to get in contact with the patient to find out what is going on. Notice that the Website cannot manage this kind of situations because cannot get in contact with the patient if he/she does not decide to enter to the Website.

With respect the presentation of the patient's evolution functionality, the main actions involved are:

- Presentation of the evolution of the patient in a graphical manner. Fig. 3 shows an example of this kind of representation. The graph shows the value of the PHQ-9 questionnaire every two weeks (when the patient answers the questionnaire). It is represented by using a semaphore light, i.e. green, yellow or red, as explained in detail in the communication module section.
- Display messages to the patient. When the patient positions the cursor over one of the lights of the graph, the messages associated with the patient's situation at that moment in time are displayed in the bottom of the graph. In that way, the patient can check the messages associated to their evolution each time he/she answers the questionnaires and, also, the messages of the past PHQ-9 values. For example, if the patient is currently at week 24 and selects the green dot shown in the graph for this week (see Fig. 3), the following message is displayed in the bottom of the graph: *Congratulations, depressive state overcome. Do not leave the medication!* If the patient is now in the week 50 the message that appears is: *Worsening rapidly; Get help, go immediately to your doctor*.

In addition to the previous mentioned messages, the system sends support citations to the patient depending on his/her current disease situation. For example if the patient is progressing adequately but slowly the following citation is presented: *Have patience with all things, but chiefly have patience with yourself. Do not lose courage in considering your own imperfections but instantly set about remedying them -- every day begin the task anew.*

3.2.2 The Primary Care Physician and the Psychiatrist

The primary care physicians and the psychiatrist have available (in both platforms: App and Website) the evolution of the patient functionality, explained before.

As in the case of the patients, this functionality presents graphically (using a semaphore) how is the patient doing with the treatment. This way the doctor can analyze the evolution of the patient in a glance.

Specific messages for the doctors are also displayed at the bottom of the graph. Following the same example described for the patient in the previous section, at week 24 the message for the doctors is: *Improves adequately; Remission*, whereas at week 50 the message is: *Worsening rapidly; Relapse*. In the last case, a *relapse* alarm is also sent to the psychiatrist. In this way the doctor knows that the patient has had a relapse without accessing the application MADRIM and can act quickly accordingly.

4 CONCLUSIONS

Our current research is focused on the development of an intelligent remote monitor (MADRIM), which helps physicians in the process of supervision and gives continuous attention to patients that suffer from major depression. A monitoring system that provides complete information of the evolution of patients in a glance, keeps both patients and physicians continuously informed and alarm them in the case of necessity is a valuable contribution when the goal is to monitor a massive number of major depression patients.

The research presented in this paper is centered on the part of this system that interacts with the actors, which are patients, psychiatrists and primary care physicians. A mobile App and a Website are developed and presented in this research. These tools allow the patient's data acquisition and the presentation of the evolution of the patient in a friendly and intuitive manner. These tools have been developed paying great attention to the specific characteristics of patients that suffer from major depression and analyzing every interaction with these patients in a very precise way.

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