Masters Program in Geospatial Technologies

CONNECTING ADDICTED PATIENTS AND THERAPISTS BASED ON GPS FOR PROVIDING CONTEXT-AWARE NOTIFICATION

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ABSTRACT

Smartphones have now become a device that everyone uses in day to day activities. Moreover, thanks to their built-in sensors, they can successfully determine the user's location, perceive the real-world and act upon those stimuli. In the previous years, a location-based and context-aware platform to support the treatment of patients with psychological disorders was developed at GEOTEC, a Spanish research group in Geospatial technologies. This platform consists of a mobile application that monitors the patient's behavior and delivers interventions, and a web-based application that allows therapists to define and steer the monitoring and intervention process. Concretely, the platform tracks the users location and visualizes it for the therapist. This thesis proposes an extension to the Symptoms platform, in two ways: to allow location- and time-based triggered questionnaires, to further assess the patients psychological state in-situ and in real time, and to extend the current location-based notifications system to use the same context—based triggers to further assist psychotherapeutic interventions. To this aim, the Symptoms administration web application is extended to allow therapists to create extended context-based triggers (e.g., based on time/duration and location), to be used to trigger questionnaires (assessment) and notification (treatment). Furthermore, the web application is extended to collect, store and visualize the feedback sent by the patients to support therapists to make informed decisions. Next to the web application for therapists, the Symptoms mobile app is also extended to allow notifications and questionnaires to be displayed (when context conditions are met), and responded to by the patient. The proposed extensions are evaluated both technical and regarding usage (usefulness, usability). As a result, the mobile app and web-based application were found to be usable with SUS score of 86.75 and 75 respectively. The web app is found to be useful for the therapists to help assess and treat patients, and better understand patient's behavior.

KEYWORDS

Mental disorder

Ecological momentary intervention

Ecological momentary assessment

Mobile health

Context-aware notification

Psychological Intervention

Visualization

ACRONYMS

API - Application Programming Interface

CBT - Cognitive Behavior Therapy

DOM - Document Object Model

EMI - Ecological Momentary Intervention

EMA - Ecological Momentary Assessment

GEOTEC - The Geospatial Technologies

GPS - Global Positioning Systems

LabPsiTec - Laboratory of Psychology and Technology

LBS - Location-Based Services

REST - Representational State Transfer

SDK - Software Development Kit

SMS - Short Message Services

SUS - System Usability Scale

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1. INTRODUCTION

Since 2010s, smartphones have become an integral part of our daily lives and have arguably improved the efficiency of our lives. Users are spending more time on their smartphone than on any other devices and the amount of time spent on using smartphone increases every day. Combining both internet and mobile technologies in health treatment upgraded the quality service, efficiency process and accessibility to a healthcare provider (Wells, 2003). Smartphones offer numerous opportunities to human beings, especially to clinicians. In recent times, health treatments are upgraded from a traditional way of caring, which requires a manual way of treatment, in to a modern controlling way, so that fast emergency action is provided to patients and they can, thus be controlled with the help of modern mobile sensing technology. Smartphones regularly contain features like multimedia, internet, camera, GPS, voice, and video calling, messaging, and capacity to deal with huge amounts of data. These points of interest make smartphones to be an appealing alternative in encouraging the appropriation, support and generalization of different remedial practices into the customer's regular day to day activities. In most therapeutic scenarios, particularly in behavioural healthcare, errors occurred due to incomplete information which leads clinicians to make a wrong analysis and medication for the patients (Hayward, 2001). Applying mobile technologies for healthcare treatment in general has an advantage in improving the overall accessibilities of healthcare service providers, gathering more systematic and accurate data about the patient and creating a consistent communication between the therapist and the patients for modern way treatment as well as minimizing the expense for healthcare service. (Raatikainen, Christensen, & Nakajima, 2002).

A location-based and context-aware platform which consists of two client-side applications (a mobile app and a web-based application) and a server-side system, was created by GEOTEC. The mobile app is responsible for capturing the user's geospatial data (i.e., location) and to a limited extent, communicate with the patient. The web-based application allows managing patients (adding them, configuring the analysis and visualizations for them) and visualizing the results of the analyses performed based on their monitoring data. The central component is the server, which stores the captured geospatial (and other) data from the patients' mobile devices, perform the analysis over the data, and provides an access point for client-side applications (such as the web-based visualizer). Currently, the system mainly does monitoring, some analysis (e.g., routes, frequently visited places, time spent in/out of home) and visualization, and only a minimal part of intervention (i.e., geo-fencing & notification when entering the fence).

Nevertheless, the platform is extensible and intrinsically capable of providing interventions through richer communication between the patient and the therapist. This thesis aims to further develop the platform with this goal in mind. Example: if we consider an alcohol addicted patient and if patient is around a bar for more than the predefined time (10 minutes) the application can automatically send a support message or a questionnaire (based on the location) to assess his current emotional state. This app is expected to be more effective than the paper-based treatment system and enhance the validity and accuracy of the data; the cycle of data collection is shortened, data delivery and data processing is automated so that the therapist can immediately visualize and interpret the data. This technique introduces new capabilities of sending automated location- and time-based messages and questionnaires, and improves the connection between patients and therapists for treatment of addicted patients.

1.1. Problem statement and Research Question

Amazingly, even in this technological era, psychologists are mostly dependent on pen and paper, asking the patient their activities, their location as well as their habits for recordkeeping. The validity of the data heavily depends on the trustworthy of the patients. The intervention between therapists and patients is very traditional, where the patients meet their therapist physically, at which time patient data gathered over a set time period is obtained by the therapist, and a therapeutic sessions (e.g., advice, motivation, exercises to perform) is performed. This kind of intervention has different barriers that appear during treatment. In an emergency, where the patients need assistance, geographical constraints make it difficult to meet with their counsellor. It causes delays at both sides and may incur significant cost due to delayed treatment. Even if the patient meets with their therapist they have a short period of time to discuss, moreover, it may be hard for the patients to reveal the information about themselves during a session. It could also be difficult to memorize the activity they have done which makes it tough for the therapists to follow the patient. Additionally, due to intentional deceit of the patient's data collection maybe inaccurate. Moreover, there is a delay between the data collection (usually daily) and data delivery and processing (usually during a weekly or bi-weekly session with the psychologist).

This thesis is set within the general objective of improving the treatment of patients with mental health problem using smart phones. In particular, our goal is to investigate if place- and time-based notifications and questionnaires may help therapists to devise a better treatment for patient suffering from a mental disorder. For this study, among other mental illnesses, "addiction" was considered.

The specific research questions are:

- ✓ Can location- and time-triggered questionnaires help therapists to better understand (assess) a patient?
- ✓ Can location- and time-triggered notifications help therapists to better treat a patient?
- ✓ Can location- and time-based gathered information (e.g., time of notifications/questionnaires, answers to questionnaires) help therapists to better tailor the patient's treatment?

1.2. Approach and Methodology

1. Understand the problem domain and scientific state of the art in mobile applications for psychological interventions and related fields.

Methods: - an explorative literature review

- interview with psychologists/therapists

2. Define the problem statement and requirements for the application(s), in cooperation with a group of experts in the field of psychology.

Methods: - through interview with psychologists/therapists

3. System design

Methods: - design the system based on the requirements obtained from the therapist and through literature review, using classical software engineering techniques (architectural design, software design diagrams).

4. Extend the existing web app by adding context-based trigger (primarily, time & location based) and allow therapists to create rich interaction possibilities for patients (e.g., notifications, short questionnaires) in-situ and depending on certain context conditions.

Methods: - The Agile software development SCRUM is used. The SCRUM methodology consists of several “sprints”, during which the developers takes a small set of requirements and implement the corresponding features (Mountain Goat Software, 2019). These features as subsequently tested and integrated into the (working) system. Subsequent iterations are performed, until a final software product is obtained.

5. Extend the existing mobile app to support time triggering for notifications and questionnaires, -and to allow questionnaires to be displayed (if the context conditions are met) and answered by the patient.

Methods: - The same as number 3, the agile development methodology SCRUM is followed.

6. Develop a module that focuses on visualizing the feedback sent by the patients to support therapists to make informed decision.

Methods: - Following 3 the agile development methodology SCRUM is used.

7. Evaluating the usability and technical part (test accuracy of time triggering) of the mobile app.

Methods: - System Usability Scale tool (SUS) is used to evaluate the usability of the mobile app.

- Technical testing is done by setting up an experiment, whereby the mobile app is run 75 times under controlled conditions, and relevant metrics are recorded.

8. Evaluating the usability and usefulness of the web app to provide context-aware, in-situ therapeutic interventions, with the help of therapists.

Methods: - usability test is done using System Usability Scale tool (SUS).

- usefulness of the web app is done using a custom questionnaire, aligned with the research questions and designed to measure various aspects of usefulness.

9. Conclusion.

1.3. Outline

Thesis structure is as follows: **Chapter one** includes introduction, goal, problem statement, research question and how the research question is going to be answered. **Chapter two** includes definition of EMI and EMA, the background concepts related to psychology treatments, as well as related work regarding questionnaires, existing literature focusing location-based systems and technologies used within the thesis. **Chapter three** describes the existing application. **Chapter four** focuses on the implementation of extended application. **Chapter five** provides detail description on the process of the evaluation, how the application is evaluated and the results of the evaluation. **Chapter six** concludes this thesis which includes the summary, the result, the limitation and future work.

2. BACKGROUND AND RELATED WORK

Due to the rapid popularity of Internet, computers and Mobile devices such as smartphones and tablets have become an integral part of everyone's daily life. Among the industries, healthcare has adopted many Internet based platforms. They have stimulated a lot of creative approaches to handle health challenges including consumer behaviour change, patient support, staff training, and management information and logistics systems(Sassi, 2012) . However, there are still a lot of areas where healthcare can utilize the constantly emerging Internet based platforms.

In 2005 alone, above 17 million people, in United States, were recorded as having an alcohol use disorder, yet only as low as 4 million people were received medical treatments at healthcare centre's (Serving, Msi, & Cbo, 2014). Beside the low turnover at the healthcare centre's, it was very difficult to follow up every treated individual after he/she left the health center. Smartphones have a huge potential that can completely enhance the traditional methodologies of many medical treatments and continuing a lot to the healthcare by providing communicative support from anywhere and at any time (Gustafson et al., 2011).

Smartphone based features can be one possible solution to provide tailored and continuous healthcare 24/7 treatment at a fraction of the traditional care cost. Such a solution can be particularly vital for addicted patients where timing is very critical to prevent relapse. This lengthened the perspective of information communication technologies with advanced capabilities that spread the reach on what type of information should be evaluated and which services should be delivered. The risk of relapse could be minimized using continuous healthcare approaches but some studies (Zuehlke, Li, Talaei-Khoei, & Ray, 2009) showed that this approach could not be applied extensively due to the shortage of time, cost and geographic distance with the patients. Even when patients take part on the off chance, the program regularly reflect treatment approaches that are provided within the initial serious care. Instead, offering a custom fitted continuing-care approach could have specifically addressed issues that patients might have encountered amid early recuperation in a community setting. Hence, improvements to the existing healthcare framework can offer better assistances, and arrangements. For example, integration with essential cares can possibly make advanced treatment adequacy and extend its reach.(Nelson & Guyer, 2012)

2.1. Ehealth

Nowadays the utilitarian of quality and effective Health care became very high (Wanless & Health Trends Review Team, 2002). Especially in the developing countries that are marked with massive rural areas and high population, have a challenge in healthcare related issues like chronic, infectious and pandemic diseases, as well as shortage of basic program of healthcare services and unavailability of experienced healthcare professionals. The involvement of computers offers some degree of obscurity which motivate the users to pursue health information. Since the technologies permits connection through internet electronic board which are always accessible online, it is easy for individuals to transmit information. (Li, Chattopadhyay, Ray, Pek, & Land, 2008).

E-health is the ability of transferring medical information and communication technologies such as media, mobile phones and computer programs in the overall functions that can affect healthcare issues (Silber, 2003). E-health is capable to deliver healthcare issues to improve therapeutic practice proficiency by making confirmation-based healthcare treatments. Developing countries have shortage of financial and technical resources, this makes it hard for them to access eHealth applications. (Zuehlke, Li, Talaei-Khoei, & Ray, 2009)

The progress of eHealth interventions endures due to the fast growth of interactive technologies in terms of data communication, data storing and processing power. "Second-generation" eHealth intervention permits a straight communication among the partaker and technologies to improve the competencies that are beyond personalized feedback messages. The second generation of intervention lets the participants choose the appropriate psycho-education information, reports on their goal, trace their progress and deliver and receive social provision via synchronous chat rooms. (Norman et al., 2007)

Mobile health(mHealth) is one of the developing areas in eHealth which uses a mobile phone technology to make effectual delivery of healthcare service (Banitsas, Istepanian, & Tachkara, 2008). The combination of mobile technologies plays a vital role to enhance access and affordability of eHealth.

MHealth applications that are available in public vary significantly in quality, and problems such as software bugs, poor design, and limited technical support are common (Wicks & Chiauzzi, 2015). The integration of mHealth into addiction treatment was successful in the high levels of patient use. It has the potential to transform health care as it can help to make effective use of every available resource. In addition, mHealth can also engage patients with addiction in ways that benefit patients without adding substantial burden on healthcare facilitators. The mHealth system can also increase treatment of addiction in the primary care and for other chronic conditions as well. (Quanbeck et al., 2018).

2.1.1. Ecological momentary Intervention

For a long time, medical practitioners have tried to help patients to get psychotherapy support in their daily life by incorporating different skill building activities within treatment sessions. Such interventions are commonly implemented within the patients' natural environment and are being adopted in behavioral health and psychosocial treatment domains. Ecological Momentary Intervention (EMI) is a term used to describe a framework for clinical treatments characterized by the provision of quality services to targeted patients while they are engaged in their routine tasks (Heron & Smyth, 2010). EMI can be either consolidated with existing interventions or implemented by new designs. EMI is conducted mainly to provide real time support within the usual environment without affecting the daily lives of the patients. This very reason makes EMI to be a more appropriate and ecologically sound approach. (Heron & Smyth, 2010)

Technological progress has brought positive changes in the provision of EMI support to patients. The availability of sophisticated and affordable technologies like mobile phones and other similar devices enabled people to have wider opportunities in obtaining real time EMI support even when they are living in different locations and varied situations. Two major devices that are commonly used to provide EMI services are Palmtop computers and mobile telephones. These two major devices are commonly used for the service. (Heron & Smyth, 2010)

Several occasions have shown that the expansion of EMI to address other treatment settings has brought several benefits. First, in contrast to the traditional practice of treating patients in health centers, EMI has created new possibilities by implementing different interventions beyond the standard treatment contexts and providing support to patients' while engaged in their usual routines. EMI has helped patients to be highly motivated in acquiring new behaviors and skills. (Hay & Kinnier, 2011). Second, EMI has allowed patients to exercise the procedures within their natural environments, and this in turn, make patients to relate the new skills and behaviors to their actual experiences, making it very relevant to their lives (Smyth & Stone, 2003).

Delivery of EMI using mobile technology can bring more additional benefits for both patients and practitioners. The portable nature of electronic devices makes it possible to deliver EMI at any time. Using technology-based systems can also help to design interventions that appropriately fits to the characteristics of patients. Mobile technology can also enable to select the right time that patients are at ease and have appropriate readiness for EMI (Kreuter, Farrell, Olevitch, & Brennan, 2000). In addition to the above advantages, technology aided interventions can give further opportunity to repeatedly exercise tasks, letting practitioners to effectively manage their time and give due attention to the multifaceted aspects of care. These benefits suggest that there is a greater need to improve treatment efficiency, decrease the time required and reduce the overall cost of the intervention. (Heron & Smyth, 2010).

2.1.2. Ecological momentary assessment

Clinical psychologists, along with behavioral, social, and health scientists are interested in people's everyday real-world behavior. This interest is perhaps especially marked for clinical psychologists, because psychopathology and its functional impairments are expressed in real life. Mood and emotional reactivity play an important role in both mental and physical health. (Businelle, Walters, Hébert, Nandy, & Nandy, 2018)

Data collection methodologies have taken different approaches based on the type of discipline to which the data is collected for. In parallel to the development of EMI approaches, in-situ and real-time data capture techniques for EMI also passed through different stages of progress (Runyan et al., 2013). Before palmtop computers were widely used for EMI, researchers used to send messages to participants at random times throughout the day, and participants reminded by these alarms would report on their subjective experiences on paper diaries they carried with them (Leonard et al., 2017). Nowadays, the collection of real-time data using random sampling is widely extended to comprise different assessments. These activities are called Ecological Momentary Assessment (EMA). The EMA framework incorporates various ambulatory assessment techniques like paper diaries, behavioral observation, self-monitoring systems, experience sampling, and ambulatory monitoring of physiological information.(Liu, Jin, Jiang, & Lin, 2011).

EMA is an assessment method involving the regular and frequent self-assessment of momentary experiences in the context of daily life. Ecological momentary assessment (EMA) techniques use mobile devices to assess thoughts, feelings, and behaviours in real-time in an individual’s natural setting. EMA has been used to evaluate dynamic changes in mood and behaviour (Businelle, Walters, Hébert, Nandy, & Nandy, 2018). This method has been used extensively in psychosis research as a means of recording and examining momentary psychotic experiences and their relationship to internal and external variables (Farhall et al., 2018).

In summary, with the advanced mobile technologies an EMA/EMI have advantages such as no data plan or internet connection are required during data collection, it can collect data off-line. As well as it also allows researchers to collect randomized data within specified hours. (Runyan et al., 2013)

2.2. Geo-fencing and Geo-triggering

Location-based systems can detect and track the location of mobile device users such as cellular phones using global positioning systems (GPS) and triangulation system which can use mobile signals. Based on movement from a reference location which has defined coordinates the location of mobile device can be determined. For this matter, location-based systems are applied for various purposes where information of location is necessary. (Yu, 2008).

Location-based services (LBS) are used to enable the search for location-based information where relevant information is being presented by a mobile application only on request by the user. The requested location-specific information is being pulled by rather than being pushed to the user. For this situation mobile device is able to notify the user about location-specific information in case the user enters or leaves from defined areas, called Geofence. This feature is essentially used by location-based reminder in suitable way for participant to be notified about activities to do at a particular area. (Garzon, Deva, Pilz, & Medack, 2015)

Geofencing is applicable in several fields such as mobile marketing, crowd sensing, fleet management and vehicle tracking. For example, a driver entering a zone which is within a fixed distance of a store can be notified of a sale using an SMS text message (Sheehan, M, 2013) Geofencing provides a notification service; it can also be used as a real time location tracking and provides an insight into how consumers behave. Geofencing has a potential application in the mobile GIS world.

The ability to use maps on tablets & smartphones and geotriggers (actions triggered on entering or leaving a zone) can be used to create intelligent features. Various transportation departments in the US use pen and paper to record field works which includes locating each asset (feature), conduct required inspection and complete report form. To revolutionize such a tiresome field work geofence can be used. ("Mobile GIS and GeoFencing Geofencing offers some fascinating opportunities to leverage further," 2017)

Geofencing is also used by location-based notifications such as proactive location-based services to remind users about their tasks at a given place. Typical location-based reminder that aims to enhance geofencing based notification is, iReminder (Tu et al., 2013). Moreover, iReminder adopted a client-server engineering with a moveable client whose primarily actions were collecting participants route information and conveying reminding messages based on their future routes. IReminder's mobile client forecasted the participants' next route based on his/her current route and by applying a prediction tree. Then, the client at that point looked the activity list to discover tasks pointed on the predicted future route as "restricted areas" instead of all future areas to avoid early reminding.

Location-based notification was proposed to address the failure of considering temporal relationship that could detect devices passing different Geofences in a predefined temporal order (Garzon & Deva, 2014). When a participant passed over or entered the defined territory, Geofencing 2.0 would address the situation.

Geo-trigger services provide a way to add geographical zones to mobile application service that will automatically trigger a survey (or any other event) when a smartphone enters, exits or dwells at a pre-determined location(s) (Alsaqer, Hilton, Horan, & Aboulola, 2015). This technology relies upon the creation of geo-fences and the availability of GPS signal. In programming the triggers, it needs to be specified when the action needs to take place: upon entry into the geo-fence, after a certain dwell-time, upon exit or after exit (with a determined delay). Therefore, the surveys happen at the time and location of any choice. Moreover, the advantages of geo triggering are: better monitoring of the respondents, broader spectrum of consumers and one can get more immediate feedback (Geo-triggering, Wish, & Mobile, 2015).

2.3. Technologies in Psychological Treatment

Implementing smartphone application as part of social-based service can be very important to closely monitor the participants' psychiatric and medical conditions (Whiteman, Lohman, Gill, Bruce, & Bartels, 2017). Smartphone technology is very helpful for clinicians as it can increase intensity and evidence-based treatment intervention and enhance clinical results without deviation in delivering intervention components. Through Smartphone interventions, the health care management can actively and constantly monitor the patients, automatically detect problematic behaviors, effectively address tailored interventions even if the participant is outside of the clinic, and greatly facilitate treatment coordination to inform clinical decision-making. Smartphone interventions are also capable of advancing clinical effectiveness, increasing reach beyond traditional settings and changing the way healthcare is being delivered. (Whiteman, Lohman, Gill, Bruce, & Bartels, 2017).

2.3.1. Mobile app and Web-based interventions

When patients visit their doctors, they have short period of time to discuss, which makes it difficult for the doctors to get up-to-date information on how the patient is doing or the events that transpired between the patients previous and present visit. There are apps that follow up on the activities of their patients in different ways. short period of time to discuss

For instance, there are apps that send messages to their patients on a daily or weekly basis to track their activities. The message could be a notice of taking their prescriptions or reminding them of their upcoming medical visit.

For example, Kevin Patrick et al. (Patrick et al., 2009) discusses on a text message–based intervention how to assist and evaluate individuals who lost or sustained their weight over 4 months. A framework was created to be both custom-made and interactive. Individual fitting was achieved to provide flexibility with the number and reception time of messages each day. A database was established for SMS, MMS (Multimedia Message Service) content and rules that can be applied to decide which message would be sent based on different periods according the participant's eating behaviors, previous answers and other factors.

The overall system contains four components:

1. Web-based application for selecting groups and setting participant preferences.
2. Database for storing participants data, rules and, sent and delivered text messages.
3. Application that controls the right timing for sending messages and to process the delivered messages.
4. Platform for sending and receiving text messages.

It is also important to mention Personalized Real-time Intervention for Motivational Enhancement (PRIME) (Schlosser et al., 2016), a mobile app intervention, which is developed to enhance motivation and improve quality of life for patients diagnosed with schizophrenia. This mobile app delivers text message (short message services, SMS) based motivational training from expert therapist and social networks by direct peer-to-peer texting as well as public "moment feed" to enhance and strengthen rewarding experience and goal achievements. The mobile app is applied in 20 people with schizophrenia owning a smartphone, accordingly the result indicates that the mobile app is feasible, tolerable, and acceptable intervention for participants with schizophrenia.

Rodgers et al. (2005) experienced the feasibility of smoking termination using mobile phone-based text message content informing to an extensive of young smokers in New Zealand. Different teams create more than 1000 EMI messages with relevant information. The message content received by the participants are based on the smoking history and obstacles to discontinuance. The timing of EMI delivery to the participants is customized according chosen quit dates. Automatic system is used to deliver the messages to participants. This intervention motivate participant by providing free text message in a month to improve social support network. Participants receive relevant messages every two weeks for providing reminders about check-up evaluation. This shows that text message intervention can increase the rates of smoking cessation in short time and proves it has the ability to reach huge number of participants without demanding large resources such as clinician time, equipment and others.

Other apps send a questionnaire to patients to monitor their activities. It enables the doctors to check up on their patients whether they are adhering to their advice or medical prescriptions. For instance, if the patient is put on a new exercise and diet regimen to lower their cholesterol, the app monitors how well the patient is doing by sending them a diet and exercise survey every few months.

A-CHESS (Chih et al., 2014) is one good example of apps that send questionnaire. Developed at the University of Wisconsin-Madison,a mobile relapse-prevention program, has been established by the Center for Health Enhancement Systems Studies to "promote patients' autonomous motivation, coping competence, and relatedness" to prepare patients for the challenges they may face on the road to recovery. Using A-CHESS services patients can search latest addiction-related news, discuss and share ideas with the patients that have the same problem, find the nearest Narcotics Anonymous places and can track their progress. Every week patients complete their brief survey instrument in A- CHESS on their smartphone so that the app predicts their lapse from self-reported and system generated data to provide a proactive support treatment.

In this study Bayesian network model has been applied to test the lapse predictive ability of the A-CHESS so that the app identify patient at high risk to act to minimize the risk and to estimate the chance of patients lapsing from one week collected data. According the predictions, an alert feature will be provided. If the patient is about to lapse, an automatic text message will be generated and sent to that patient. As the same time the therapists will receive an alert email which mention about patient's risk and contact the patient by text message, email or Telephone call. This application is extremely crucial to address patients' issues with addictions in an effective and efficient manner. However, it is important to recognize that there were no methods put in place to predict the potential lapse of a patient. Therefore, this study presents that evaluation of the patients' data collected via A-CHESS and furthermore, develop said prediction function.

King et al. (2008) designed palmtop computer intervention for middle and older aged adults that are actively using a palmtop computer-based EMI. Each participant receives EMI (N=19) and activity education materials. In 8 weeks, assessment, they are requested to fill a brief EMA questionnaire twice each day. The assessment requested is about information regarding location, physical activities, behavioral and motivational factors of the participants. After the assessment EMI delivered daily and weekly on the platform computer which contains feedback on progress, individualize goal setting, and evaluation of barriers and enablers of meeting goals. Those participants who receive EMI physical activity reported high level of physical activities than those who only received psychoeducation materials.

There are also apps that try to track patients' activities based on their location. These apps send a question or a message to the patient it tries to track when he/she checks in a given location that is a red flag. A recovering alcoholic checking into a liquor store would interest the doctor and as such a question or message could be sent to the patient. Some apps which send message or questionnaires based on location are as follows:

Fabian Wahle et al. (Wahle, Kowatsch, Fleisch, Rufer, & Weidt, 2016) has studied on detecting daily activities of patients with the help of sensor information technology to determine the level of depression and discover the potential intervention deliverability to those with a high level of depression. The smartphone application mobile sensing and support was tested in adults and has collected context sensitive sensor information to provide just-in-time interventions derived from cognitive behavior therapy (CBT) (NHS, 2016). To adapt to each subject's preferences and improve recommendations with respect to time and location, personal preference based real-time system was applied. It showed an improvement in creating opportunities for unobtrusive mental health and screening potential to alert participants when they reached in serious mental state. The authors demonstrated the concept of detecting depression level using smartphone features such as Wi-Fi, accelerometer, GPS and phone usages and providing context information for the clinicians to monitor a critical mental healthcare state.

It is also worth to mention a mobile application called "MoodTrainer" (Addepally & Purkayastha, 2017) is developed for people with high depression and anxiety. The mobile application was created based on the CBT website where users can access the service without a qualified profession and they can prepare questionnaires to assess the user's mental health status and the sternness of their current disorder. However, the developed mobile application brought improvements on the delivery process associated with some innate disadvantages, which caused user dropout and reduced adherence to the therapy. This mobile application was focused on creating a dynamic supportive treatment to users which could change the negative thought process and act as a supportive tool for both users and clinicians.

MoodTrainer can track user's behavior in real time and provide timely recommendation for effective results. it also tracks user location and asks for answers when they check into an isolated location, recognize using Bluetooth beacons and location services. Thus, MoodTrainer tracks the patient movement and isolated behavior consequently, the application delivers suggestion to help users' mood.

MoodTrainer has a feature to retrieve user locations with the help of Google maps APIs every few minutes and displays the current location on a map. Based on a user's location, the application checks whether the user is on the right place. When the application detects issues with a user, a notification will be showed to improve their mood and, in such situations, let the clinicians, nurses and close friends notified to help the user. All the modules and features of the applications are flexible so that users can enable and disable the features according their interest and comfort level with their trainer. Those all supportive feature made the application to be a dynamic supportive of psychotherapist which means “be with the patient” interacting with the patient and sharing experience (Viederman, 2008).

Mobilyze! (Burns et al., 2011) Is a web-based mobile application designed as a multimodal treatment for depression which contains graphs that demonstrates patients self-reported states and improving tools that teach patients behavioral attraction. Machine learning models are used to predict patients’ activities, moods, emotion, motivational states, environmental context, and social contexts based on phone sensor data like GPS, ambient light, recent calls, etc. Participants are encouraged via message to define their location, activities, social context, and state of their emotion. Web-based behavioral activation intervention, and supplemental messages were provided to overall symptom reduction. Telephone calls and emails are used as feedback mechanism from clinicians to promote adherence.

However, the challenge with this kind of apps (MoodTrainer, Fabian Wahle et al. (Wahle, Kowatsch, Fleisch, Rufer, & Weidt, 2016)) is that they are not flexible enough to track whether the patients are passing through the given location or spending enough time to warrant the follow-up.

In general, all these apps have their own features that distinguish them from each other. Some send messages, others request questionnaire be filled by their patients while some track the patient's location to follow up on them. However, we could not find any apps that comprise the characteristics of the above three group of apps together with time triggering. As it stands, there aren’t apps that reach the patient with a message or a question after the patient had spent a predefined amount of time in the specified place/location. This thesis arises from the need to fill on this void that there aren’t apps that comprise the features of the present apps with the time sensitivity aspect.

2.4. Tools and Technologies

To extend the existing application different platforms are used. They are explained as follows:

Android

Android is an open-source platform, based on the Linux kernel, used in cell phones and mobile devices developed by Google and the Open Handset Alliance. In November of 2007, Google released the first beta version of the Android Software Development Kit (SDK) to the public. The problems that can be alleviated by Android are fragmentation, using Proprietary software stacks, and using closed networks. By providing a standard mobile phone application environment, Android created a big opportunity for application software developers (Rogers et al., 2009). Starting from the first commercial Android version, Android 1.0, released on September 23, 2008, to the most recent version of Android, Android 9 Pie, released in August 2018, Android has seen several updates and improvements in its features. A statistic (Statista. 2018) showed the global market share held by the leading smartphone operating system, in the second quarter of 2018, 88 percent of all smartphones purchased by end users were Android operating system-based cell phones.

This clearly shows Android is becoming the most widely used in the world in contrast to its competitors such as iOS, Microsoft, RIM, Bata, and Symbian. While Android is the winner in the market share, it is less encrypted, and privacy is more unprotected related iOS mobile devices (Lazareska,2017).

As defined by the Android architecture, Android applications have four basic component types: activities, services, broadcast and intent receiver, and content providers. The activity provides the window in which the application shows its user interface to the user and usually correlate with display screens. Services are application components that usually run in the background from the time of their instantiation until the mobile handset is shut down and they don't provide user interfaces. Broadcast and intent receivers respond to requests for system-wide service such as battery low notifications.

Content providers are created to manage and control over the permissions for accessing data and to provide data sharing with other applications or services (Rogers et al., 2009).

Android is designed to go in a seamless way with limited resources such as memory, processor, and battery on most mobile devices. To conserve those limited resources, Android provides mechanisms in its activity lifecycle. Android activity lifecycle (Figure 1)

defines the states or events that activity goes through from the time it is created until it finishes running.

onCreate: Invoked when an activity is first created. This is the place where views should create and in general where activity should initialize.

onStart: Called just before an activity becomes visible on the screen.

onResume: This method Called right after onStart if an activity is the foreground activity on the screen, and at this time the activity is running and interacting with the user. onPause: Invoked when an Android is just about to resume another activity. The activity that has no longer access to the screen should stop consuming battery and CPU cycles unnecessarily.
onStop: Invoked when the activity is no longer visible.
onDestroy: This callback is called before the activity is destroyed.

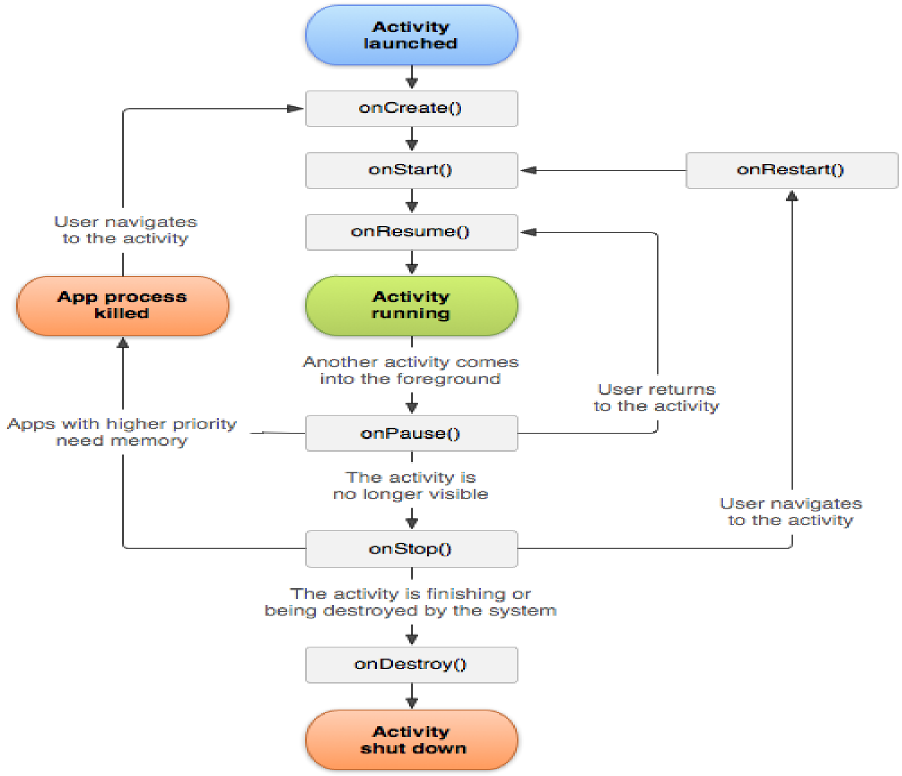


Figure 1: Simplified Android Activity Lifecycle (Statista. 2018)

Angular

Angular is a platform and framework designed for developing web applications. In the very first beginning, Angular was named as AngularJS (Angular 1). AngularJS is a JavaScript traditional MVC framework developed by Google to build maintainable web applications. It enables developers to decorate their HTML with a special markup that synchronizes with JavaScript by letting developers write the application logic instead of manually updating views (Article, 2014). However, AngularJS had many flaws and limitations on its performance and how things worked under the hood. As a result, a different Angular platform is developed based on TypeScript (M, 2018). To improve the performance, Angular implements unidirectional tree-based change detection and uses a hierarchical dependency injection system.

Angular has a component-based architecture whereas AngularJS has MVC or MVVM architecture. The controllers and scope in AngularJS were replaced by components and directives in the new Angular versions. In every Angular application, there is at least one component called the root component. The root component connects a component hierarchy with the page document object model (DOM). Every component has an associated defined class that handles the business logic and the view layer, an HTML template that defines a view to be displayed in a target environment. The data in the component is presented on the view using data binding, it can be event binding or property binding.

Firebase

Firebase is a flexible backend, database service, that enables web application developers to make a web application without server-side programming. As a result, the development process will be easier and quicker (Kumar, Akhi, Gunti, Sai, & Reddy, 2016). When we use Firebase, we do not have to stress on the server-side controls or building REST APIs with minimum configuration; Firebase can perform the activities such as user's verification, data storage, access rules implementation. Firebase supports the Android, iOS, OS X, and web clients. Generally, it is not necessary to write a server-side code when using firebase. In a Firebase based applications, Firebase database can take care of real-time information updates and the data is stored in the cloud i.e. it has easy access for clients regardless of their location (Kumar et al., 2016). Firebase saves development time, uses 2048-piece SSL encryption for every information exchange to protect data, handles a volume of information, and data is stored as JSON.

3. THE SyMptOMS PROJECT: EXISTING APPLICATIONS

SyMptOMS is a research project that marries the technical expertise of the GeoSpatial Technologies Research Lab (GEOTEC) with the theoretical and domain knowledge of the Laboratory of Psychology and Technology (LABPSITEC) to develop innovate solutions to promote mental health, diagnose and treat mental health problems, and prevent relapse (Geotec, 2016).

A location-based and context-aware platform, which consists of two client-side applications (a mobile app and a web-based application) and a server-side system, was created by GEOTEC. The existing applications have the capability to collect data on the behavior of patients in psychological treatment making use of their mobile phones, and put this information within the reach of therapists, thus improving the decision-making process during treatment. Within this framework, three large software artefacts are developed, i.e., an Android client (mobile application), a web client (web application) and an analysis service (Figure 2).

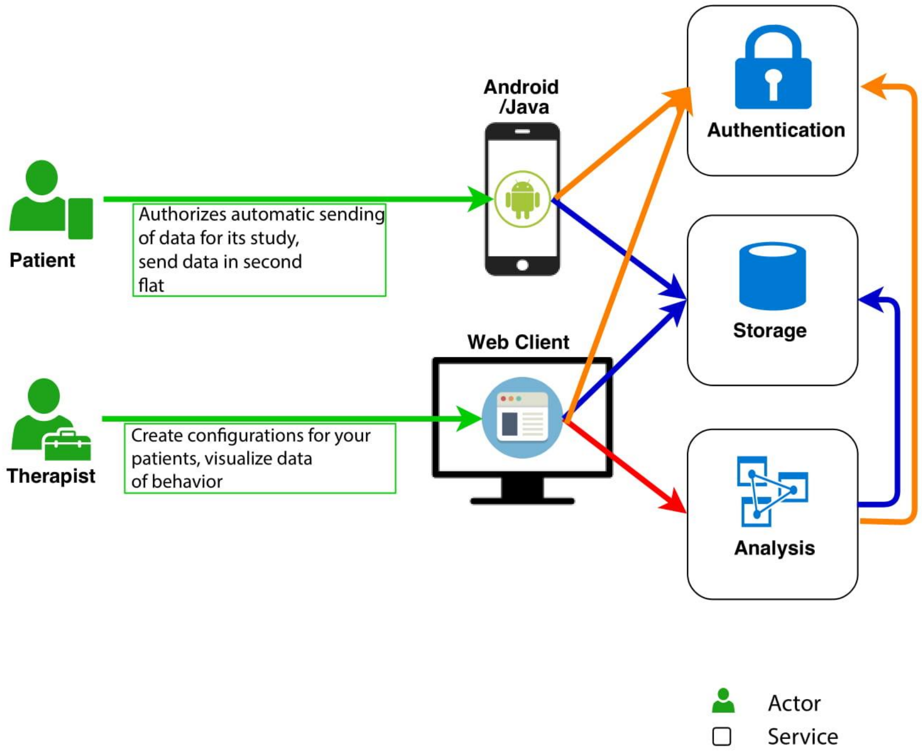


Figure 2: Overview of the developed platform Alberto (Alberto,2018)

The mobile application, which is available for the Android platform, is responsible for capturing the user's geospatial data (i.e., location) and to a limited extent, communicating with the patient by sending simple notifications. The main service of the mobile application is called the patient tracking service, which is used to capture all sensor information and required location, required by the configuration, linked to the patient.

The mobile application depends only on the authentication services (Firebase Authentication) and document database (Firebase Firestore), as shown in Figure 3. The document database, which has a client to access to it from an Android application, is used to retrieve details about the patient that the application uses (using an access key) and the details of the configuration associated with its treatment, and to store captured sensor and location data every so often while the patient is in treatment.

Figure 3: Android application and elements of the platform with which it interacts Alberto (Alberto,2018)

The web-based application is only accessible for the therapists. From this application, the therapists can register patients, create a configuration for each patient for the mobile application (using an assistant) and examine the evolution of patients during the treatment by visualizing the analytics obtained from the data that were sent to the platform through the mobile application. The web client also accesses the API gateway to request and retrieve results of the analysis executed. (figure 4)

The application also communicates with Firebase Firestore (Figure 2), to read and write data about therapists, patients and application configurations, among others. Moreover, it employs Firebase Authentication for the registration and login of the therapists. Finally, the web-based application uses Firebase Hosting which allows developers to upload their web project to the platform directly from the command console (it is not necessary to use the typical FTP client).

Analysis services allow access to different data sources available in the platform with the aim of extracting information that may be useful for the therapists to improve the treatments offered to their patients. The service includes analysis of time inside and outside the habitual residence, travel analysis, analysis of habitual residence, analysis of times outside the habitual residence, analysis of patient mobility and analysis of important places.

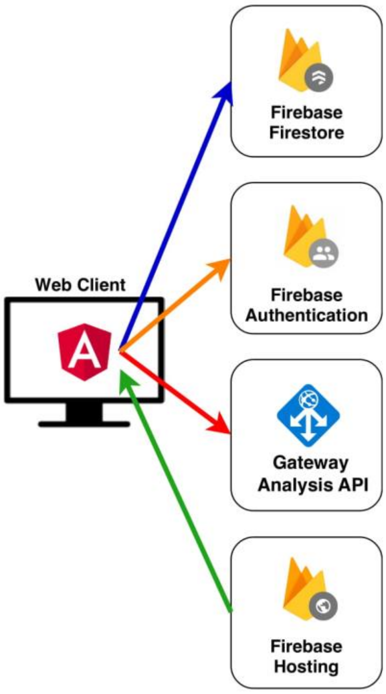


Figure 4: Web application and elements of the platform with which it interacts Alberto (Alberto,2018)

4. SYMPTOMS: APPLICATION EXTENSIONS

Currently, the therapist can only communicate with the patient through the messages shown; when the patient enters an area of interest, which is one side communication. Moreover, the current application is more into monitoring than intervention. So, to increase the communication between the therapist and patients, new mechanisms are being added to intervention, such as the possibility of answering a small number of questions and establish a bi-directional patient-therapist communication through messaging instantaneously among each other.

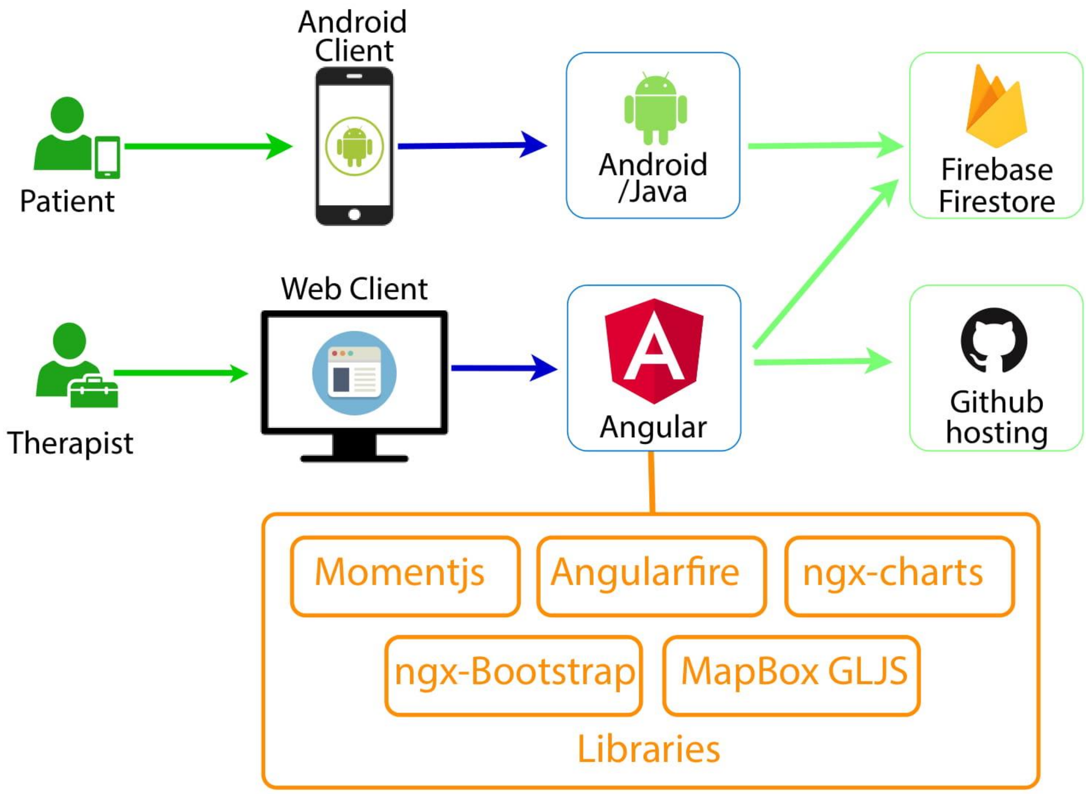


Figure 5: General overview of the technology stack

As shown in Figure 5, the application has two actors, the therapist and the patient. The therapist uses the web app which is developed using angular platform, to create configuration for the patients and to visualize location data and the feedback sent by patients. Several angular libraries are used to do those tasks. AngularFire2 (GitHub, 2019) is used to integrate Firebase services with Angular. To formant dates Moment.js

(Moment, 2019) is used. Ngx-bootstrap (ngx-bootstrap, 2019) provides easier ways of interacting with the components. It is used to make the web app consistence and responsive. Ngx-charts (GitHub, 2018) are used to display the results in the form of charts. Mapbox GL JS (MapBox, 2019) is used for visualizing spatial data.

The mobile app is developed to be used by the patients. To develop the web app an Android version “Android Studio 3.2” and an android emulator version “Nexus 5X API 28” are used. It is responsible for displaying the questionnaires and to be answered by the patients.

Firebase is used to store all information related to the therapists, their patients, configuration settings of the mobile application as well as the data sent by the patients throughout the treatment. Finally, the extended application is hosted using GitHub platform.

4.1. Mobile application

The Android application is basically designed to track patient’s location based on their will and to interact with therapists who are responsible for taking care of the patient. The application uses GPS - to trace the location of the patient and enables the patients to communicate with the therapists with the help of questionnaires prepared by the therapists.

The rationale behind designing the mobile app is mainly to help patients by tracking their progress. It has two main functions. The first one is to facilitate communication between therapists and patients in the form of questionnaire or notifications being sent to the patient whenever he/she enters a selected area. This is done by adding a module that allows questionnaires and notifications to be displayed and answered by the patient. The selected area is related to the patient’s condition that the therapist wishes to track. The second function is the mobile app supports time-based triggering. The questionnaire/notification doesn’t reach the patient immediately upon entering the area rather it will reach the patient after the patient have spent a pre-decided specific time in the selected area.

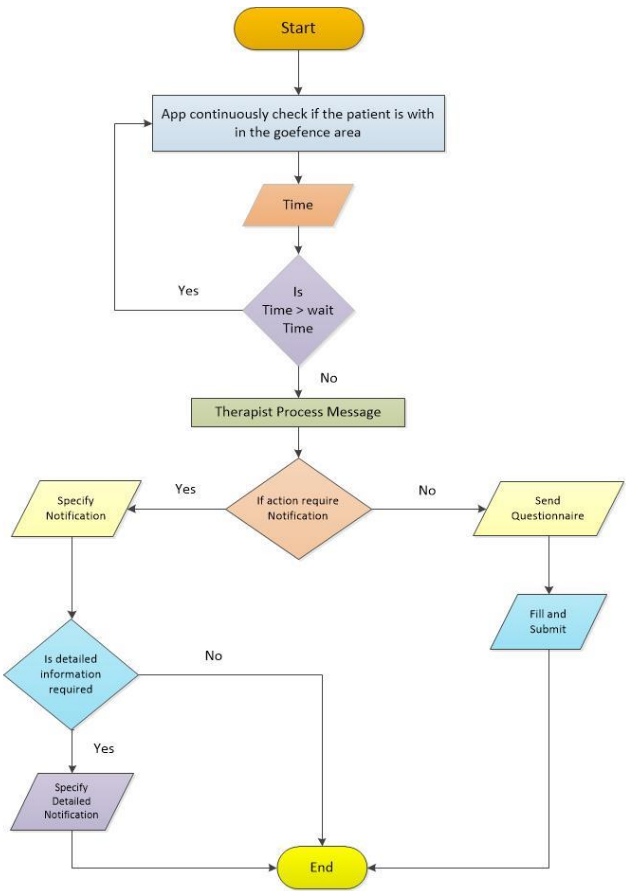
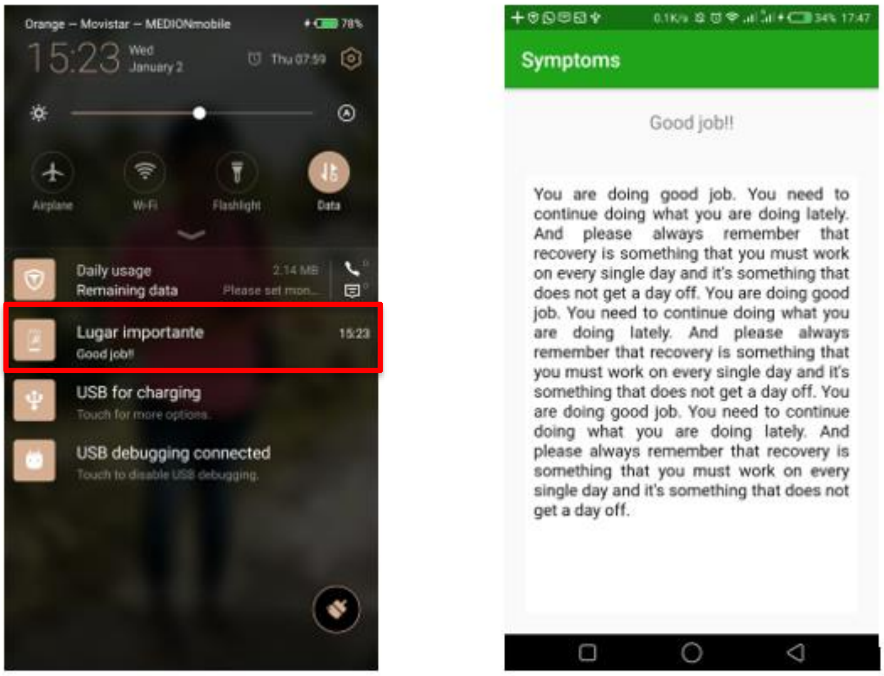


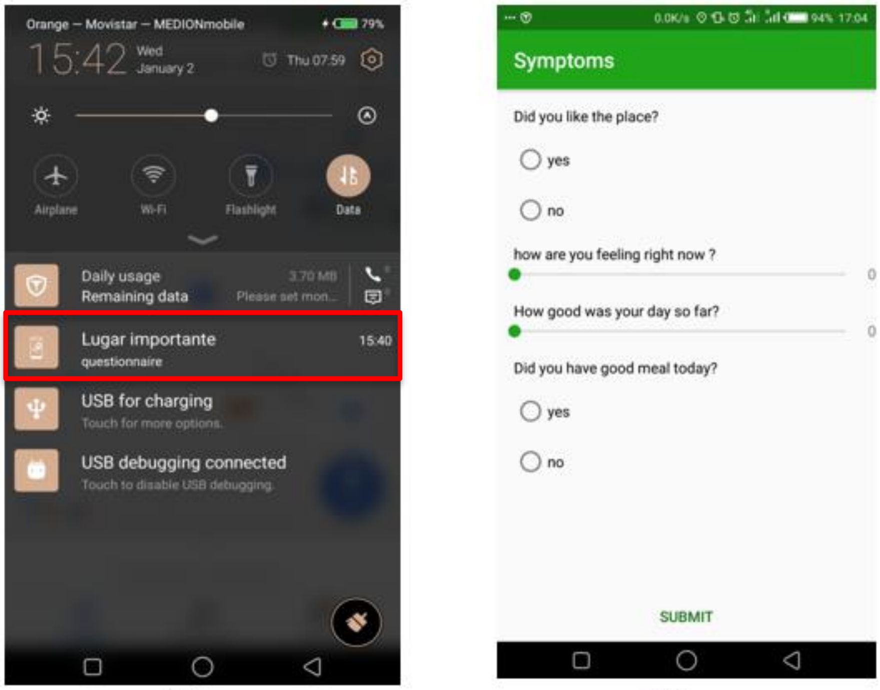
Figure 6: Flowchart of mobile app

After installing the app, the patient must enter the given user-name and give consent permission to be tracked. As shown in Figure 6, then, the app will start checking if the patient is within the geofence area. If the patient is within the geofence area, it will start to track for specified time. For example, if the patient leaves the fence within this time, the application will immediately terminate counting and start from checking phase. Otherwise, after waiting for a specified amount of time, the system will trigger a message, which can be either a notification or questionnaire (which will be decided by the therapist of the patient). If it is a notification (Figure 7(a)), a detailed description of the notification (Figure 7(b)) will be shown on the screen of the app when it is clicked. If the message is a questionnaire (Figure 8(a)), a list of questions will be displayed on the app (Figure 8(b)) to be answered by the patients.



(a) (b)

Figure 7: Mobile application displaying notification (a) short notification (b) detail description of the notification



(a) (b)

Figure 8: Mobile application displaying questionnaires (a) notification of questionnaire (b) set of questions

When we look at the detailed implementation part, tracking service is used to capture all sensor information and location of the patients. This service executes every one minute. Whenever the patient is in the selected area, the application starts to count for the specified time. This is done using Evernote Android-Job library, which allows the execution of jobs planned over a given time. If the patient is still in the selected area within the specified time, the notification manager allows components of the application to send notifications to the user. Those notifications are displayed using Android activities.

In addition to the existing actives, the extended application has 3 more activities (description, questionnaire and success) which intervene in the process of interaction with the user. In Android, the activities represent different screens that are shown through the graphical interface and those activities allow users to interact with the application.

For storage purpose, different repositories are available in the application. These are divided into local and remote. Using Room Persistence Library 11, the local repositories store data in the local SQLite database. In our case, the local repository is used to store patient's data (for example place name, location, messages etc.). In the case of remote repositories, Firebase Firestore client for Android, is used to store and retrieve data. The result of the questionnaire (answered by patients) are placed in remote repositories.

4.2. Web-based application

The therapists use a web-based application to prepare questionnaires, to track the patient location, to send a message to the patients mobile and to view the questionnaire response of the patients.

Web-based application, which only the therapist has access to, is developed with the intention to help therapists provide the best possible care to their patients. This app has a multifaceted function. Firstly, it helps the therapist to create his/her own context-based feedback tailored to the need of the patient he/she is trying to care for (Figure 9). Different patients require different type and level of follow up and the web app enables the therapist to take this into consideration. Moreover, the web app is flexible enough to allow the therapist to develop dynamic questionnaires. They can comprise open, polar and rating types of questions.

Additionally, it enables the therapist to select the areas/locations that the web app is going to be administered. For instance, if the patient is a recovering alcoholic then the therapist will personally enter the location of the bars or liquor stores and as such when the patient enters that specified location the web app will be sending the message (questionnaire or notification).

Secondly, the web-based visualization tool, which focuses on visualizing feedbacks sent by patients, and which it supports therapists to make informed decisions.

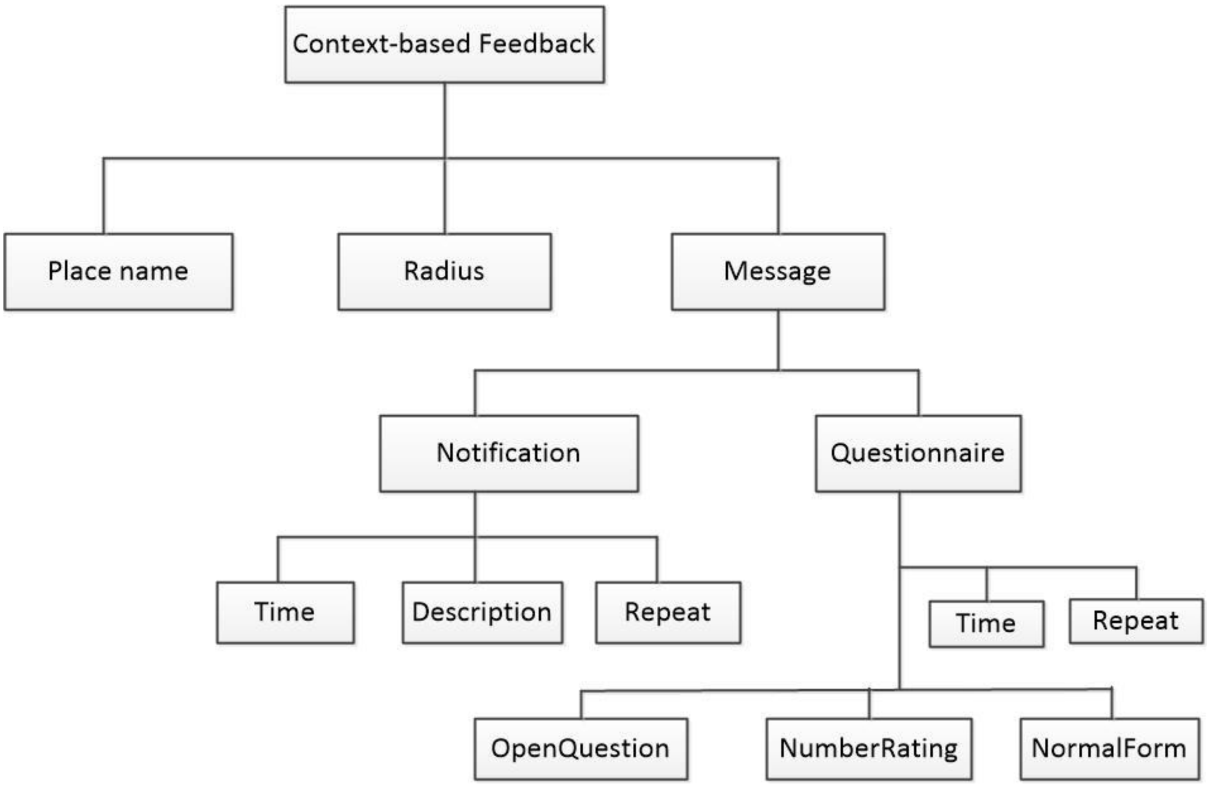


Figure 9: General structure of context-based feedback

Context-based Feedback

As shown in Figure 10, the registration module is used to enter the selected locations (using a circle) that patient can visit (1), the radius of the location (circle) (2), and the message to be sent to the patient if he complies with the conditions specified for visiting the place (3). The therapist can choose what type of messages, notification or questionnaire, can be sent to patients (when the patient is within the selected area).

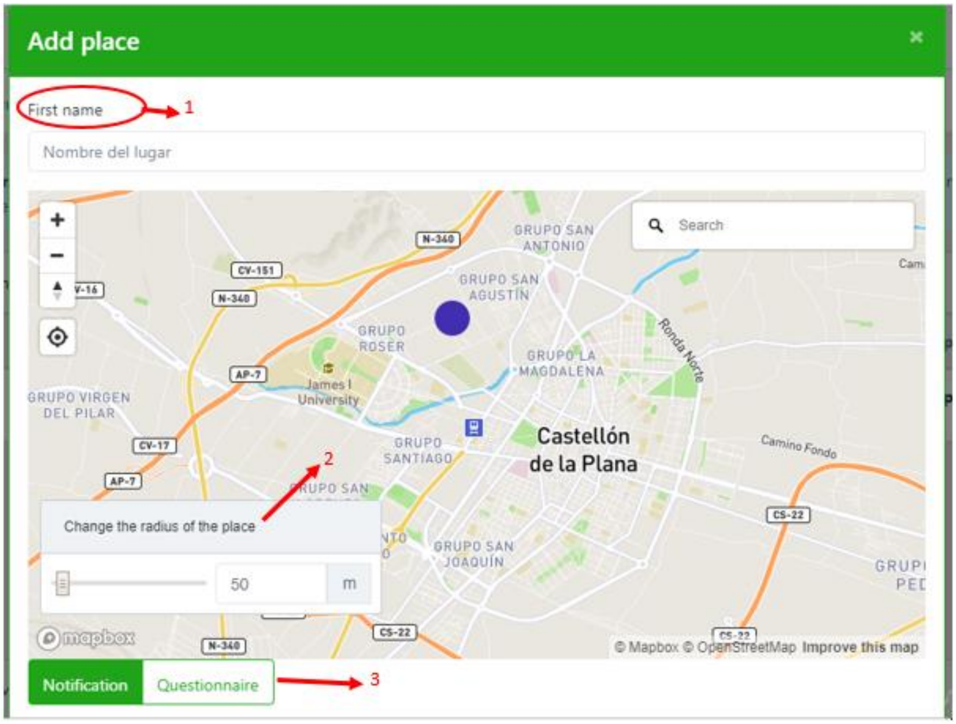


Figure 10: General view of place selection and message configuration

Notification (Figure 11) is used to enter a customized notification which will pop up when the patient is in the selected area. Within this field, the therapist can also give a detailed description of the notification (1). Time field (2), available in both type of messages, states for how long the patient should stay in the selected area to receive the message. Repeat checkbox (3) is used to decide whether the message should be sent repeatedly, every given minute until the patient leaves the selected area or only once.

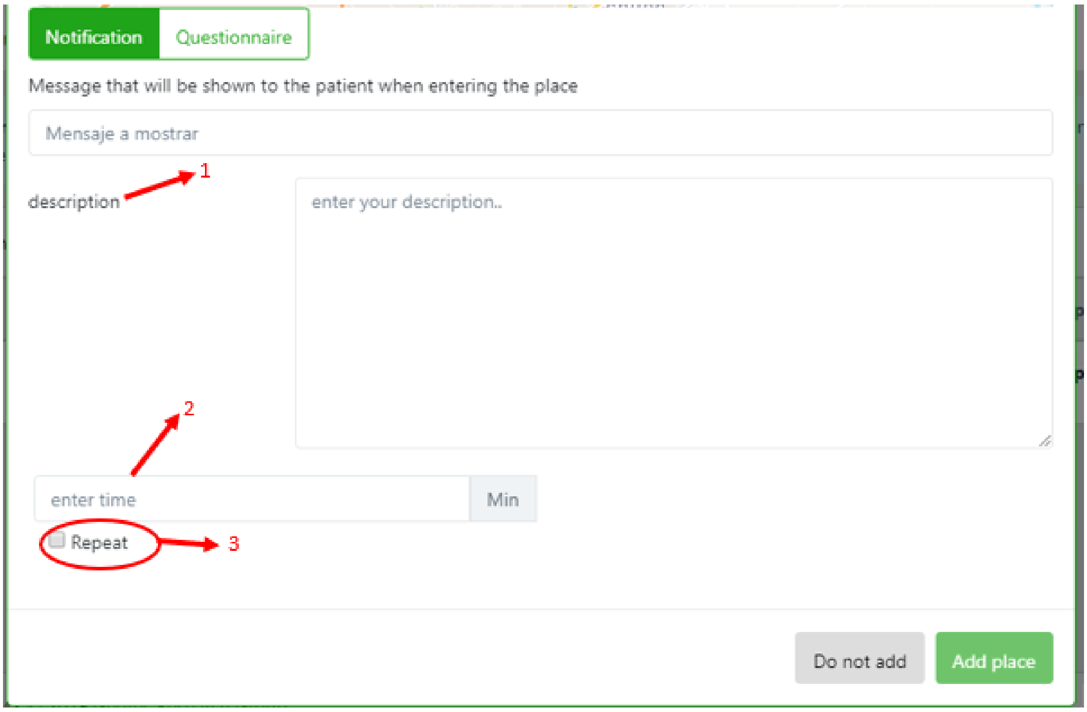


Figure 11: General view of notification form

Questionnaire field (Figure 12) is focused on creating dynamic simple questionnaires which supports three kinds of questions. Open question: allows a patient to write anything (free text), polar question: with 'yes' or 'no' questions and the rating question: questions that can be answered by selecting a number from 1 - 5 scale rating where 1 is the lowest and 5 is the highest rate. The "+" sign (1) used to add extra questions.

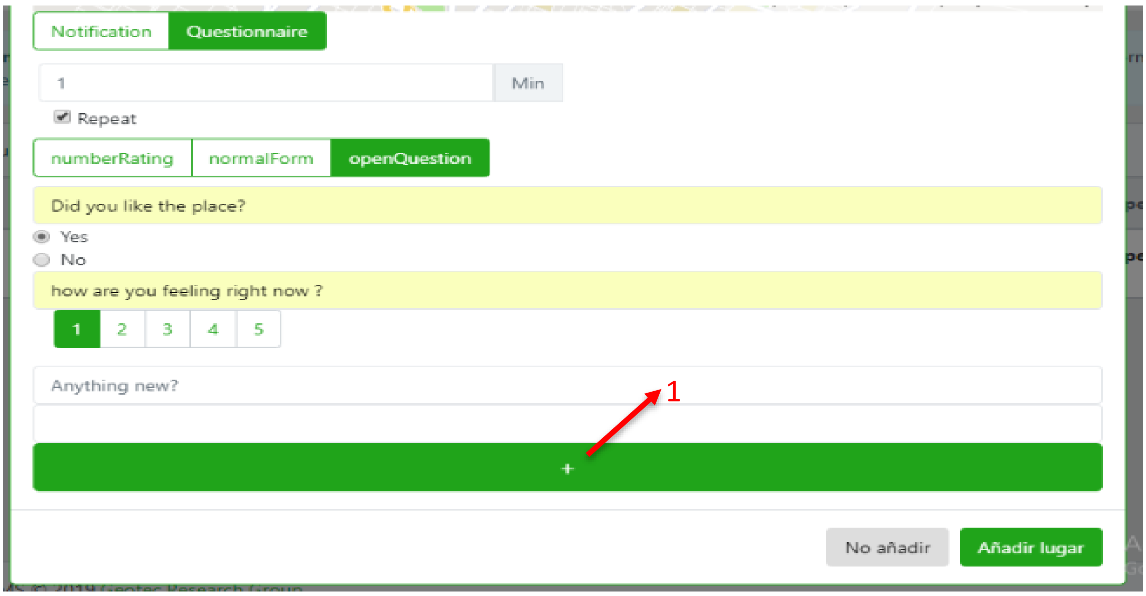


Figure 12: General view of questionnaire Form

Visualization of Questionnaire results

To be able to visualize the result of questionnaires the analysis part of the existing system is modified, a module that displays the response of questionnaires is included.

The web application allows therapists to visualize the results of the questions sent from patients. Only one display window is used to visualize all the results (Figure 13) by using previous and next buttons (1). The visualization can be filtered based on the time or the name of the registered places. In the time field, only the days in which the patient uses the mobile application are enabled. The therapist can choose one day or certain ranges easily (3). The time interval has a dropdown button (whole day – "0-24", morning– "0-8", afternoon – "8-16", evening – "16-24") (4) which allows filtering the charts based on those time slots. The second type of filtering is based on the place name (2): a drop-down menu is foreseen, containing a list of registered place names per patient i.e. different place names can have different questionnaires.

Figure 13: General view of visualization of patient's feedback

To make the visualisation understandable to therapists, different visualisation tools are used for certain question types (polar, rating and open questions). The result of the open question is displayed using tables with two columns: the submission date and the comments sent (Figure 14). To visualize the result of 'yes' or 'no' questions an ngx-bar-chart is used. As depicted in Figure 15, the X-axis represents a submission date, the values are placed on Y-axis and the legend shows the colours of 'yes' and 'no'. The ngx-line-chart is used to visualize the result of rating questions as shown in the Figure 16, the X-axis is the submission date, on the Y-axis are the values. In both ngx-bar chart and ngx-line chart, the average value and the number of responses is also displayed (Figure 16, number 1). The location of patients when submitting the result is displayed on the map using MapBox GL JS. (Figure 17)

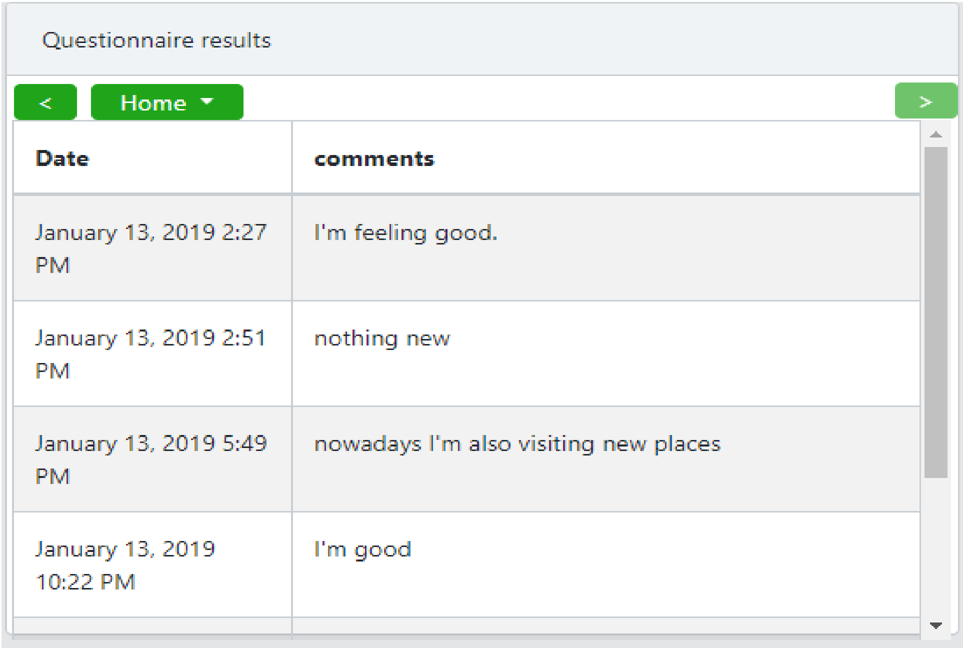


Figure 14: Response representation of open questions

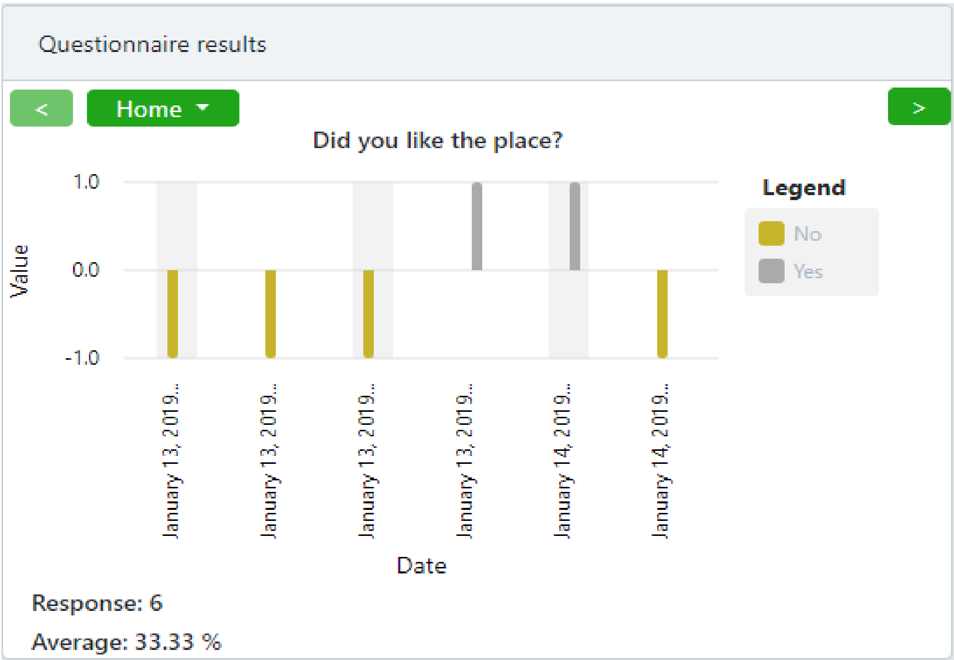


Figure 15: Response representation for ‘yes’ or ‘no’ question types

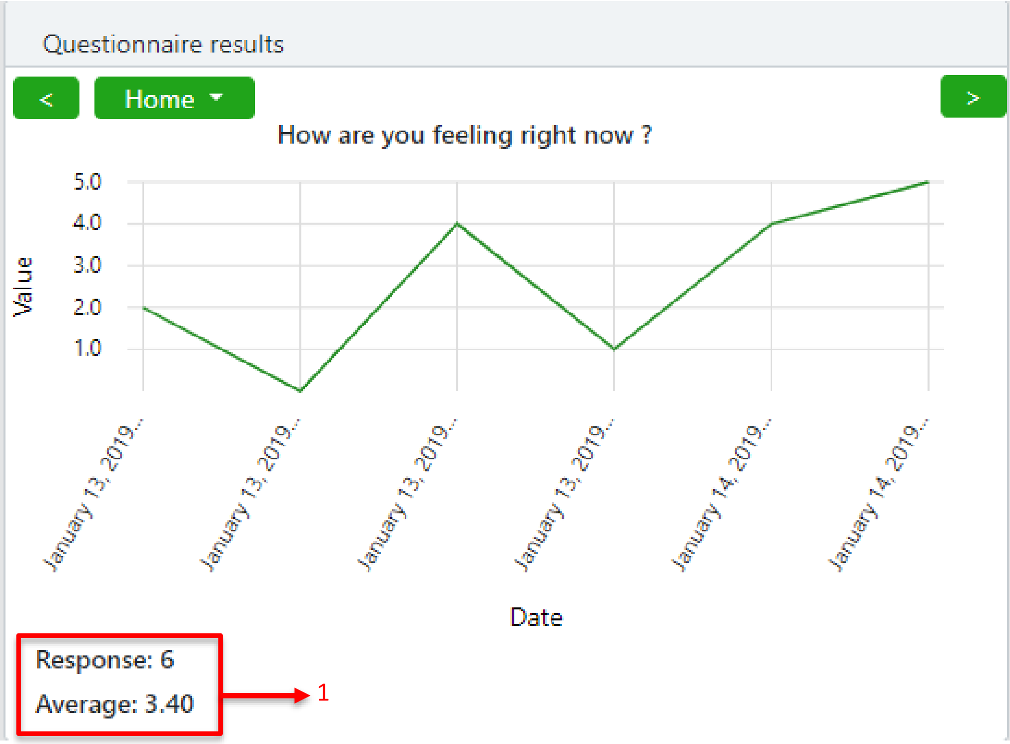


Figure 16: Response representation for number rating question types

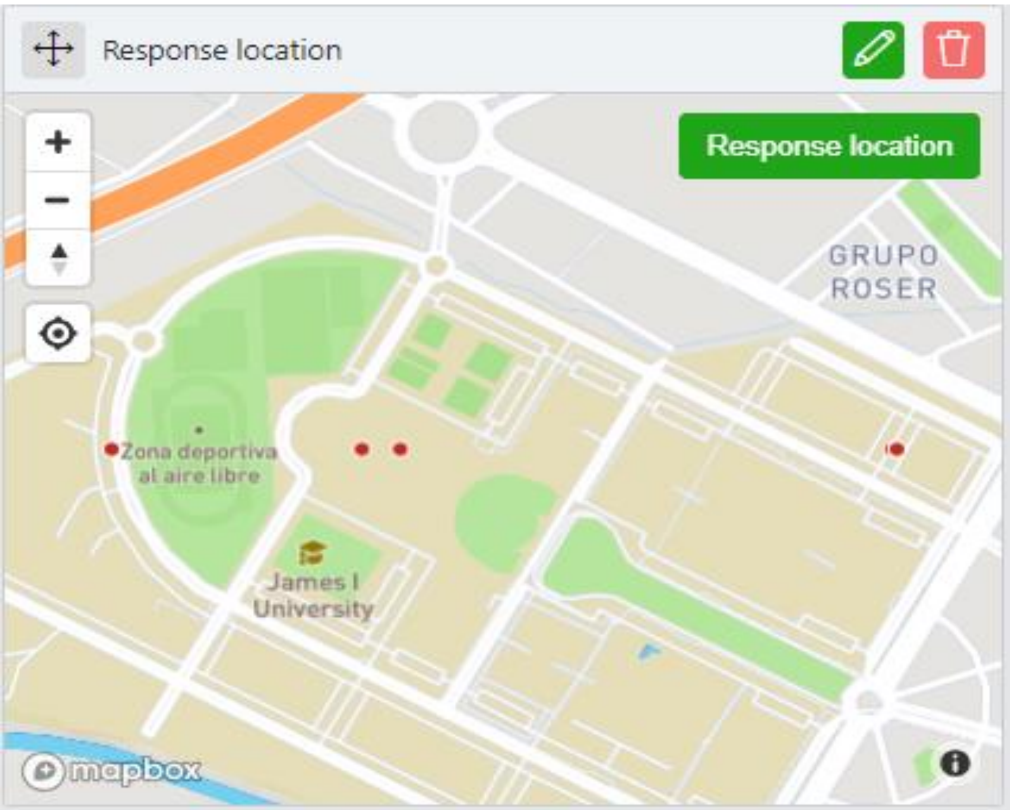


Figure 17: General view of Map

5. EVALUATION

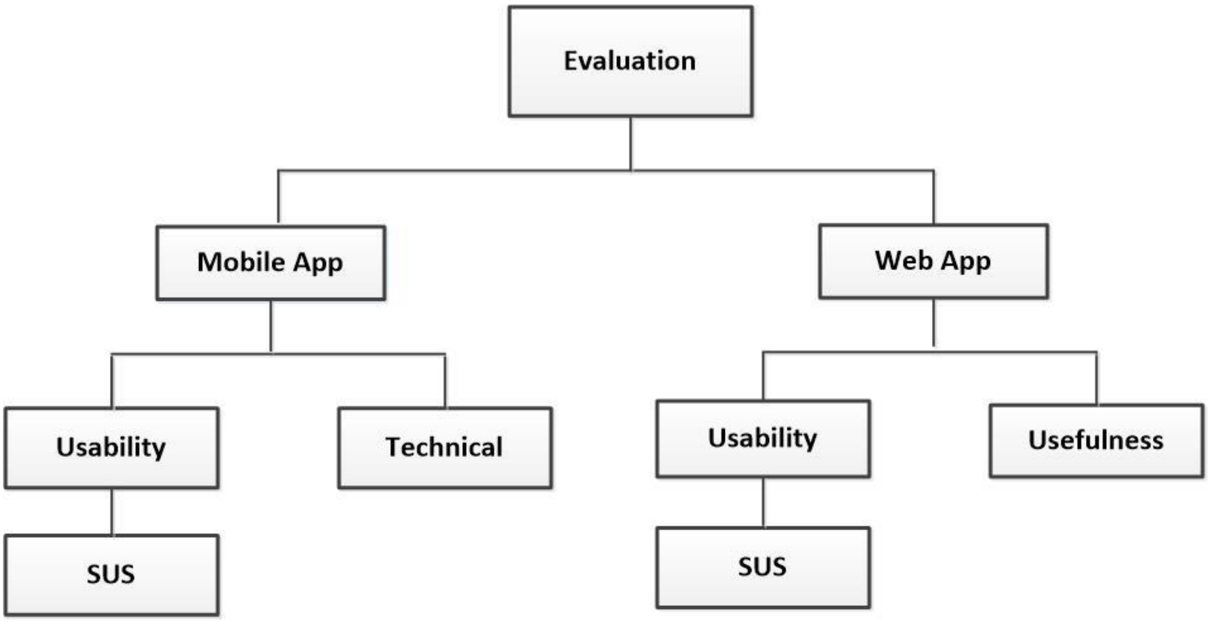


Figure 18: General overview of the evaluation

After describing the implementation details of the platform, this chapter focuses on the evaluation process. As shown in Figure 18, both the mobile app and the web app are evaluated. The evaluation of the web app focuses on the usage (usability and usefulness) of the application. The technical and usability of the mobile app is also evaluated. To measure the usability of both the mobile app and the web app, System Usability Scale (SUS) (Brooke, 1996) is used.

The usability of the designed system is checked to know how people used the system as it stood, and to identify where the system should be improved. The usability of a system can be viewed in terms of the context in which it is used, and its quality of being suitable to the context. According to ISO 9241-11, measures of usability should cover the ability of users to complete tasks using the system, the quality of the output of those tasks, the level of resources consumed in performing tasks and the users' subjective reactions to using the system.

There are different designs of testing the usability of a system that help to gather statically valid data, among them SUS is the cheaper and easiest method. SUS (Brooke, 1996) is ten-item scale that is used to assess the usability of the developed system. SUS is based on forced choice questions, where a statement is made, and the user then indicates the degree of agreement or disagreement with the statement. These statements cover a variety of aspects of system's usability, such as the need for support, training, and complexity, and thus have a high level of face validity for measuring the usability of a system. (Diot, Zarka, & Lemarié, 2002)

When SUS is used, the participants are asked to give a score of the 10 items with the range of one to five which lead to extreme expressions of the attitude being captured, that is from strongly agree to strongly disagree.

To calculate the SUS score, first, add the total score given to each item. Each item has a score range from 0 to 4. Strongly Disagree: 1 point, Disagree: 2 points, Neutral: 3 points, Agree: 4 points, Strongly Agree: 5 points. Change each item score scale into a number for each of the 10 questions. For items 1,3,5,7, and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SUS. Each of the questions has a weight of 10 points and the total score is 100.

5.1. Evaluation of mobile app

As depicted in Figure 18, using SUS the usability of mobile app is tested. 12 random participants (neither patients nor therapists) (8 males and 4 females, 6 with intermediate knowledge of ICT) were included to take part in the usability test of the mobile app.

SUS comprises ten questions (five positive and five negative statements, odd and even numbered questions respectively) that require a rating on a scale from 1 ("strongly disagree") to 5 ("strongly agree"). Figure 19 shows the response distributions for each of the 10 SUS questions obtained from 12 participants. For visualization purposes, the response is converted to a range of 'strongly disagree' to 'strongly agree'. 'strongly disagree' is a scores of 1 and 5 for odd- and even-numbered, respectively. And 'strongly agree' is a scores of 5 and 1 for odd- and even-numbered, respectively. (Dorr et al., 2015).

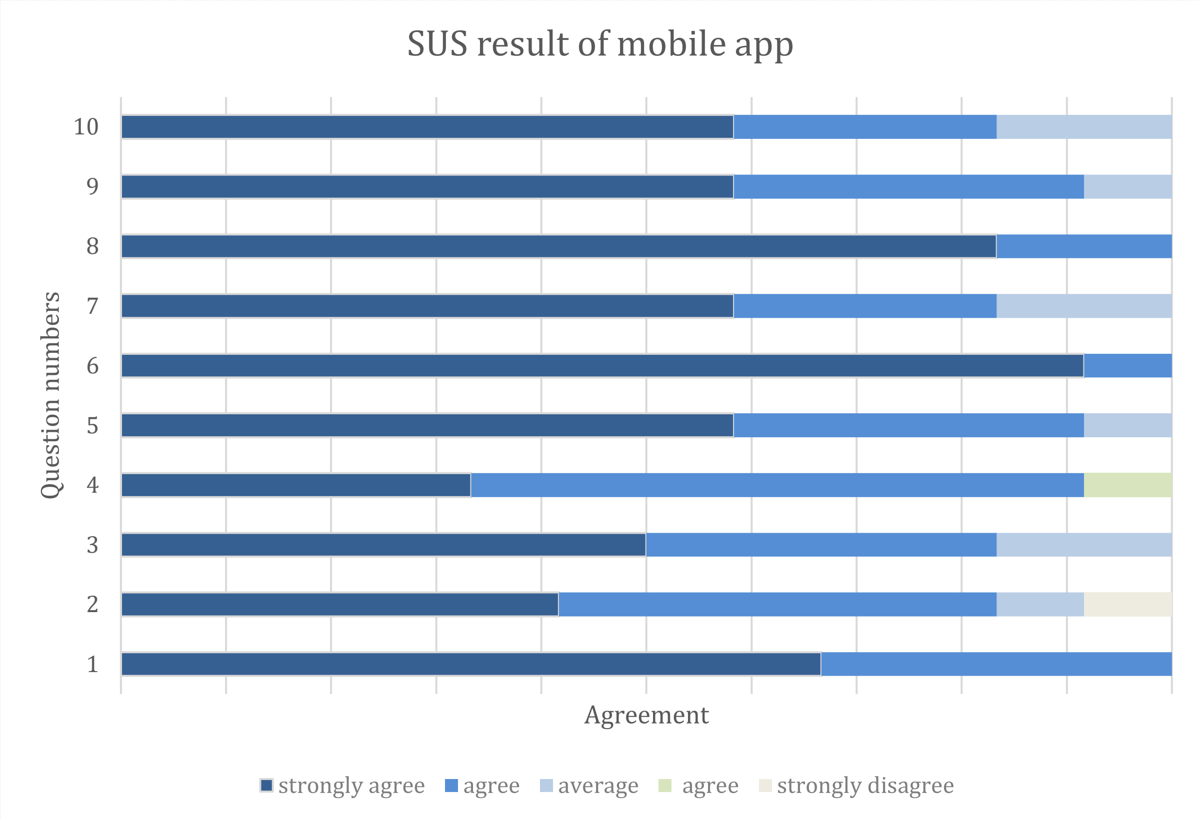


Figure 19: Results of the System Usability Scale questionnaires for the mobile app

The overall average of the usability test is 86.75. As stated by the grade ranking of SUS (Figure 20), if the average is below 50, it means it is not acceptable. From 50 to 70 is moderate and above 70 is acceptable. Therefore, according to the grade ranking of SUS scores, the result indicates that our system is acceptable.

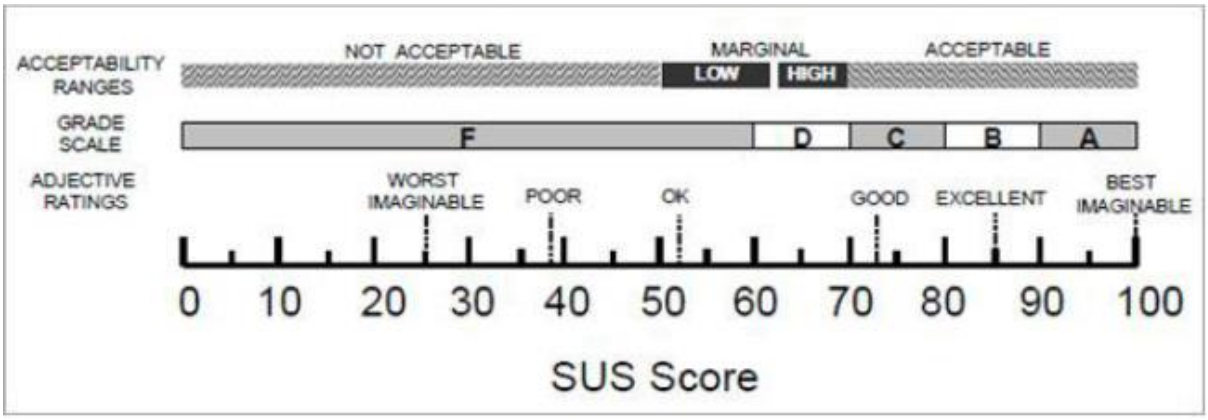


Figure 20: Grade rankings of SUS scores (Leonard, Busby, Hoelzer, & Zinkle, 2009)

In addition to the usability test of the mobile app, the technical component is also evaluated. GPS-enabled smartphones are typically accurate within a 4.9 m (16 ft.) radius under open sky (van Diggelen, 2015). However, their accuracy worsens near buildings, bridges, and trees. Since the accuracy of time-triggering is dependent on the precision of the GPS, there is no 100% guarantee that the message will pop up exactly at the specified time.

Due to this reason, the accuracy of time-triggering is tested by running the app for three different durations (1 minute, 3 minutes and 5 minutes). For each duration, the app has run 25 times. As a result, the average and the standard deviation of the error are calculated. This evaluation was performed by one evaluator, the author of this thesis.

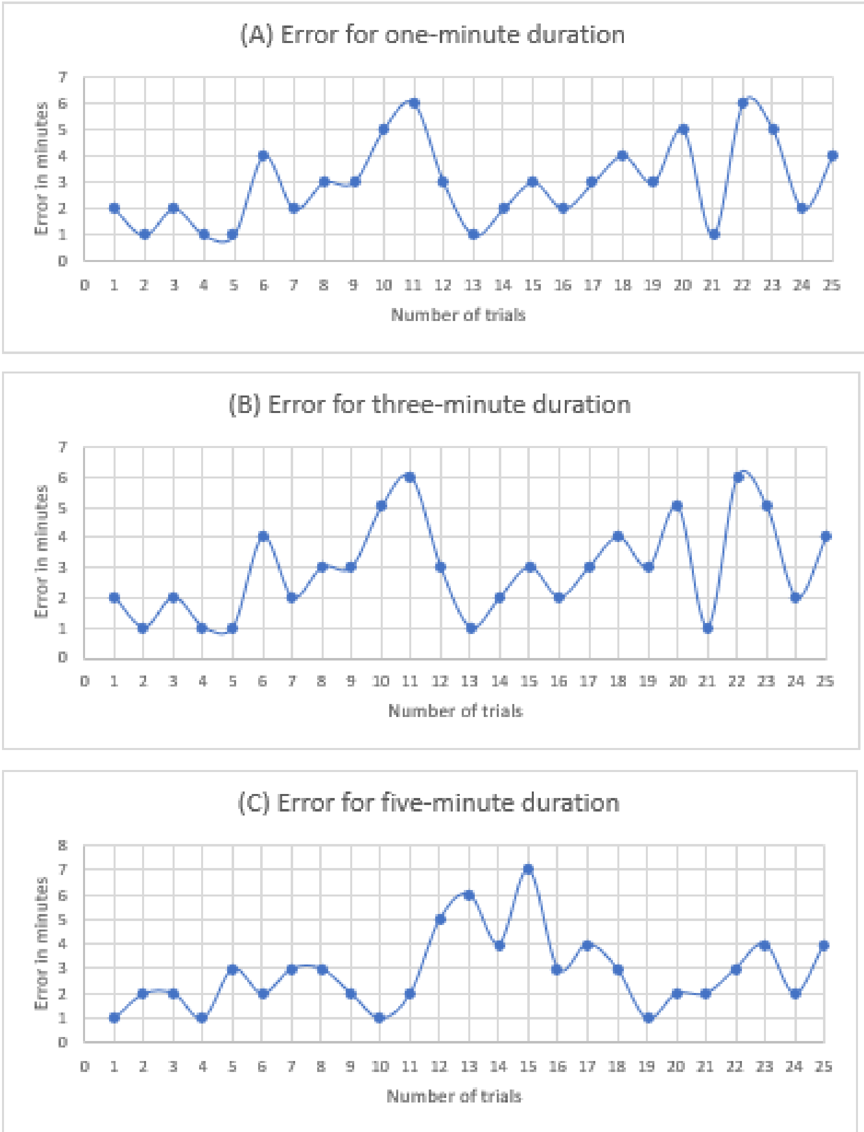


Figure 21: Line chart showing Error per number of trials for one, three and five minutes respectively

Figure 21 shows the error occurrence (in minutes) in different trials. Thus, the x-axis is to indicate the number of trials and y-axis to show the error appeared in the trials within the one-minute interval. Figure 21 (A) and (C), we can observe that the maximum error occur is 6 minute and the minimum error is 1 minute. Whereas from Figure 21 (B) we can see that the maximum error is 7 minute and 1 minute is the minimum error occurred from those 25 trial numbers.

The standard deviation of the error is calculated in order to understand whether a specific data point is standard and expected or unusual and unexpected. Low standard deviation indicates that the data is closely clustered around the mean. A high standard deviation, on the other hand, indicates that the data is dispersed over a wider range of values.

Table 1: Average error and standard deviation of time triggering (GPS dependent)

Time given	Average Error	Standard deviation
1 minute	2 minutes 55 seconds	1 minute 33 seconds
3 minutes	2 minutes 57 seconds	1 minute 34 seconds
5 minutes	2 minutes 52 seconds	1 minute 31 seconds
Total average	2 minutes 55 second	1 minute 33 seconds

As seen in table 1, since the average result of standard deviation is high, it implies that the data points are spread out over a large range of values. The standard deviation of time triggering for 1-minute duration is 1 minute 33 seconds minutes which indicate 1 minute 33 seconds difference occurred from the mean value (2 minutes 55 seconds) and 1 minutes 34 seconds difference from the mean value 2 minutes 57 seconds for a given time of 3-minutes. For 5 minutes there is 1 minutes 31 seconds difference from the mean value of 2 minutes 52 seconds. On average, 1 minutes 33 seconds difference occurred from the average error value of 2 minutes 55 seconds.

The average error for a given time of 1 minute is 2 minutes 55 seconds this tells us 2 minutes 55 seconds delay will occur in the system to pop-up the notification/questionnaires for a given time (1 minute) which is a big error as compared to the given time. For a given time of 3 minutes 2 minutes 57 seconds delay occur and has a tolerable error as compared to the given error. Similarly, for 5 minutes duration the system delays for 2 minutes 52 seconds minutes to pop-up the notification/questionnaires. Comparing with others the error for given time of 5 minutes is less significant.

According to the average error result, while entering the time: which tells the system after how long the notification/questionnaire should pop-up, the therapist should take the average error into account. Which means if the therapist wants to send the notification/questionnaire after 5 minutes, it means based on the average error we got, the message will be received after approximately 8 minutes.

5.2. Evaluation of the web-based application

The web app is tested with the help of LABPSITEC, a group of psychologists/therapists at the University of Jaume I, to determine the usage of such in-situ, context-aware questionnaires and notifications.

To evaluate the usage (usability and usefulness) of web-based application, two types of questionnaires were prepared. The first one is SUS which is used to get quick and clear judgement about the usability of the web app. (the SUS form can be found in Appendix B). Four therapists' (all females) were recruited to take part in the usability test of the web app.

Like the mobile app, the result of the response is visualized in Figure 22. The average of the usability test is 75. Based on the grade ranking of SUS scores (Figure 20), our system is acceptable.

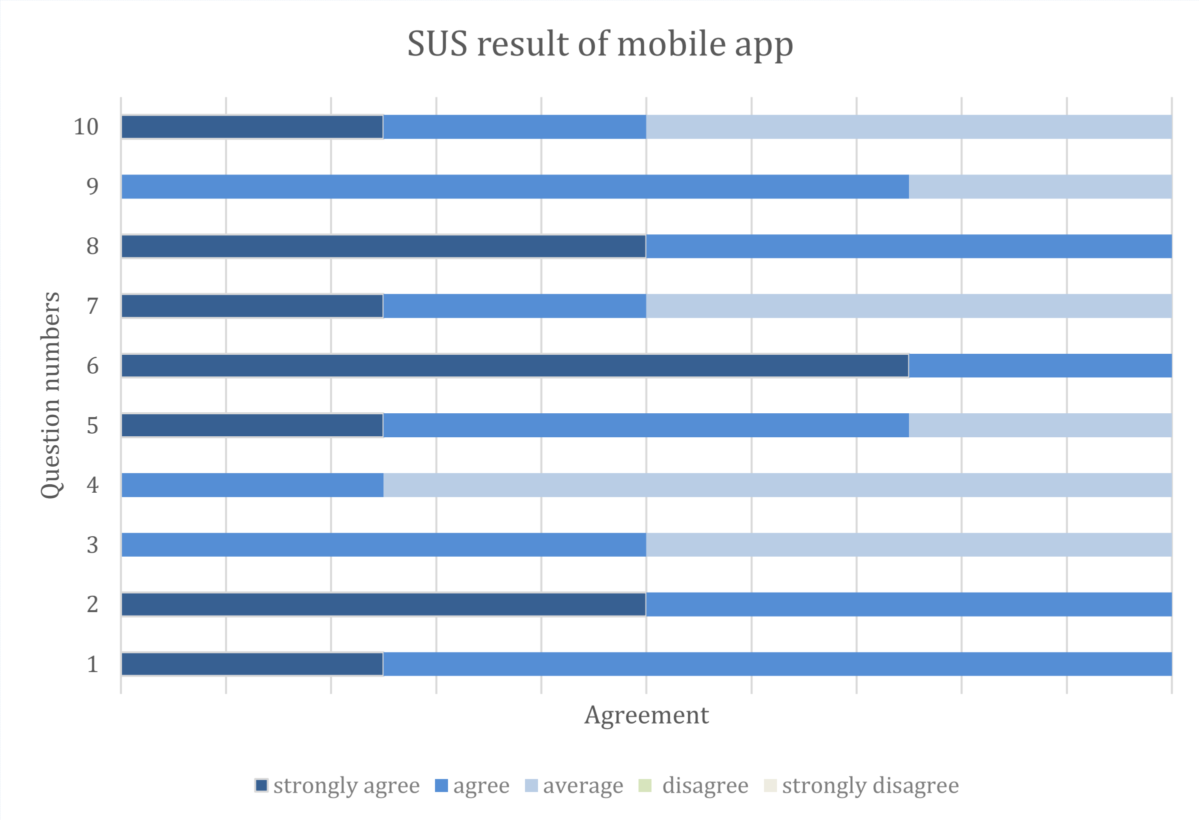


Figure 22: Results of web app for System Usability Scale questionnaires

But SUS is not diagnostic as it does not tell whether the system is useful or not. It is also more general with no precise information about the app's weaknesses. Due to the above-mentioned reasons, we created our own questionnaire, which was designed to check the usefulness of the web app and have the potential to answer the research questions. This questionnaire had 21 questions with four different sections. The first section is general evaluation section, which focuses on evaluating the overall usefulness of the app and the second and third section is context-based questionnaires and context-based notifications section that evaluates the usefulness of the questionnaires and notifications respectively. The last section, further exploration section, is an open question which aims to find out the drawbacks for further improvement, to generate ideas for future work and further applications, and to know for which mental disorders can the application be useful (Questionnaire form is attached in Appendix C). Each question has 1-10 scale answering possibility, where 1 is not useful at all, and 10 is extremely useful.

For this evaluation, the number of participants was 4 (all females). So, the participants (= the therapists), were asked to fill out the questionnaire of usefulness with the aim to find out the usefulness of each item.

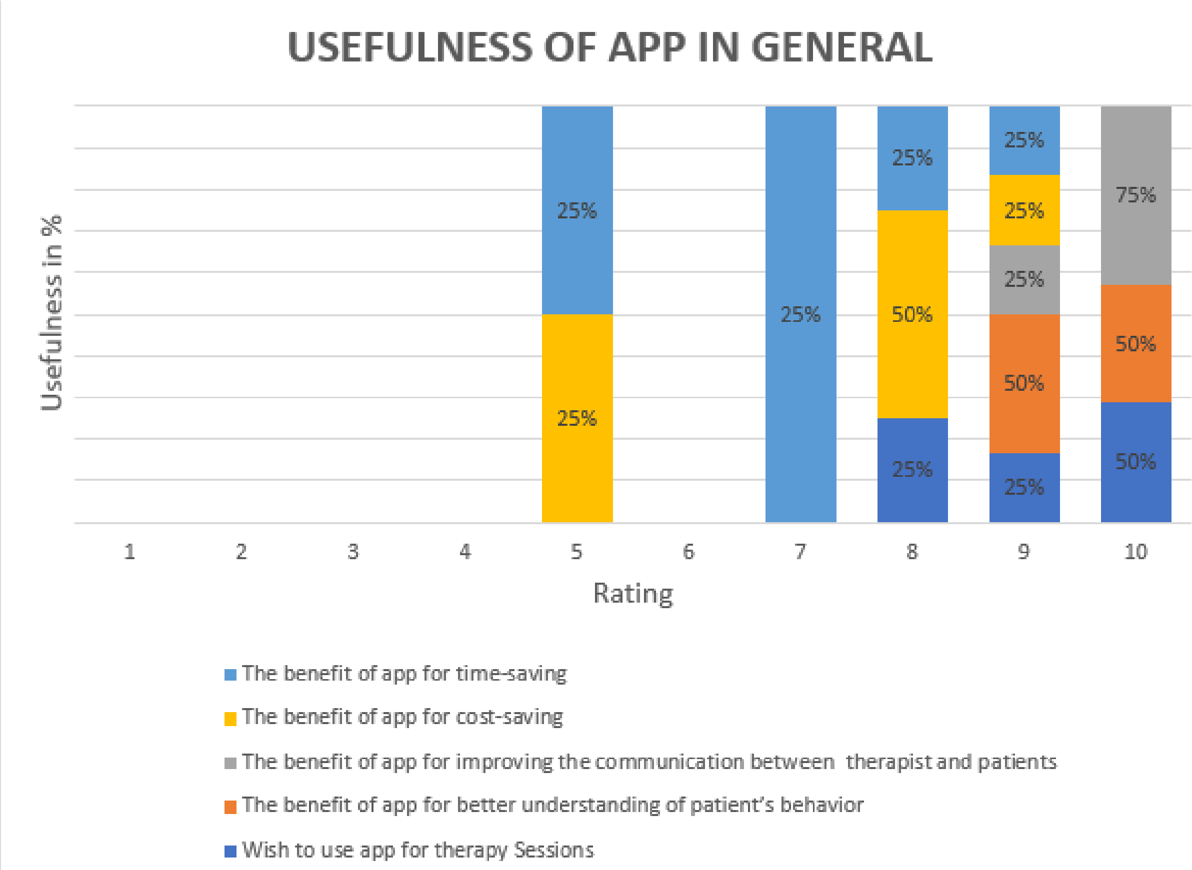


Figure 23: Usefulness of app in general

The bar chart (Figure 23) shows the overall usefulness of the app developed rated by the therapists. The horizontal axis which registers the ratings given by participants runs from 1(not useful at all) up to 10 (extremely useful). The overall usefulness of the app was measured using five metrics, namely the benefit of the app for time-saving, cost-saving, improving communication between therapists and patients, understanding patient's behaviour, and the wish to use the app for therapy sessions. The scores given to the benefit of the app for saving time by the participants was evenly divided between the scores 5,7,8 and 9. The cost-saving benefits of the app were rated a neutral (5) by 25% of the participants, while 50% of them agreed on a rating of an 8 and the rest on a rating of a 9. The benefit of the app for improving the communication between therapist and patients got the highest score of usefulness by 75% of the total participants while the rest

25% chose to give a score of a 9. The app's usefulness for understanding patient's behaviour was rated a 10 by half of the participants and the other half rated it with a score of a 9. Lastly, the wish to use the app therapy sessions was a perfect 10 by 50% of the participants and the other 50% were equally divided between a rating of an 8 and a 9.

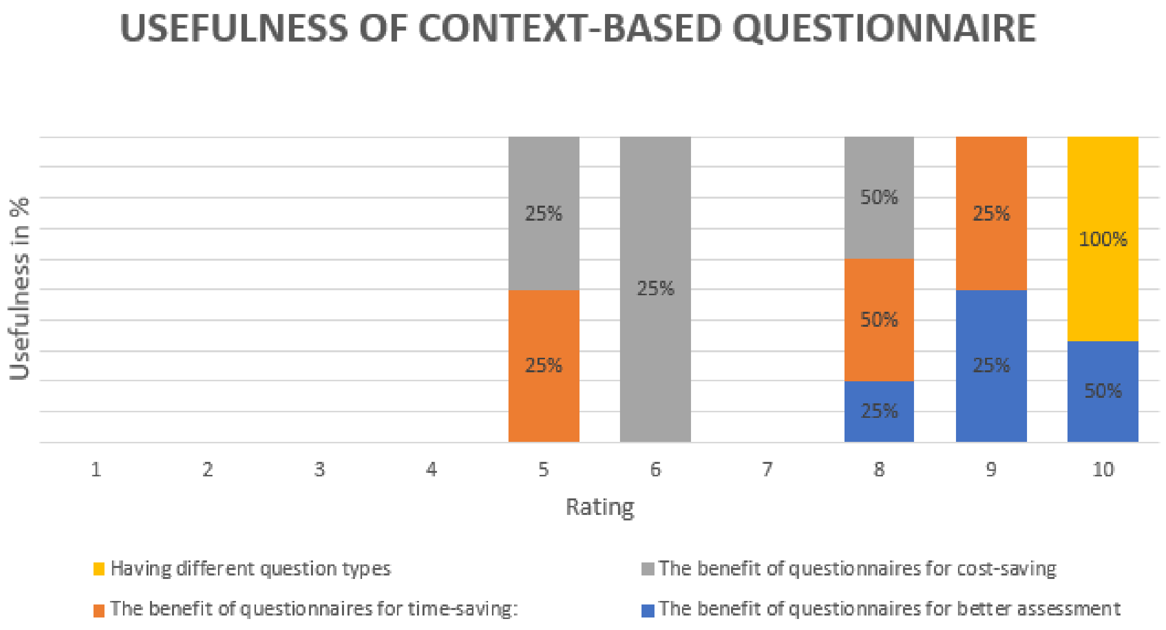


Figure 24: Usefulness of Questionnaires

Figure 24 shows the result of questions related to the context-based questionnaires. The horizontal axis shows ratings in the scale of 1 to 10. The bars with different colors depict the percentage of study participants that gave the specific score. The usefulness of context-based questionnaire was answered using four sub questions, the benefit of questionnaires for better assessment, for time-saving, for cost-saving and other question types. The benefit of questionnaire for better assessment got a score of a 10 from half of the participants, while the rest were equally divided into giving a rating of an 8 and a 9. The benefit of questionnaires for saving time was given a score of 8 from 50% of the participants, a 9 from 25% of the participants and a score of a 5 from the rest of the participants. 50% of the study participants gave a score of 8 for the benefits of questionnaires in cost-saving, while the rest chose a rating of a 5 and a 6 equally among themselves. All the participants agreed on giving a score of 10 for the different question types sub category.

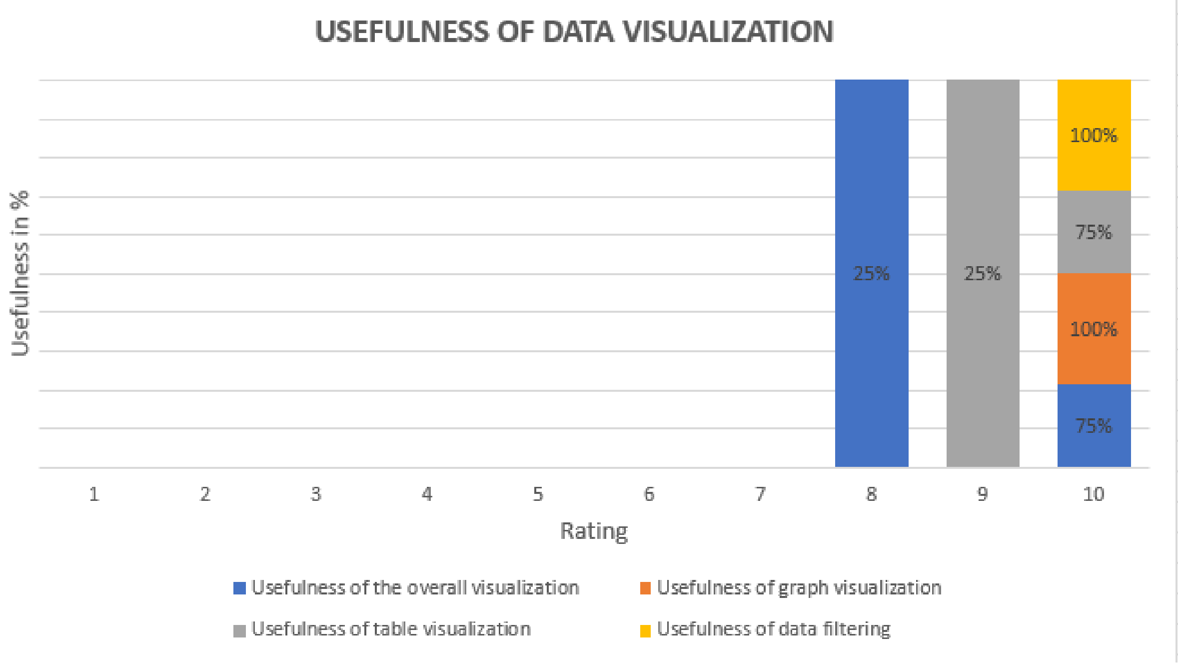


Figure 25: Usefulness of Data visualization

The above bar chart (Figure 25) illustrates the usefulness of data visualization according to the ratings given by the users. The usefulness of the data visualization was measured in terms of the usefulness of the overall visualization, graph visualization, table visualization and data filtering. The usefulness of data filtering and graph visualization were given the maximum score by the study participants. The usefulness of the table visualization was given a rating of a 10 by 75% of the participants and the rest rated it with a score of a 9. Similarly, 75% of the total participants gave a rating of 10 to the usefulness of the overall visualization, while 25% of them rated the usefulness with a score of 8.

Figure 26 shows the result of questions related to context-based notification. The bar chart displays the percentage of study participants who agreed on several ratings of the usefulness of context-based notification depending on three different questions. A rating of 1 refers to a complete disagreement while a 10 implies a complete agreement with the questions posed. For the question if notification benefits patients for a better treatment got a perfect rating of a 10 by 75% of the total study participants. The other 25% also highly agreed on the importance of notification for better treatment of patients by giving a score of a 9/10. The usefulness of notification for time-saving got a score of 9 from half of the participants and the other half was evenly divided between the ratings 6 and 8.

Finally, for the question if notification is beneficiary in saving cost got a rating of 6 from half of the participants and the other half agreed on a rating of a 9.

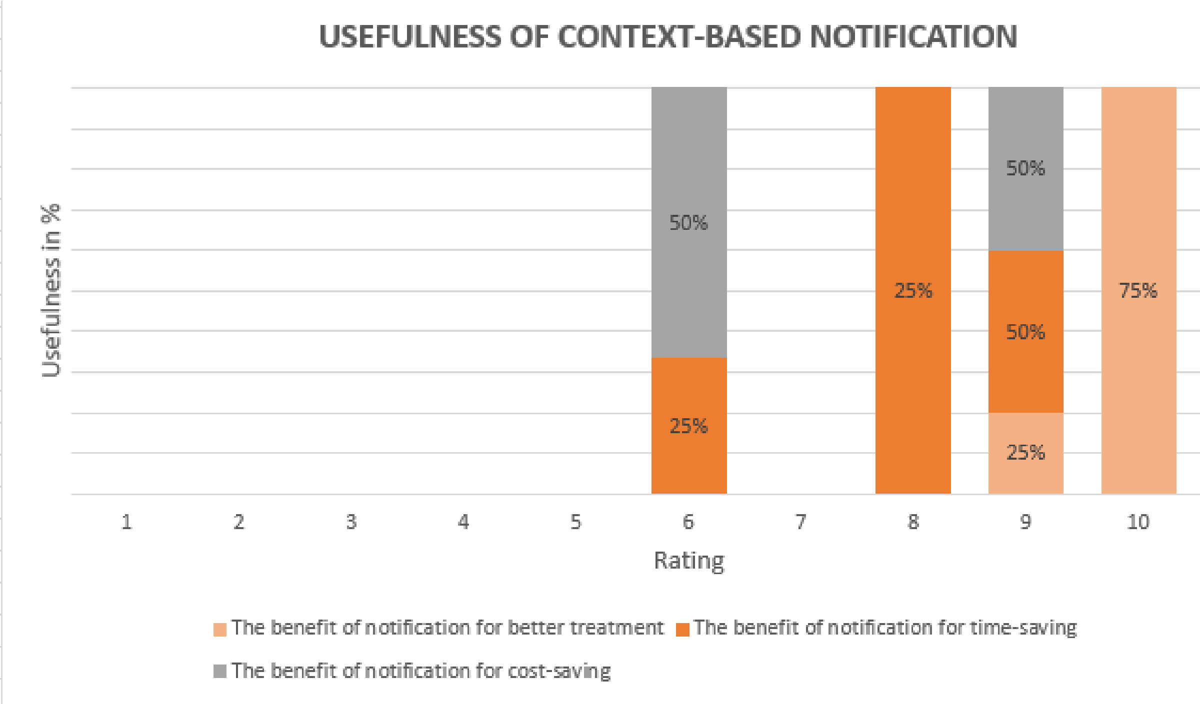


Figure 26: Usefulness of Notifications

Table 2 table shows the responses from open questions asked in the questionnaires.

Table 2: The response of open questions

Questions	Comment
Suggestions for improvement	- make the interface more visual when creating new patients - include detailed instructions on how to add configuration - include range of time within specific place - make buttons bigger
Purpose of time- and location-based notifications	- very useful to send some reinforcement messages to the patients (or warnings messages for prohibited sites as happens in pathological gambling). - to self-control his/her behaviour - to send positive reinforcement - to achieving the therapeutic goals
For which mental disorders does time- and location-based questionnaires be can useful?	For people with - depression - panic and agoraphobia

	- different specific phobias (i.e. acrophobia) - behavioral addictions (game addiction, gambling disorder) - social anxiety - bipolar disorder - obsessive-compulsive disorder
Purpose of time- and location-based questionnaires	- very useful to assess patient´s behaviour, or the thinking, at the same site (significant place for the therapy). - These questionnaires (number rating, normal form, and open question) can give us a lot of information about thoughts, emotions, and behaviors of the patients. The answers can be used to know if patients are progressing properly. - to be aware of the urge to avoid situations or to behave in a specific way, as well as to be aware of his/her emotions or other clinical measures that have influence in the behaviour that we want to increase or reduce. - It permits to have more accurate registers of the patient in real time and it is really important to treat numerous mental disorders.
For which mental disorders does time- and location-based notification can be useful?	For people with - Substance use disorders, anxiety disorders, mood disorders, bipolar disorder, obsessive compulsive disorder - Addictions (i.e. gambling) - situational phobias (acrophobia, claustrophobia, flying phobia etc.). - depression

In conclusion, we have conducted a usability evaluation of the mobile app from 12 participants with SUS score of 86.75, which is acceptable. The accuracy of time triggering is tested and 2 minute 54 second average error was found. This error is big for small time intervals, and in these cases negatively affects the treatment (for example, if you have an error of ~3 minutes when you expected a message after a minute, that’s a big error). But for larger time interval, this error becomes less significant. Based on the result, while creating a configuration, the therapist should consider the average error into account.

SUS result of web app obtained from 4 participants found to be usable with score of 75%. And the usefulness evaluation of the web app was administered with a custom questionnaire comprising 21 questions. From the sample respondents, 85.3% of participants response were between 8 to 10 (very useful - extremely useful). The usefulness of data filtering, graph visualization and having different question types were given the maximum score by the study participants. While 5.6% of the respondents gave a score of 5 (average) for four questions (the benefits of the app for time saving, the benefits of the app for cost saving, the benefit of questionnaires for saving time and the benefits of questionnaires in cost-saving). For the open questions, the response of the therapists with respect to the tool was positive and the application can be used for many types of mental disorders. Based on the result of the evaluation we can conclude that the tool can be beneficial for psychological treatment.

6. CONCLUSION

6.1. Summary

This MSc. thesis has presented an improvement to an existing system called Symptoms which deals with the treatment of patients with mental health problems using smartphones. Symptoms, which was created by GEOTEC, is a location-based and context-aware platform and mainly focused on monitoring, with secondary focus on intervention. In this thesis, three modules are developed and added to Symptoms to provide interventions through richer communication between patients and therapists. The first module extends the Symptoms web application and allows therapists to define time- and location-based triggers for notifications and questionnaires to be send to the patient. It also provides tool to build questionnaires based on some predefined question types. In this work, both time- and location-based triggers are tested. The second module is added to the existing mobile app, that allows questionnaires and notifications to be displayed and answered by the patient. The last added module is a web-based visualization tool that focuses on visualizing feedbacks sent by patients, and which it supports therapists to make informed decisions.

After implementation of the three modules, the technical part of the mobile app (its time triggering accuracy which is dependent on the precision of the smartphone GPS app) is tested. To perceive usability, an evaluation of both the mobile app and the web app is performed using the, SUS (System usability Scale). The SUS checks the general usability of apps but not usefulness. To measure the usefulness of each tool a custom usefulness questionnaire was prepared. The questionnaire consisted of 21 questions, 16 questions had the possibility to answer by 1-10 scale (1 is not useful at all, and 10 is extremely useful). And the rest (5 questions) were open questions.

6.2. Results

6.2.1. Detailed results

The usability of the extended mobile app is tested by 12 random participants and found to be usable with a SUS score of 86.75 (excellent). The accuracy of time triggering is tested and 2 minute 54 second average error was found. This error is big for small time intervals, and in these cases negatively affects the treatment (for example, if you have an error of ~3 minutes when you expected a message after a minute, that's a big error). But for larger time interval, this error becomes less significant. For the evaluation of the web app's usability and usefulness, 4 therapists participated. The web app was found to be easy to use by therapists with SUS score of 75 (good).

Based on the results from the usefulness questionnaires we can see that the majority of responses are between 8 to 10 (very useful – extremely useful). The usefulness of data filtering, graph visualization and having different question types were given the maximum score (extremely useful) by the study participants. one of the main results is the fact that therapists perceive the real value of the app in improving communication, better understanding of patient's behavior, better assessment and for better treatment of patients. While only four questions (the benefits of the app for time-saving, the benefits of the app for cost saving, the benefit of questionnaires for saving time and the benefits of questionnaires in cost-saving) were marked a score of 5 (average) with small percentage (5.6%) of participants. From the open questions, the response of the therapists with respect to the tool was positive, with many positive comments (for example, "the tool is very useful to assess patient´s behavior", "it permits to have more accurate registers of the patient in real time", "it is really important to treat numerous mental disorders", "the questionnaires can give us a lot of information about thoughts, emotions, and behaviors of the patients" , "very useful to send some reinforcement messages to the patients" and so on).

6.2.2. Answering the research questions

The main research question has been decomposed into 3 sub-questions. The sub-questions and their respective answers are detailed as follows

> *Q1: Can location- and time-triggered questionnaires help therapists to better understand (assess) a patient?*

A1: The location- and time-triggered questionnaires are shown to help the therapists to better assess patient's feelings and behavior at the right place and time with reasonable time and treatment cost. From the collected results, the usefulness score of the benefit of questionnaires for better assessment is average score of 9.5/10 and this shows the context-based questionnaires are extremely useful for patient assessment. They minimize the treatment time and cost with a satisfactory result as well.

Q2: Can location- and time-triggered notifications help therapists to better treat a patient?

A2: The context-based triggered notifications are also shown to deliver and enhance the treatment process to the patient. With usefulness average score of 9.75/10, notifications are shown to be extremely useful for the better treatment of patients.

Q3: Can location- and time-based gathered information (e.g., time of notifications/questionnaires, answers to questionnaires) help therapists to better tailor the patient's treatment?

A3: Gathering location- and time-based information helps therapists to understand the patient's' behavior, denoted with a usefulness average score of 9.5/10, which shows that it is extremely useful.

6.3. Limitations

The main limitation of this thesis is lack of adequate time to have more therapists and patients participate in the evaluation. Due to time constraints, random participants were selected to participate in the questionnaires rather than real patients. In addition, the research was only able to incorporate a small number of therapists due to their busy schedules and lack of time on our part. Hence, the evaluation result from 4 therapists can be only considered as preliminary result and need to be confirmed with a larger scale experiment.

6.4. Future Work

In addition to our own observation about the functionality and future development of the app, we have also administered a questionnaire to gain the therapists' insights on how the system can be further improved. The therapists have suggested to make the interface more visual when creating new patients and make the buttons appear bigger. They also recommended for the app to comprise detailed instructions on how to add configuration and range of time within specific place.

While we were developing the app, we have observed that some parts of the app can be further improved. As future work, the app can be extended to predict lapses from the data collected via the questionnaire using statistical techniques (e.g., interpolation) or machine learning. Moreover, there is a room for further improvement, no getting a feedback from patients as it is significant to improve the quality of health care. Adding a voice message feedback to the system can help therapists to understand the state of their patient more effectively. These will ultimately push health providers to strive for a better health care system. Finally, the evaluation methodology can be further improved to be more extensive: more test subjects and larger sample of patients.

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8. APPENDICES

8.1. Appendix A: System Usability Scale (SUS) Form

System Usability Scale for mobile application

For evaluating the usability of the mobile app created for patients.

I APPRECIATE YOUR PARTICIPATION AND THANK YOU FOR YOUR VALUABLE TIME.

* Required

Introduction

1. Gender *

- ◯ Male
- ◯ Female
- ◯ Other: ____________

2. Age *

- ◯ Younger than 18
- ◯ 18 - 24
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 or older
- ◯ Prefer not to say

3. Study level *

- ◯ Younger than 18
- ◯ 18 - 24
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 or older
- ◯ Prefer not to say

4. Knowledge of ICT *

- ◯ None
- ◯ Basic
- ◯ Intermediate
- ◯ Advanced
- ◯ Expert
- ◯ Other: ____________

Evaluation of usability

5. I think that I would like to use this mobile app frequently. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

6. I found this mobile app unnecessarily complex. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

7. I thought this mobile app was easy to use. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

8. I think that I would need assistance to be able to use this mobile app. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

9. I found the various functions in this mobile app were well integrated. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

10. I thought there was too much inconsistency in this mobile app. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

11. I would imagine that most people would learn to use this mobile app very quickly. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

12. I found this mobile app very cumbersome/awkward to use. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

13. I felt very confident using this mobile app. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

14. I needed to learn a lot of things before I could get going with this mobile app. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

8.2. Appendix B: System Usability Scale (SUS) Form

System Usability Scale for web application

For evaluating the usability of the web app created for therapists.

I APPRECIATE YOUR PARTICIPATION AND THANK YOU FOR YOUR VALUABLE TIME.

* Required

Introduction

1. Gender *

- ◯ Male
- ◯ Female
- ◯ Other: ____________

2. Age *

- ◯ Younger than 18
- ◯ 18 - 24
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 or older
- ◯ Prefer not to say

3. Study level *

- ○ Younger than 18
- ○ 18 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55 or older
- ○ Prefer not to say

4. Knowledge of ICT *

- ○ None
- ○ Basic
- ○ Intermediate
- ○ Advanced
- ○ Expert
- ○ Other: ____________________

Evaluation of usability

5. I think that I would like to use this website frequently. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

6. I found this website unnecessarily complex. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

7. I thought this website was easy to use. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

8. I think that I would need assistance to be able to use this website. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

9. I found the various functions in this website were well integrated. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

10. I thought there was too much inconsistency in this website. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

11. I would imagine that most people would learn to use this website very quickly. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

12. I found this website very cumbersome/awkward to use. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

13. I felt very confident using this website. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

14. I needed to learn a lot of things before I could get going with this website. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

8.3. Appendix C: Usefulness of SyMptOMS web app

For evaluating the usefulness of the web app created for therapists.

I APPRECIATE YOUR PARTICIPATION AND THANK YOU FOR YOUR VALUABLE TIME.

* Required

Introduction

1. Gender *

- ○ Male
- ○ Female
- ○ Other: ______________________

2. Age *

- ○ Younger than 18
- ○ 18 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55 or older
- ○ Prefer not to say

3. Study level *

- ○ Younger than 18
- ○ 18 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55 or older
- ○ Prefer not to say

4. Knowledge of ICT *

- None
- Basic
- Intermediate
- Advanced
- Expert
- Other: ______

General evaluation

5. If the system were available, I would like to use it for my therapy sessions. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

6. I think using the application has the potential to give me a better understanding of the patient's behaviour. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

7. I think using the application may improve the communication between therapist and patient. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

8. I think using the application may minimize treatment time. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

9. I think using the application may minimize treatment cost. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

Context-based questionnaires

10. I think using location- and time-triggered questionnaires may help me to better assess a patient. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

11. I think using location- and time-triggered questionnaires may minimize treatment time. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

12. I think using location- and time-triggered questionnaires may minimize treatment cost. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

13. I think it is useful to have different question types (i.e. open question, ‘yes’ or ‘no’ questions and numerical rating). *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

Evaluation of visualization

14. I think visualizing the answer in this way is useful for my work. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

15. I think it is useful to have graphs that visualize the result of numerical rating and 'yes' or 'no' questions. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

16. I think it is useful to have tables that displays the result of open questions. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

17. I think it is useful to have the possibility of filtering data based on the submission time of the questions. (start and end date and time slot; whole day, morning, afternoon and evening). *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

Context-based notifications

18. I think using location- and time-triggered notification may help me to better treat a patient. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

19. I think using location- and time-triggered notification may minimize treatment time. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

20. I think using location- and time-triggered notification may minimize treatment cost. *

	1	2	3	4	5	6	7	8	9	10	
not useful at all	○	○	○	○	○	○	○	○	○	○	extremely useful

Further exploration

21. Do you have any suggestions of functionality to add to make the tool more useful? *

Your answer

22. How do you think time- and location-based notifications can help the treatment of a patient (i.e., for what purpose can they be used)? *

Your answer

23. For which mental disorders do you think time- and location-based notifications can be useful? *

Your answer

24. How do you think time- and location-based questionnaires can help assess patient's behaviour (i.e., for what purpose can they be used)? *

Your answer

25. For which mental disorders do you think time- and location-based questionnaires can be useful? *

Your answer