A Diabetes Prevention Mobile App based on Health Projection and Gamification

Samantha Jiménez, Erick Arroyo, Reyes Juárez Ramírez, Ángeles Quezada, Bogart Yail Márquez Lobato, Arnulfo Alanis.

[a] Instituto Tecnológico de Tijuana, samantha.jimenez@tectijuana.edu.mx, Tijuana, Baja California, México.
[b] Instituto Tecnológico de Tijuana, erick.arroyo17@tectijuana.edu.mx, Tijuana, Baja California, México.
[c] Universidad Autónoma de Baja California, reyesjua@uabc.edu.mx, Tijuana, Baja California y México.
[d] Instituto Tecnológico de Tijuana, angeles.quezada@tectijuana.edu.mx, Tijuana, Baja California, México.
[e] Instituto Tecnológico de Tijuana, bogart@tectijuana.edu.mx, Tijuana, Baja California, México.
[f] Instituto Tecnológico de Tijuana, alanis@tectijuana.edu.mx, Tijuana, Baja California, México

Resumen

Diabetes tipo II afecta al 90% de la población en el mundo y es el resultado de una vida sedentaria y de malos hábitos alimenticios. La automonitoreo de una alimentación saludable y actividad física desempeñan un papel importante. Las aplicaciones móviles pueden ser usadas como una herramienta efectiva como mecanismo de automonitoreo. Sin embargo, las aplicaciones móviles actuales están enfocadas en el manejo de la enfermedad y no en la prevención. Otra desventaja de estas aplicaciones es que no incluyen elementos para mantener la atención del usuario y la motivación para seguir interactuando con la aplicación. Esto puede deberse a que se han desarrollado estas aplicaciones pensando en que el manejo de la enfermedad y están dirigidas a personas con 50 años en promedio. Sin embargo, cada vez personas más jóvenes tienen este padecimiento. Es por eso que este estudio presenta una aplicación móvil para la prevención de diabetes basada en gamificación y proyección de salud. La aplicación calcula la probabilidad de tener diabetes en el futuro y está dirigida a usuarios entre 16 y 27 años. Se evaluó la usabilidad de la aplicación con 12 usuarios, particularmente la satisfacción del usuario. Los resultados sugieren que la satisfacción del usuario es buena, al igual que la aprendibilidad de la aplicación. La aplicación presentada en este trabajo es un inicio para crear consciencia de la prevención de diabetes en usuarios jóvenes.

Palabras clave—Diabetes, Aplicación móvil, proyección de salud, gamificación.

Abstract

Type II diabetes affects 90% of people with diabetes around the world and is largely the result of excess body weight and physical inactivity. The self-monitoring of healthy eating and exercise play an important role in the prevention of this disease. Mobile applications can be used as an effective tool in different self-monitoring techniques. However, most of the current diabetes apps are focused on managing the disease, not on prevention. Another disadvantage of mobile applications is that they do not include elements to keep users' attention and motivation. The applications for diabetes prevention do not consider these elements because they aimed to manage the disease or try to prevent it but in adults. This study aims to prevent the disease earlier with users aged between 16 and 27 years. Thus, this study presents a mobile application for diabetes prevention based on gamification for younger users. Also, it includes the health projection calculating the probability of getting diabetes in the future. The app's usability was tested with 12 users. The results stated that the usability was good, also the learnability of the app. The app presented in this work is a start point on diabetes prevention in young users.

Keywords*— Diabetes, Mobile App, Health projection, gamification.*

1. INTRODUCCIÓN

The global incidence of diabetes is significantly increasing, and by 2025 this is predicted to reach more than 5 million patients [1]. Type II diabetes affects 90% of people with diabetes worldwide and is largely due to excess body weight and physical inactivity [2]. It is a challenge for healthcare providers to find strategies that reduce the number of diabetes patients in the future.

The foundation of successful diabetes prevention is an education in the disease, promotion of healthy eating, and physical activity. The self-monitoring of healthy eating and exercise play an important role in preventing this disease [3].

Mobile applications can be used as an effective tool in different self-monitoring techniques. They are useful for all user groups, from people with no overt health problems to chronic patients [3]. They have been tested on type II diabetes, asthma, chronic obstructive pulmonary disease, and different psychiatric conditions. Also, there are several self-monitoring blood glucose systems that help the patients in the reduction of risk of serious secondary clinical complications [3].

There are several mobile applications for diabetes patients [4]. However, most of them are focused on managing the disease, not on prevention [5]. According to Waite et al. [2], the diabetes management apps are generally categorized into four areas: 1) Glucose-tracking diaries, 2) Carbohydrate estimation, 3) Recipes, and 4) Diabetes education.

Another disadvantage of mobile applications is that they do not include elements to keep users' attention and motivation. The idea of 'gamifying' applications has become a promising approach to get users actively involved and keep them engaged [6]. However, the current applications do not include gamification. It could be because more of the diabetes apps was designed thinking that the main user would be an adult aged 50 years. After all, the apps did not design for prevention.

Gamification is the use of game design elements in non-game contexts [6]. Schmidt-Kraepelin et al. [6] suggest several dimensions to include gamification in the healthcare applications: 1) Concept-to-user communication, 2) User identity, 3) Rewards, 4) Competition, 5) Target group, 6) Collaboration, 7) Goal setting, 8) Narrative, 9)

Reinforcement, 10) Persuasive intent, 11) Level of integration, and 12) User advancement.

The applications for diabetes prevention do not include any gamification theory because they aimed to manage the disease or try to prevent it but in adults. The average age of onset for type 2 diabetes is 45 years. Thus, to prevent diabetes, the apps should be designed for users aged from 12 to 25 years. For that reason, this study presents a mobile application for diabetes prevention based on gamification and health projection for younger users. The app includes the user identity, rewards, goal setting, and competition dimensions in the design. Also, it includes the health projection calculating the probability of getting diabetes in the future.

The rest of the paper is organized as follows: Section II describes the related work. Section III provides a complete explanation of the user model. Section VI is presented the system architecture and the mock-ups. Section V explains the evaluation process and results. Finally, Section VI concludes the study.

2. RELATED WORK

There are several mobile applications for diabetes patients in the market [4]. According to Waite et al. [2], these apps are generally be categorized into four areas: 1) Glucose-tracking diaries, 2) Carbohydrate estimation, 3) Recipes, and 4) Diabetes education. Some of these applications are set all in one.

The app mDiab [7] is an electronic logbook where you can record your self-monitoring data, such as blood glucose values, injected insulin, bread units, and sports activities. Furthermore, you can record your weight and blood pressure. In mDiab lite, you can record up to 50 entries. In the full version of mDiab you can save an unlimited number of records. The toolbox helps to personalize mDiab lite by setting preferred units and alert limits for hyper and hypoglycemia. The medication list facilitates the choice of the medication you take. As a reminder, a BMI calculator and an insulin calculator extend the functionalities of the application. This app is of area 1) Glucose-tracking diaries and Carbohydrate estimation. It is also designed for patients with diabetes, is not for prevention. In the same way, it is designed for adults aged between 40 and 60 years. For that reason, it does not include any gamification technique.

Lark 24/7 Health Coach [8] can track the user's diet, exercise, sleep, medications, and weight, to get fit, prevent diabetes, control chronic conditions, or lose weight. This application uses AI and real-time health monitors to provide support and advice to help the user make healthier decisions. It tracks the activities and weight of users to give personalized
advice. This application's design is based on prevention, so it was designed for users aged between 30 and 40. This application does not consider competition or communication between users.

Meaning “my Health” in Sanskrit, myArogya [9] is the first-of-its-kind chronic disease prevention mobile App designed to advance Indians on their personal health journeys and help them lead healthier lives. myArogya includes rich content on awareness and prevention of chronic diseases, including diabetes, heart disease, stroke, kidney disease, and other complications of diabetes. myArogya also has food and activity trackers to help people make healthy lifestyle choices. Other features, including a smoking cessation mHealth program, healthy recipe videos, nutritional icons for India, and additional trackers, are planned for later phases. This application includes the four areas proposed in Waite et al. [2], but it does not include gamification theory on the application's design or development.

Diabetes prevent [10] app can help prevent obesity and diabetes. It wants to motivate the users into following a healthy life, they can synchronize a Patia pedometer or any activity bracelet, like Fitbit, Jawbone, or Google fit; and the app measures the distance users walk or run and the calories burnt daily, the data is synchronized with the web page to help the user maintain a healthy routine. Like the other applications, this app is not based on gamification theory.

All the applications reported in this section do not include any gamification theory, but it could be because they aimed to manage the disease; or prevent it in adults. However, it is time to go one step back and prevent the disease earlier with users aged between 12 and 25. For that reason, this study suggests incorporating gamification in the design of a mobile app for diabetes prevention.

3. MOBILE APPLICATION DESIGN

This section describes the user model, the designs of the avatars, and each view's mock-ups in the mobile application.

3.1 User model

This section describes the attributes that characterize the target user. As mentioned before in this work, the app aims to prevent diabetes, so that, the target user is a young user aged between 16 to 27 years. The user model considers different aspects such as the relationship with diabetes, lifestyle, and physical condition. The user model considers three types of data: requested data calculated data and physical activity. The app requested demographic and generic information to the user in the registration process. The user has the option to change the information anytime. The user is able to register a physical activity and the app calculates some parameters such as the probability of get diabetes in the future, ideal weight, among others. Fig. 1 shows the classification of all the attributes considered by the user model.

Fig. 1. Data classification.

At the time of registration, data such as name, nickname, password, email, birthdate, sex, height, weight, hip and waist circumference, gender, height, weight, hip, and waist circumference are especially important for identifying the physical condition of the user, the first four attributes can be used to calculate most of the factors used in the system, and the last two (hip and waist circumference) are used to calculate the user's probability of getting diabetes in the future, all the formulas are described in the next sections.

The data generated by the user-app interaction are the objectives and physical activity records. These records are used to calculate the body's impact resulting from the physical activity.

The system calculates the following factors based on anthropometric calculations [11]–[13] using the user data.

3.3.1 BMI

One of the most important values for the system is the Body Mass Index (BMI) [12], the BMI describes the relationship between body weight and height. It is widely used in public health and clinical nutrition to provide a quick evaluation of nutritional well-being, calculated as follows:

$$BMI = \frac{weight\ (kg)}{height\ (m^2)} \quad [1]$$

The BMI is calculated after the user registration, and it is updated every time that any parameter change.

3.1.2. Ideal Body Weight

The Ideal Body Weight (IBW) is used as a reference value to estimate the optimal physical condition for the user, can be calculated by the following formula (it is the same formula for men and women) [14]:

$$IBW = 22 * height^2 \quad [2]$$

3.1.3. Waist to hip radio

The Waist to Hip Ratio (WHR) [13] is used to calculate the probability of diabetes and is defined as the waist circumference (*wc*) divided by the hip circumference (*hc*).

$$WHR = \frac{wc}{hc} \quad [3]$$

3.1.4. Probability of Diabetes

The system calculates the probability of getting diabetes based on the prediction presented in [13]. The formula uses as a parameter: Equation 3, user's age, and the BMI. The calculation is different for men and women, and equations are presented as follows:

$$\frac{e^u}{1+e^u)} \quad [4]$$

In men u is:

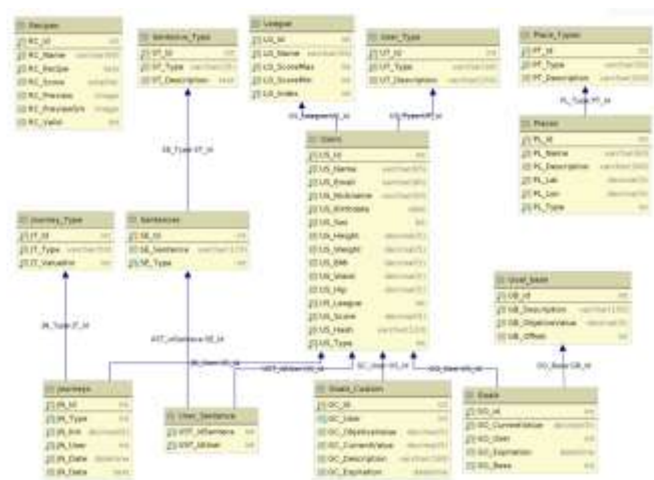
$$u = -11.84 + 10.01 * WHR \quad [5]$$

In women u is:

$$u = -13.9 + 0.05431 * age + 6.789 * WHR + 0.07881 * BMI \quad [6]$$

Considered all the above, Fig. 2 shows the user model represented in an entity relation model.

Fig. 2. Entity relation model.



There are also some elements of the system that are intended to persuade the user. Some attributed the gamification factor as the goals and leagues and others with a psychological factor such as the avatar to influence the user to adopt favorable behaviors that benefit their health and decrease their probability of diabetes.

3.2 System Architecture

The construction of the system is based on the following requirements:

- The system must allow login the registered users.
- The system must show the user the distance that has walked, jogged, and run.
- The system will have a league section where users will compete with others weekly.
- The system will be able to create a character that physically resembles the user.
- The character will improve or worsen his state of health according to the user's actions.
- The system will have software to manage the user's data.

Firstly, the user needs to create an account where a detailed profile is fell in; the system saves all this information. After the registration, the user can select one of the modules in the application. The main module is where the application tracks the user's physical activity considering the only distance, time, and rate to know if they had walked, jogged, and/or run.

3.2.1 Leagues

Based on the competition and rewards of the gamification theory, this app includes a league module. There are five leagues; at the beginning of the week, users can start generating points, they get them by completing one of the following tasks:

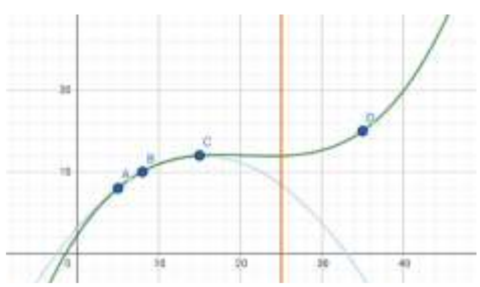
1. Walking.
2. Jogging.
3. Running.

The application calculates the points according to the rate of the user during the activity according to the next equation:

$$score = \frac{x^3}{840} - \frac{31x^2}{420} + \frac{417x}{280} + \frac{9}{4} \qquad [7]$$

Where x is the current speed of the user in km/h. The next Fig. 3 graphs the function where is represented the rate of a walking (A), jogging (B), a running (C), and Usain Bolt's rate (D).

Fig. 3. The tendency of the score function.



The league module provides a multiplier depending on the user's activity duration in a day and/or week.

When registering will be categorized in the first league, these are made up of 50 users in the way shown in Fig. 4, users who are in the first 10 positions will advance to the next league unless they are in the last league. Likewise, the users who are in the last 5 positions will go down to the previous league. Unless they are in the first league, the users who finish these positions will remain in the actual league. The final calculation of the total points of each user will be done on Sundays. Users will be added to a league group until they generate their first points for the week.

Fig. 4. Leagues view.

3.2.2 Avatar

Based on the user identity dimension of the gamification, this app includes an avatar. The system assigns an avatar type depending on the user's health status. The app determines the health status considering the user's data. Then, when the user performs actions that improve their health, the avatar image will be replaced by a more cheerful one, or on the contrary, if the user stops performing healthy actions, the avatar will change to a less cheerful one. Fig. 5 depicts the set of avatars.

Fig. 5. Male and female avatars.

The app displays the avatar and some of the requested information, calculated information and physical activity in the views. The Fig. 6 (a and b) shows these views.

Fig. 5. Screenshots of the app's views.

(a) (b)

4. EXPERIMENTS AND RESULTS

This study analyzes the app's usability. The analysis is focused on user satisfaction. According to several Human-Computer Interaction studies, a sample of five users is enough to demonstrate 85% of errors in a system.

4.1 Sample

A total of twelve subjects installed and interacted with the mobile app. All the participants had previous experience in the use of mobile applications. Due to the COVID pandemic, the study applied a convenience sampling method. The participants were aged 23 years (*SD*=1.4638); were 11 males and one female. The participation was voluntary. According to [15], the System Usability Scale (SUS) needs at least 10 users to represent the 80% correct conclusions.

4.2 Instrument

The authors used the SUS scale, which is widely used as an effective tool to evaluate user satisfaction. The SUS has ten statements, each having a five-point Likert scale that ranges from Strongly Disagree to Strongly Agree. There are five positive statements and five negative statements, which alternate. The average score is 68, which means that above 68 is above average, acceptable (according to the adjectives used to define the score ranges) [15]. We also asked the participants an open-ended question, where they can suggest improvements to the app.

4.3 Method

All the participants interacted with the mobile application. They sign up into the app to login, and then they registered a GPS activity, to see the distance, score and burned calories calculated and presented by the system. After the interaction, the participants answered the SUS instrument. Moreover, the authors collected the responses and analyzed the data using descriptive statistics. The descriptive statistics analyzed the responses by participants and by questions. The next section presents the results.

4.4 Results

From the results, we present a bar charts of the SUS calculations by participants and by questions. Combining both dimensions yielded a heat-map with positive and negative reactions (see Fig. 7). On average, the SUS score was 80.62 which is above the average. The SUS scale with adjective uses the adjective good or excellent to describe this score.

Fig. 7. Detailed view of SUS scores in a heat map matrix.

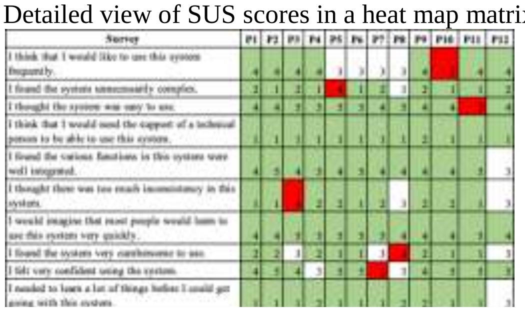


Fig. 8. displays the SUS scores by participant. The red line is situated on average score (68 points). Only one participant scored the app below the 68 points. Clearly, the findings indicate that the app was in anywhere between acceptable and excellent.

Fig. 8. SUS calculation results by participant (*x* axis). The red line is situated on the 68 (average score).

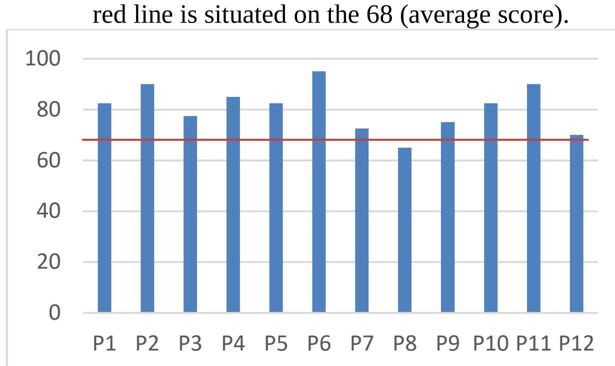
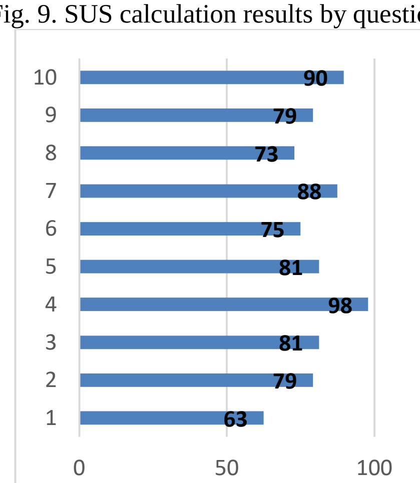


Fig. 9 describes the SUS score by question. We also looked at subset of questions, for example questions 4 and 10 particularly address learnability, while others cover usability. Questions 4 and 10 had the highest scores which means the app is learnable. The first question regards the frequency of use was the lowest value. It could be because the users are not interested on this type of health applications, it was not the objective of this work to address on the reason of why the users do not want to use health apps; but it could be addressed in future studies.

Fig. 9. SUS calculation results by question.



Finally, we collected qualitative answers and the participants' suggestions were the following: "the app should include a section to personalize the avatar", "the app should have a help section in each view", "the app should be more specific of the formats that are correct for the registration".

5. CONCLUSION

This study presents a mobile application for diabetes prevention based on gamification for younger users. The app includes the user identity dimension, including an avatar that can evolve according to the user behavior and fitness status to provide an immediate reward. The immediate rewards play an important role because the human being needs to see changes to be motivated. Also, the users can set their own goals in the application. Finally, the app considers the competition dimension using leagues where the users can get points according to the type of exercise, distance, time, and rate.

Also, the application includes the health projection calculating the probability of getting diabetes in the future considering simple metrics such as waist to hip ratio. To the best of our knowledge, any app in the market provides this information. The app provides to the user the option to be aware of the future considering it as something that is not so far.

The application was tested by 12 users who evaluated the usability of the app, particularly the satisfaction. The study applied the worldwide used SUS test. The results reveled that the app was somewhere between good and excellent, it scored 80.62 on average. It is important to note that the questions regard to the learnability got highest scores. It means that is easy to learn how to use the app.

The users suggested to include a view where they can personalize the avatar. Also, they suggested to include a help option in case that the user does not know how to interact in the app. In general, they were satisfied with the app.

This paper is the base of several lines of future work:

- Analyze the efficiency and effectiveness of the app.
- Conduct an acceptance analysis, and a longitudinal study analyzing if the mobile application is reducing the risk of getting diabetes in the future.
- The generation of a dataset that can correlate the risk of getting diabetes and behavioral patterns.

This mobile application is an example of how technology can help prevent Mexican children and young people from getting diabetes.

6. ACKNOWLEDGEMENT

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