Internet of Things as support for health insurance

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ABSTRACT

This project's main objective is to produce an mHealth system targeted at health insurance in which are present the advantages of the IoT, EHR and wearables technologies, to analyze health data from clients of the insurance company (collected and recorded via the client's wearable and personal phone) that make use of the system, as well as producing some indicators that let these have a greater knowledge of their health condition. At the same time, insurers benefit from this system since it allows them a greater knowledge of the health data of its customers through its records and consequently a more appropriate adjustment of the premium. The measurements collected can be inserted manually by the client or registered by a wearable, and need to be validated by partners of the insurance company, which will have as its main goal to confirm the data entered by customers. This system comprises the functional and nonfunctional requirements that, once tested, made it possible to understand that, as expected, this is a good option to fulfill the goals of this project.

Author Keywords

IoT; Wearable; Health Insurance; mHealth; EHR

INTRODUCTION

With the technological advancement emerged various concepts that have been adopted by health professionals, namely eHealth and electronic health records (EHRs), allowing the existence of medical records in a digital format which make possible a better management of this data due to a centralization of the information and a format that makes it easier to be shared [12,18]. Later, with the introduction of mobile devices and cellular networks, it has become possible to access these records anywhere, giving rise to the mHealth systems [7,12,13,18]. Due to the evolution of smartphones, mHealth systems have been extensively studied for their benefits, because in addition to being able to consult the patient's data, it started also to be possible to obtain some of these data remotely through the various sensors present in smartphones [4,8,18,22,23]. Another innovative factor that has recently emerged was the Internet of Thing (IoT), which presents a scenario in which the various equipment we use daily are connected to the Internet, being this technology applied, among other sectors, in the health systems [14]. The devices that best seem to withstand the IoT in terms of health records are the wearables because of their small size, the constant contact with the body, low resource consumption and reliable and rigorous registration of various measurements such as heart rate, physical activity, galvanic skin response, among others [1,5,9,19,22].

Objectives

This dissertation proposes a system that combines the technology of wearables and mobile computing with the business model of health insurance, presenting a solution that includes the advantages inherent to the IoT, wearable and mHealth technologies. It is intended that customers of an insurance company can register their health data and have a better control and knowledge of their health condition while insurance companies have a better knowledge of the risks and are able to adapt the client's insurance premium depending on their health records. Thus, this project aims to design a functional architecture that complies with the determined requirements, in accordance with the existing literature and other work developed so far in this area.

RELATED WORK

There are several concepts and related work that will be used as theoretical support to this dissertation.

eHealth and mHealth

eHealth systems make possible to store medical records in electronic format, making it easier to store and share these records, allowing an improvement in the field of healthcare by making patients' medical history more accessible to health care professionals and by reducing the costs associated with medical expenses as it was demonstrated in previous studies [20]. With the trivialization of mobile devices and cellular networks, the concept of eHealth evolved into mHealth (mobile Health), making it possible to access these records anywhere, anytime [7,12,13,18,19]. These systems became even more complete with the introduction of the smartphones, once that besides being possible to access patients' records anywhere, it also started to be possible to obtain them through the several sensors present in the smartphones and through devices that communicate with them (i.e.: wearables) [8]. As there is a big number of applications in this sector, three of the most used were selected (Noom Walk, Instant Heart Rate e Diabetes:M) in order to study their functional and implementational positive and negative aspects [8,13,18].

Collected measurements

In order to allow the insurance companies to know the risks and the physical condition of their clients, it was decided to collect Metabolic Syndrome indicators. This syndrome is defined as a set of risk factors reported by the patients and relates to the likelihood of heart problems, diabetes and other conditions that can lead to death [10,16]. For Metabolic Syndrome diagnosis, the patient must present at least three out of five factors: elevated waist circumference, elevated triglycerides, reduced HDL-C, elevated blood pressure and elevated fasting glucose [2,3,11]. These symptoms show both in adults and children, alerting to the need for disease prevention and the adoption of a healthy lifestyle. For this reason, it is pertinent to evaluate clients' physical activity by their number of daily steps and heart rate, knowing that the World Health Organization recommends at least 30 minutes of daily physical activity, which translates into 10,000 steps [15,21].

Internet of Things

The Internet of Things, which refers to the ability of daily used devices to connect to the Internet, has been expanding and having an increased impact on the daily life. [14]In the scope of this project, IoT has particular interest when applied to the health services, since it has been beneficial to the improvement of the patients' quality of life. The use of IoT in healthcare allows to monitor patients using sensors that provide information in real-time to the patient and all the health professionals. In what concerns the sensors to be used, the most suitable to perform these measurements are the wearables due to their discretion and ease to carry.

Wearables

According to several studies, the wearable market is mainly relevant for the healthcare branch, since the most adopted ones are the medical and fitness devices. For this project, it was necessary to identify the most suitable types of wearables. Thus, after some research it was understood that most used wearables are the fitness bands, and it's expected to remain like this what can be justified by the fact that they are cheaper than the rest (i.e.: smartwatches and smartglasses), being the price one of the main factors considered by the buyers when looking for one of these devices [6,17]. Considering all this, several low-cost wearables directed to the healthcare and fitness sector were analyzed, and it was concluded that the most adequate wearable to test with the system developed in this project would be the Xiaomi Band 1S, due to its low cost and its ability to collect the necessary measurements. Even though there are many wearables and mobile applications in the health and fitness branches, it is necessary to have in mind some factors that enhance their use, since the dropout rate is very high [5]. The fact that the system allows the user to be rewarded with a lower insurance premium and provides him with indicators about his health can motivate him to use the system [6].

Wearables Interaction Models

To collect the measurements made by the wearables, there are two possible interaction models. In the first model the developed application uses a specific API for the wearable and communicates with it through Bluetooth using that API (Figure 1). In the second model a third-party application deals with the wearable-mobile phone communication, and with the way the measurements made by the wearable are collected by the phone, while the developed application only has to request the data collected by the third-party application through an specific API or through a REST API in case the third-party application stores the collected data in a remote server (Figure 2).

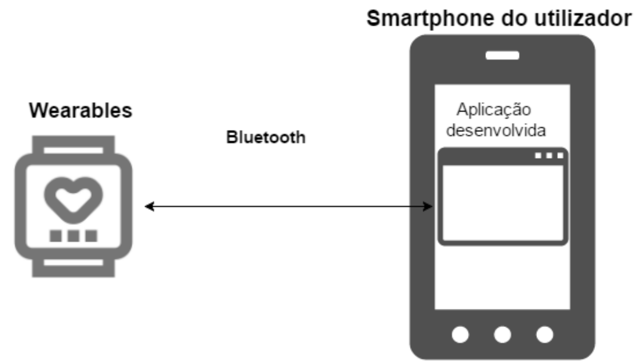

Figure 1 - Model where measurements done by the wearable, are collected directly

Both models have advantages and disadvantages. While the first model allows a better control of the data collected from the wearable, because the data is not shared with other applications, the second model allows that the developed application supports a wide range of devices without any additional effort because the communication between the devices and the wearable it's delegated to a third-party application the usually support a large number of devices (one example of a third-party application is GoogleFit).

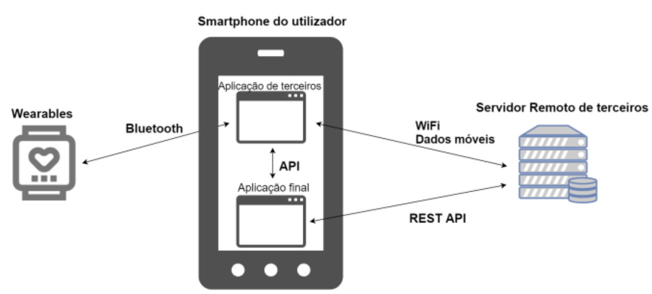

Figure 2 - Model where measurements obtained by the developed application, are obtained from 3rd Party services

Outsystems Platform

It was analyzed the possibility of developing the present project on the Outsystems platform [24] due to the several advantages that arise from the use of this platform, including a much lower development time, easy visualization, storage and exchange of data and easy implementation of security in applications. On this platform, it's possible to implement both Web Apps and native mobile applications that can be exported to both iOS and Android. To get a better understanding of the platform, it was carried out an online course provided by Outsystems ("Developing Outsystems Mobile Apps"), and then, in order to test the platform, it was created a basic application where the user could manage his diabetes and body mass index, have access to a schedule of health appointments and to a chat where he could talk with someone from the support team in case of any doubt. In a week span, it was created not only the application but also a Backoffice where the insurance company could see their clients' information (which confirms the fast development that the platform offers).

Analysis

Making a conclusive analysis, it is noticeable that despite the mHealth systems are in constant growth and show some advantages in the healthcare sector, it is necessary to have a special attention with regard to the privacy of clients' health data as it circulates through the Internet. Despite not having been found any specific application for insurance companies, some of the available applications in the healthcare sector were analyzed in order to find out positive and negative aspects of these applications, which served as the basis to provide some features for the project application. With regard to wearable interaction model, the selected model was the one were the developed application gets the measurements made by the wearable through a third-party application, because this way the number of compatible devices increases, giving the use a higher flexibility in the choice of the wearable to use. The chosen third-party applications were Google Fit for Android devices and Apple Health for Apple devices. Another advantage of this model, is that it allows the insurance company client to use other applications as long as they can be synchronized with the third-party apps, giving him the possibility to use his usual applications without any constraint, allowing that the measurements done during the use of this applications to be obtained by the developed application. Regarding the measurements to be collected, due to the lack of knowledge in the medical area, it was decided that the selected measurement would be the ones used for Metabolic Syndrome diagnosis since it allows to determine the patient risk according to a set of risk factors. In addition to these, the heart rate and the number of steps were also included in a way to determine the physical activity level of the user, since this is one of the principal means to fight Metabolic Syndrome. The selected device to test the prototype was the Xiaomi Band 1S as it has a very low cost, collects the necessary measurements for the present project and can be synchronized with Google Fit and Apple Health. Finally, due to the very positive results obtained in the Outsystems platform test, it was decided to (unless it is not possible to implement some functionalities) use this platform to develop the solution proposed in this project (both database and all the required interfaces).

REQUIREMENTS

After some research and according to the analysis performed on the related work, it was decided that there should be a third entity (hospitals, pharmacies and clinics which are partners of the insurance company) responsible for the periodic validation of the data inputs made by the insurance company clients, in order to avoid fraudulent data. It was necessary to identify a set of requirements that the system must comply with in order to achieve the project objectives. The functional requirements identified were:

- Development of a mobile application for the insurance clients that allows them to register on the system, allows the measurements made by the wearable are obtained through Google Fit or Apple Health (depending on the device), includes a screen where the users can manually input, through a form, the measurements made by themselves, and another screen where they can have access to their measurements and health indicators;
- Development of a Web App and a mobile application for the insurance company partners where they will have the possibility to input, through a form, measurements made on the insured clients;
- The creation of a Web App for the insurance company that allows the access to the health data of their clients.

The non-functional requirements identified were the following:

- The security since the system exchanges and stores health data;
- Usability, once the system must be easy to use and intuitive in order to make it appealing and easy to adopt by the users;
- Mobile applications should be cross-platform;
- Efficient usage of the mobile phone resources (battery and mobile data);
- Interoperability with different wearables, not restricting the users to the wearable selected to test this project

ARCHITECTURE

In this section will be presented the architecture adopted for the development of the project (Figure 3). For a better understanding of the architecture, each component will be explained individually.

User / Client

In this component of the architecture, it will be developed a mobile application using the Outsystems platform where the user can consult his electronic health record, insert measurements made by himself and obtain measurements made by the wearable. The measurements made by the wearable will be obtained through third-party apps (Google Fit or Apple Health) and as such the application must be able to communicate with these entities in order to obtain the measurements stored by them. The application must also be

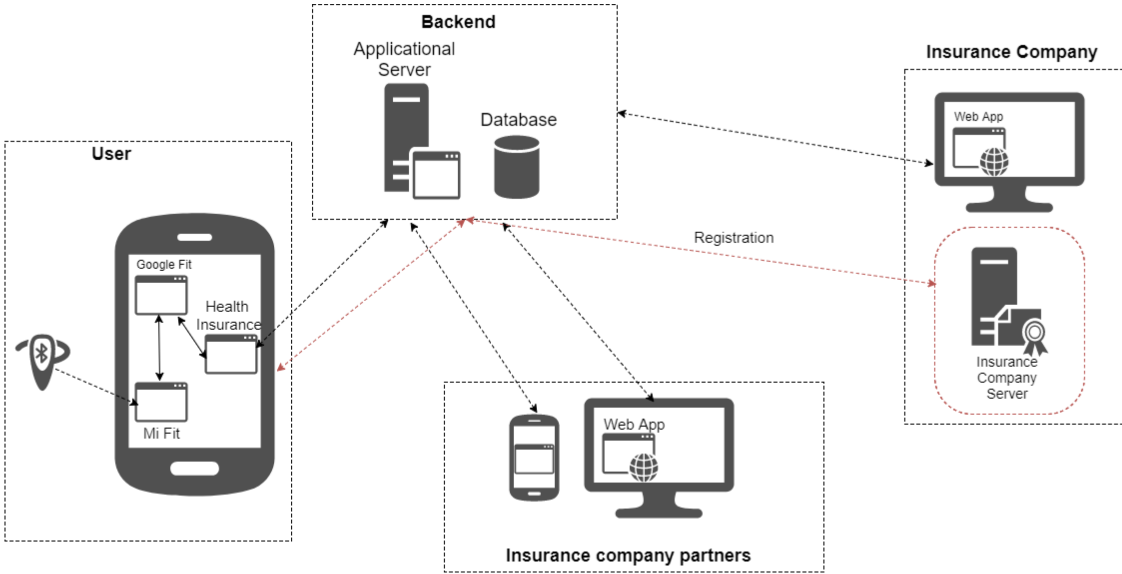

Figure 3 - System architecture

able to communicate with the insurance company server in order to know if a user is already their client before allowing his registration in the system.

Healthcare provider

Regarding the healthcare providers (i.e.: pharmacies, clinics or hospitals partners of the insurance company) will be created two interfaces: a responsive Web App and a mobile application where they can only insert new measurements made to clients of the insurance company, not having the possibility of consulting the clients' data to respect their privacy.

Backend

It consists of the Outsystems platform constituted by the application server where the developed Web Apps are hosted, and by the Outsystems database where all the information used in the system is stored and managed.

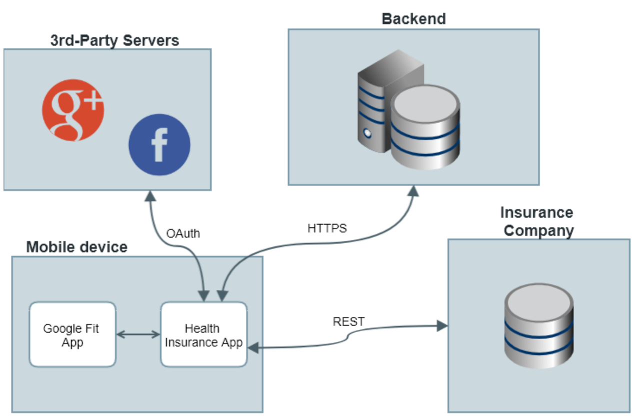

Figure 4 - Architecture of the client component

Insurance company

In this component of the system the insurance company will be provided with a responsive Web App, also created in Outsystems, where the company can access all the data and information related to their clients that use the application.

IMPLEMENTATION

For the implementation of the system, it was decided that the designed solution should be external to the insurance company's environment to facilitate the integration of the system, as the insurance companies do not have to make changes in their current environment to use the system.

Methodology

The development methodology adopted for the implementation of the project was based on the Scrum framework, dividing a set of requirements identified previously in three-week Sprints, thus allowing a periodic evaluation of the system in order to detect possible weaknesses and potentialities rather than doing a single final analysis of the system.

System Database

In order to store all the information necessary to the functioning of the system, it was created a database. The database is composed of several tables namely the "Measures" table where will be stored all the users' measurements, the "AggregateData" table where is stored a monthly summary of the users' data and indicators and a "QRCode" table where the information about the QRCodes generated by the clients will be stored. The data relating to the accounts of the users of the system are stored in the "User" and "SystemUser" table.

Insurance Company Database

In order to simulate the interaction with the insurance company database, it was created a separate database, where all clients and partners of the insurance company are stored (in the "Users" and "PartnerLocation" tables respectively). In order to obtain the data present in this database were created two REST Web Services: one to get the insurance company partners and respective locations and other to verify if a user was already a client of the insurance company.

Client Application

In this application the client, after logging in, can consult a dashboard with all his collected measurements as well as some indicators of his health condition and physical activity. In order to improve the usability of the system was implemented the functionality of logging in through social networks (Facebook and Google+) making this process a lot faster since the user does not to enter his credentials manually. Thus, the client application communicates with the Facebook or Google+ using the protocol OAuth in order to get the user's email. Once the application gets the user email, it verifies in the backend server if there is any registered user with the email obtained and, if so, performs his authentication.

One of the ways found to integrate the developed system with the health insurance's system was to only allow current customers of the insurance company to register on the system. To do this, if a user tries to log in via social networks and there is not an account in the system with the obtained email, the customer is asked to insert his tax identification number, citizen card number and date of birth. After the customer enters this data the REST Web Server created in the insurance company is invoked with the data entered by the user, and the Web Server returns a Boolean indicating whether the user is an insurance company client or not, and if it is, the user is asked to select a password to create an account on the developed system with the obtained data.

To collect the measurements was created a form for the client to enter the measurements made by himself and a button where the user can request the collection of the measurements made by the wearable and stored on Google Fit/Apple Health. To obtain these measurements it was necessary to create an Outsystems plugin since the platform does not have any module for this. In the Outsystems platform, it is possible to create native plugins through plugins developed for the Apache Cordova framework, once the mobile applications developed in Outsystems are built on top of this framework. To create this plugin the Cordova plugin "cordova-plugin-health" [1000000] (which allows the application to collect the data stored on Google Fit or Apple Health depending on the device) was imported and were created two JavaScript functions using the imported plugin: one to collect the steps, where is requested the number of steps made between the date of the last collection and the current date, grouped by day, and another to collect the heart measurements made, were are requested all the heart rate measurements made between the day of the last collection and the current date. Both functions return a JSON object with the measurements done between the stated dates, that is parsed in order to get the values of the measurements and to update the system's records.

Since the client has to periodically visit the health insurance partners to validate his measurements, it was decided to mark on a map the locations of the partners to facilitate these visits. Thus, was created a REST Web Service on the insurance company so the application could get the insurance company partners and respective locations. The application, after making the request to the Web Server, receives a JSON object with the data of the partners, parses the JSON and for each partner, it is created a marker on Google Maps with his name and respective location using the Google Maps JavaScript API. After creating all the markers, the application requests the user current location and makes zoom on his location to facilitate the search for nearby partners.

Also with the objective of facilitating the visit to the insurance company partners and at the same time to give some privacy to the users of the system, was created in the application a window where the users can generate a QRCode that will be read by the application implemented for the insurance company partners with the objective of identifying the client. When a client generates a QRCode in the application, the server generates an alphanumeric token with 32 characters, valid for one hour, and that can only be used once and sends it to the client application that generates a QRCode with the received token.

Finally, and in order to have a greater interaction with the user the use of Push Notifications was implemented as a means to provide feedback, suggestions or indications to the users because with this type of notifications the user does not need to be using the app to obtain these informations. Once the system is cross-platform it was decided to use the OneSignal service which facilitates the sending of notifications since it detects what type of device the user is using, and if it is an Apple device, sends the notification through the Apple Push Notification Service or if it is an Android, sends the notification through the Google Cloud Messaging.

Healthcare Providers Interfaces

The healthcare providers interfaces (Web App and mobile application) are the interfaces that will be given to the partners of the insurance company to insert the measurements made to the clients. Thus, after logging in, the partners have only one window where they can scan the clients' QRCode and, once scanned, the application sends to the server the token obtained through the scan so the server can check if the token is valid. If it is, the application opens a window with a form where the partner of the insurance company can enter the measurements made to the clients. After entering the measurements, the application sends the token to the server along with the measurements made, and the server verifies once again the validation of the token and, if valid, searches the issuer of the token. This way the server identifies to which user the measurements belong to and updates his records.

The partners who use the application can only insert client records, not having access to their information (both personal data as other measurements registered previously) in order to respect their privacy.

Insurance Company Web App

In this Web App, the insurance company will be able to (after logging in) to consult a list of all his clients and the profile of each client, where it can edit their data and see a summary of all the client's records (in the form of graphs or tables) through a dashboard. It was also created a window where the insurance company may consult a listing of the aggregate data of their clients.

Aggregate Data Table

Since the clients' data must be converted into health and physical activity indicators and this is an operation that can take some time because it involves many calculations, was created a timer (a functionality of the Outsystems platform that allows to schedule actions) that triggers on the first day of each month at 4AM, which makes the processing of the data from the previous month for each client and stores the result in the "AggregateDate" table. This way it becomes easier for the insurance company to get a sense of the physical activity and health condition of their clients.

Security

The security and privacy of the clients is a crucial factor in this system since it stores and transmits health data. The Outsystems platform, by the way it is implemented and manages the applications developed on it, provides protection against the top 10 vulnerabilities of the Open Web Application Security Project, namely code injection, cross-site scripting and sensitive data exposure [25,26]. In addition to these vulnerabilities defended by Outsystems, as a way of strengthening security all stored passwords are encrypted and all data exchanges are made using the HTTPS protocol.

As for the privacy of the user, was established in the application a functionality that allows the user to delete all the data present in the system (personal and health data) giving him the right to be forgotten, and all data obtained through both Google Fit/Apple Health and Facebook/Google+ must be authorized by the user. Also with the goal of enhancing privacy, the partners of the insurance company are not allowed to have access to the clients' data and the implementation of the QRCode allows clients to identify themselves without having to reveal their personal information.

RESULTS ANALYSIS

Analyzing the results from the tests performed, it can be confirmed that all functional requirements were successfully implemented. Concerning the non-functional requirements, a usability test (Wizard of Oz) was performed on 10 participants (70% with average familiarization with technology and 30% with high familiarization), asking them to perform several tasks with the developed client application (table 1), followed by a subjective evaluation questionnaire about the experience. None of the parameters obtained a negative result. The lowest scores were related with neutral answers ("I don't agree or disagree"). In most cases, the parameters obtained the higher scores ("Slightly agree" and "Completely agree").

Tasks	Paricipants that accomplished the task	Number of participants that made mistakes
Log In	10	0
Collect measurements done by the wearable	10	7
Insert weight measure	10	0
Edit Profile	10	0
Consult BMI indicator	10	0
Check notifications	10	2
Logout	10	1

Table 1 - Results of the usability test

The cross-platform test as shown that the application works with both systems (Android and iOS) and that, in consequence, this requirement was respected. To test the fitness band it was asked to 4 participants to use the Xiaomi Band 1S during a week and to fill out a pre and a post-test questionnaire about their usual weekly physical activity level (in the pre-test), and the physical activity during the week of the test (post-test). The levels of physical activity reported by the participants matched the level obtained by the fitness band, which confirms that the wearable device selected for this system is functional and reliable (table 2).

The interoperability of the system is one of the main requirements and it was demonstrated by the test that it has been respected, once the results prove that the user does not need to use the Xiaomi Band 1S for the developed application to work.

The requirement concerning the resource management of the application was also tested, being the results very satisfactory: during a complete day, the application used 3% of the smartphone, 1,83 MB of sent data, and 2,57 MB of received data.

Physical activity level (Post-test)	Average daily steps	Physical activity level (reported by the band)
High	15822,57	High
Medium	7623,57	Medium
Medium	8840,14	Medium
Low	5692,43	Low

Table 2 - Results of the band test

CONCLUSIONS AND FUTURE WORK

The results from the system test confirm that the system is functional and effective. The test was also useful to identify aspects to be improved in the future. The objective of this project was accomplished, once that the system developed gives not only the users the ability to monitor and reflect in a more practical and informed way about their health condition, but gives also the insurance companies the possibility of adjusting the insurance premiums of their clients according to the way each one of them manages his health. It should be pointed out as a positive point the fact that the clients are offered a system that helps them in the management of their health data and contributes for a higher self-awareness, motivating them at the same time to improve their health having in mind they will be rewarded with a lower insurance premium. On the other hand, this system requires the share of health data, what can cause some reluctance from the insurance company clients to use it, even if the data safety is assured. The fact that the insurance company will have access to health data from clients adhering to this system raises a dilemma: on one hand, if the measurements recorded are satisfactory, the client will benefit from a lower insurance premium; on the other hand, if the records from the client show his behavior and health management are not appropriate to his health condition he will be penalized with a higher insurance premium.

Even though the goals of the project were mainly achieved, there are a couple of factors that should be taken in mind for future developments, namely:

- the security requirement should be tested against attacks to the system in order to detect eventual fragilities;
- some of the suggestions made by the usability test participants should be implemented in order to improve the usability experience of the client. The test should also be applied to the rest of the interfaces;
- the physical activity indicator should also be improved once that on this prototype the indicator uses only the number of steps for physical activity evaluation, which leaves out other activities like cycling or swimming that would not be recognized using this indicator;
- use the Open ID authentication protocol to avoid the client will need two accounts (one for the system and other for the insurance company) or to make the authentication more robust through Facebook and Google+. The authorization is currently made using the OAuth protocol.

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