Adapting a Classic Platform Video Game to the Carbohydrate Counting Method for Insulin-Dependent Diabetics*

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ABSTRACT

Digital games designed for children and adolescents in the Diabetics Education (DE) context aim at positively influencing diabetics' behavior or teaching DE knowledge and skills. Previous work has not considered playful learning of difficult content, such as the Carbohydrate Counting Method, which involves counting the number of carbohydrate grams in a meal and matching that to the appropriate dose of insulin in order to manage the blood glucose levels. Sugar Mario was designed to have a familiar and simple gameplay based on classical platform video games, such as Super Mario, Donkey Kong, and other similar games. The carbohydrate counting method was seamlessly integrated in the gameplay in order to provide an educating, entertaining, and compelling experience to diabetics of all ages, even family members and friends. Our implementation suggests that a classic and engaging platform video game is malleable to the infusion of serious content without significant dilution of the gameplay. Notably, a diabetic person has designed Sugar Mario and the source code has been shared online for inspection and contribution by interested parties.

[https://github.com/ionio-seriousgames/Sugar_Mario].

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.CCS CONCEPTS

• **Applied computing** → Computer-assisted instruction

KEYWORDS

Diabetes Education, Health Games, Serious Game, Carbohydrate Counting Method.

1 INTRODUCTION

Hundreds of millions of people live with diabetes, and thus, diabetes management is critical in order to reduce complications [12]. Therefore, Diabetes Education (DE) seems a matter of great importance. Digital games have already successfully employed as alternative means of teaching various aspects of DE, such as the appropriate diet, the exercise, the self-monitored blood glucose level, and the medication adherence using situation problem-solving methods and techniques [5]. Most digital games deal with the general behavior of diabetic patients and their aim is to change potential risk behaviors while some others teach various issues of DE, such as the carbohydrate counting method which is useful for calculating the appropriate insulin injection dose for each potential meal [9]. The educational content integration within the game world seems very critical for a playful and effective game. More research could be conducted in order to design entertaining health games that are also effective and appealing to a broad audience.

This study aims to present the design and development of a digital game, which addresses certain curriculum of DE. In particular, the carbohydrate counting method for calculating the appropriate insulin injection dose for diabetic patients is being taught. Familiar game mechanics will be used in order to integrate the educational content within the game world, aiming at successfully transferring the appropriate knowledge and skills to

the players. We use a popular game-play paradigm in order to enhance the entertaining parameter of the game and make it more appealing to patients of all ages. As a result, we expect that players will practice on this important theory of DE in a pleasant and educating way.

2   RELATED WORK

2.1   Diabetics Education

According to the American Diabetes Association (2014), diabetes is a group of metabolic diseases characterized by hyperglycemia due to the partial or total lack of insulin, a hormone that is responsible for the blood glucose level. The blood glucose level in healthy people is less than 100 mg / dl when fasting and less than 135 mg / dl one hour after a meal. Lack of insulin in diabetics is due to different reasons depending on the type of diabetes. Especially for diabetes mellitus type 1, the insulin therapy is necessary for patients' health. Diabetics must control their blood glucose level as chronic hyperglycemia of diabetes could cause severe damage to different organs, such as the eyes, kidneys, nerves, heart, and blood vessels [20][6]. Moreover, blood glucose level lower than 80 is also a very dangerous condition, called hypoglycemia. Diabetic ketoacidosis (DKA) and severe hypoglycemia are the major life-threatening complications of type 1 diabetes in children [16]. Therefore, diabetics come to pay attention to their diet and physical exercise, and they must often monitor their blood glucose levels. Carbohydrate counting, or "carb counting," is one of many meal-planning options for managing blood glucose levels. Carb counting involves counting the number of carbohydrate grams in a meal and matching that to the appropriate dose of insulin. The Carb counting is a useful method of dietary management for glycemic control [12] and gives flexibility for choosing a meal. DE seems to be necessary for supporting diabetics on their effort to manage their treatment.

2.2   Health Games for Diabetics Education

Zyda (2005) defines the game as a physical or intellectual competition governed by rules that aim to entertain or reward the participants. This definition does not differ from that for digital game, which defines it as an intellectual contest, with the help of a computer, with specific rules and for entertainment or a prize. According to Prensky (2001), a digital game consists of rules, goals and objectives, output and feedback, conflict / competition / challenge / confrontation, interaction, and representation or script. In particular, the rules of a game set limits and force the player to use specific paths while the goals and objectives engage players within the game world. Moreover, the outcome and feedback inform players about their progress and whether their strategy to play the game is right or not. Conflict, competition, challenge and confrontation are features that contribute to the immersion of the player by causing feelings of pleasure. Finally, the interaction concerns the player's interaction with the game and the relationship of the player with other players.

Since the 1980s, there have been publications on the use of video games for therapeutic purposes. According to Kato (2010), health games could have indirect clinical implication as they can improve surgical skills of doctors and clinical skills related to patient care. Additionally, health games can help in improving patient participation in important diagnostic tasks, enhance patient knowledge about their disease, and increase patient adherence to aversive yet lifesaving treatments. There are various health games which concern diseases, such as the asthma [7], psychosomatic diseases [18], or diabetes. Especially, diabetic games appeared to be helpful tools for educating patients, whereas gamification and virtual environments increase extrinsic motivation and provide positive reinforcement [19]. For example, the popular game Tower Defense which belongs to the genre of real-time strategy games, addresses diabetes related numeracy [2]. Another diabetic game is called Packy & Marlon and it has been published from 1994. This game is an action-adventure side-scrolling Nintendo console game for children and adolescents with type 1 diabetes [14]. Diabetic Mario is a more recent developed game and it is based on the fundamental principles of role play games. In this game, the main character, Mario, has type I diabetes and he must make the appropriate food choices; he also must regular exercise himself, and inject suitable amounts of insulin when needed in order to end the game [3]. Despite the various games which have been designed and developed, aiming at a positive influence on diabetic patients' behavior or at enhancing specific knowledge and skills, the design of a health game for diabetes, which could be used from all in order to learn difficult knowledge and skills with a pleasant and effective way, could be a useful tool. For this reason, we designed Sugar Mario which is based on a familiar and simple gameplay which integrates difficult DE curriculum, such as the carbohydrate counting method. As a result, it could be used not only from children and adolescents but also from their family and friends and even older patients. Moreover, players could discuss their results with their friends, family, other patients, and maybe medical stuff. This feedback could support them to their effort to learn difficult and important content and give them a picture in order to assess their ability to control their blood glucose levels effectively.

3   GAME DESIGN

The game's design was based on existing commercial platform games, e.g. Super Mario and Donkey Kong. In such games, the central character gathers objects, avoids obstacles, and faces enemies. These familiar and popular gameplay mechanics were employed in order to offer an entertaining experience to the player [4]. Chorianopoulos and Giannakos (2015) argue that serious games, such as the mathematics, support players in order to recognize their mistake and identify what they could have done differently. At the same way, Sugar Mario design supports players through messages in order to understand their mistakes and apply the appropriate corrections.   (constructive trial and error principle). Therefore, this game's design was based on two main principles, the use of familiar game mechanics and the constructive trial and error.

3.1 Aim of the Game

The game aims to teach the carbohydrate counting method for insulin-dependent diabetic patients. Blood glucose level control needs from patients to be aware about the influence of various foods on their blood glucose level. This knowledge is necessary for calculating the appropriate insulin injection dose. Bread for example increases the glucose level differently than the meat, the fish, the poultry, the starchy vegetables or the pasta. For the needs of the game design, the numbering was determined based on the carbohydrate counting method: one carbohydrate equivalent corresponds to 30 grams of the bread group, 120 grams of the meat group, 150 grams of the fish group and 40 grams of poultry, starchy vegetables and pasta [10].

3.2 Game Content

The game is based on the action of the main character (player), interacting with a number of lollipops that are the player's opponents who move and can neutralize the player and with different types of foods that affect the blood glucose level according to the certain type: insulin injections that reduce the blood glucose level, platforms that consist of many small orthogonal or square floors suspended in the atmosphere, the keys that open the doors, and the doors leading the player to the next track.

3.3 Gameplay

The game consists of three levels. In each level, the player (main character) must collect a key in order to advance to the next level. This means that he must go through the entire track, keeping his glucose level between 80-180 mg / dl by making the right decisions for food choices and insulin injections. If the blood glucose level is below 80 or over 180, a warning message appears to the player, and the key disappears. Therefore, balancing the blood glucose level is the player's main priority.

3.4 Content Integration

On all levels, there are multiple food choices that represent most food groups encountered daily. Insulin is placed at specific points so that the player can collect them on his way to find the key, but they are not necessary to complete the level. On the contrary the player has the choice to decide when and how much insulin is needed in order to balance their glucose level.

Lollipops take the opponent's role in the game and if the player touches them then he must re-run the same level but without having to play the game from the beginning.

If the glucose reaches a level that is less than 80, the player can apply the appropriate correction to the blood glucose level; however, if the level becomes zero, the player loses the game. The reason for this game-design choice is to force the player understand how severe hypoglycemia is and that it can be fatal. The same thing applies to the case that the glucose level is too high. By this process, the player learns to control his blood glucose level. The game is designed in such a way that it does not punish the player over certain occasions (zero glucose level, contact with bad lollipops) because the goal is for the player to experiment, trying to balance the insulin injections with the food choices. For example, they can see the different influence of meat or bread on the glucose level. Such calculations need to be made by diabetics on everyday life and in that way this practice could prove useful due to its importance for their health balance. Although all the nutritional groups have not been added to the game, we tried to include the most important ones as well as most foods that more affect the blood glucose levels. Nevertheless, the code design allows with minor changes more meals from all food groups to be included.

Finally, user progress is recorded, and the player is guided through several text messages during gameplay. In the top left, the player's score is the price of his / her blood glucose level while in the lower part of the stage is displayed the blood glucose values he must have during the game. As mentioned previously when the player's glucose level decreases or rises beyond the allowed values, warning messages appear and disappear as soon as the player makes the desired correction.

3.5 Introductory scene - Game story

The introductory video teaches players what they need to know about the carbohydrate counting method and how to play the game. John the Cat explains to George, who is the game's main character, the Carbohydrate Counting Method and subsequently guides him on the game functions and gameplay. After the introductory video, the player enters the gaming environment.
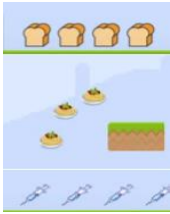
4 RESULTS

4.1 Game Development Tools

The video game was developed using the Javascript Programming Language and the Phaser Video Game Development Library, which features many of the features of that traditional video game development libraries employ, such as the provision of ready-made functions / methods for moving objects on the scene, collision detection, simulation of physics laws etc. For the development of the video game, the node.js development environment was used in order for Javascript to run on servers and not on the web browser allowing the creation of an application that does not depend on its web browser efficiency and exploit the capabilities of a high-level language. Finally, the "Brackets" development tool was used write the code. This tool was chosen primarily because it has built-in the node.js development environment that supports running the application and it has a development platform that automates processes in code writing, such as automatically completing commands. The game is a classic HTML application based on the use of the CSS language for the player's display and JavaScript, which is the language in which the main source code of the game is written.
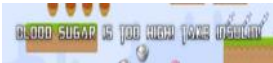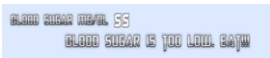
4.2 Game Description

The content integration within the game world was based on the mechanics of classical platform video games such as the Super Mario and the Donkey Kong. Such games utilize characters that act as enemies and must be avoided and objects that must be collected by the player in order to complete the game. This relationship between clearly recognizable objects is employed for integration of the educational content. Moreover, the Score feature is used in order to inform the player about his blood glucose level depending on his choices for food and insulin injection (See Table 1).

Table 1: Educational Content Integration

Game Element	Educational Purpose	Example
Enemies to be avoided / destroyed by the player	Lollipops must be avoided as a no-good meal choice	
Objects to be collected by the player in order to collect the key for the next level	The player needs to choose his meals, controlling at the same time his blood glucose level with the appropriate insulin shots.	
Score is placed on the top left side of the screen	Score is used to inform the player about the current blood glucose level	

The player is also educated using game-messages and advice in order to make the appropriate decisions (See **Table 2**).

Table 2: Game Constructive Messages

Message	Example
Appropriate range of blood glucose level	
Payer is informed that he needs insulin injection	
Player is informed that he needs a	

meal

There are three levels with increasing difficulty. The player needs to collect a key which appears on the right top side of the screen in order to open a door which will take him to the next level. To get the key, he must also collect several food items, keeping at the same time his blood glucose level within the appropriate range (See **Figure 1).**

The insulin injections are placed in a way that the player can go only if he wishes so. This choice is made in order to provide the choice to decide if an injection is needed or not. Finally, the player loses the game only if his blood sugar level becomes 0 as this is a critical for his life-support, while he is free to experiment with different groups of food and insulin injections in order to learn.
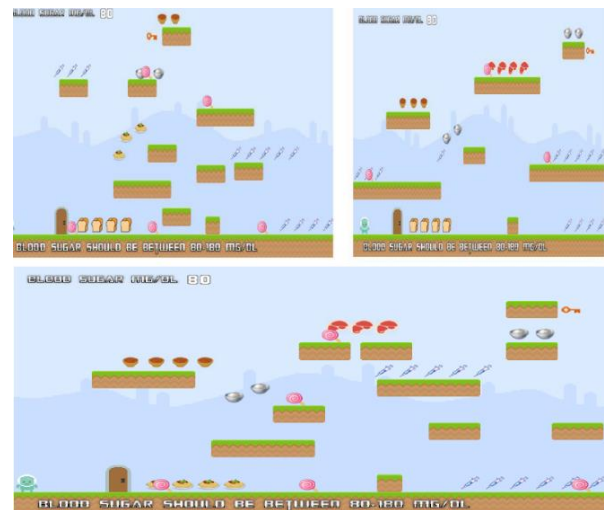

Figure 1: The Levels of the Game and the Game Track

An introductory video provides the player with the necessary information about the carbohydrate counting method for insulin-dependent diabetic patients and how the game can help learning through the completion of all game levels (See **Table 3**).

Table 3: Introductory Scene and Purpose of the Game

Carbohydrate Counting Method	Game Instructions

5 DISCUSSION

The goal of this study was to design and develop a health game aiming at teaching useful curricular of DE, such as the Carbohydrate Counting Method for insulin-dependent diabetic patients. This is an important curriculum, which is needed in order to calculate the appropriate insulin injection dose for a specific meal. We integrated the educational content within familiar game mechanics, giving players the opportunity to learn by playing and not by using a simulator tool or reading a book. Moreover, Sugar Mario was designed in order to promote players' exploration and experimentation according to the constructionist perspective [8]. However, the integration of this demanding curriculum in a simplified way within the video game, having a strong recreational element was a challenging process. The structure of the video game was based on classical platform video games such as Super Mario, Donkey Kong and other similar games found on android and iOS operating systems. Therefore, the player is jumping obstacles, avoiding bad guys and collecting objects. The game contents were used with an educational purpose due to the serious game nature. The educational content that was incorporated in the digital game was consisted of "*baddies*" (meals to avoid, e.g. lollipops), objects (foods and insulin shots), and the player's score (the amount of the blood glucose level). Additionally, the player is supported on his effort with messages and a constructive trial and error process in order to better understand the game's content. There is also a gradual increase in the difficulty of the digital game from level to level (more enemies, more difficult obstacles). Successful ending of each track advances player to the next level.

This study implications concern the enrichment of DE with an alternative-learning medium, which could be used from all ages in a variety of ways. Patients could practice themselves in order to improve their skills related to blood glucose level control and / or share their results with others in order to have constructive feedback. According to Egenfeldt - Nielsen (2017), a new generation of digital games relies on constructivist learning theories and a deeper understanding of the potential and limitations of computer games in educational praxis. Therefore, digital games are just another tool for the teacher / doctor / nurse which can support learning but have clear limitations which require the use of more methods in order to motivate and enhance learning. Such methods could be the feedback, the guidance, and the support from specialists, peers, and family. This easy-to-use application has been developed and can be run by many electronic devices (computers, tabs, smart mobiles), it is easily modifiable and extensible.

There are, of course, many possibilities to extend this application. For example, we could include more food groups, such as vegetables and fruits. The digital game could also be modified to educate patients about other aspects of diabetes (educating patients to avoid smoking, encouraging physical activity) or include more levels in a variety of ways and maybe have a greater variety of opponents. However, the source code is structured in such a way that it allows the developer to modify it without having high programming capabilities. Moreover, the application could have a larger musical investment of one as sound is a catalyst for increasing the user's education on the subject.

Finally, Sugar Mario has been designed and developed in order to be used in DE. Therefore, we are planning to evaluate this game in a variety of ways in order to improve it, to suggest ways to be used in the context of DE, and to propose a design framework for health games for learning purposes.

6 CONCLUSIONS

Serious games are considered useful tools aiming at changing potential risk behaviors or / and enhancing DE content. However, the content integration within the game world seems very critical for a playful game which will transfer knowledge and skills to patients of all ages and even to friends and family members. We have designed and developed a digital game for diabetes which addresses certain curriculum of DE, such as the Carbohydrate Counting Method for choosing meals and calculating the appropriate insulin injection dose for diabetic patients. Familiar game mechanics were used in order to integrate the educational content within the game world, aiming at successfully transferring the appropriate knowledge and skills to the players. The popular game-play paradigm was used in order to enhance the entertaining parameter of the game and make it more appealing to patients of all ages. Moreover, a constructive trial and error process through messages fosters the learning of difficult content. As a result, we expect that players will practice on this important theory of DE, in a pleasant and effective way. Our implementation suggests that a classic and engaging platform video game is malleable to the infusion of serious content without significant dilution of the gameplay.

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