

Investigating the potential of Interactive Media to Encourage Engagement with Type 1 Diabetes Management

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Abstract

The effective management of type 1 diabetes is very challenging for a number of people. Improving the management skills of those suffering with the disease is even more so due to the sheer number of Type 1 diabetes sufferers. We believe that a serious video game which targets diabetes education has the potential to significantly improve the management of Type 1 Diabetes. In light of this we have developed a series of game mechanics which are able to represent Type 1 Diabetes management in a video game. We have developed a prototype video game to demonstrate the effectiveness of these game mechanics, and we have identified potential areas of future development in this field.

Keywords: Video Game; Serious Video Game; Diabetes; Medical Video Games

1 Introduction

Diabetes is a serious medical condition with far reaching consequences on the lives of those living with the disease and their friends and family. Effective management of diabetes requires the management of many interrelating systems such as diet management, exercise management and medication management (Hanas 2007). Failure to effectively manage the symptoms of diabetes can lead to serious health consequences: Hyperglycemic episodes can lead to blindness and organ failure, while hypoglycemic episodes can lead to fainting, mood swings, anxiety and dizziness. Effective management of diabetes symptoms is challenging and an area of interest to many. Better symptom management has been shown to reduce the long term health impact of diabetes on patients lives (Norris, Lau, Smith, Schmid & Engelgau 2002)(Norris, Engelgau & Narayan 2001) (Deakin, McShane, Cade & Williams 2005), as well as reducing the financial burden the disease places upon New Zealand as a whole (Wagner, Sandhu, Newton, McCulloch, Ramsey & Grothaus 2001). Additionally, it is known that tailored healthcare which accurately represents and deals with the issues facing individuals and their circumstances is significantly more effective at improving healthcare outcomes when compared to non-tailored solutions (Mensing & Norris 2003) (Rickheim, Weaver, Flader & Kendall 2002)

(Hiss 1996). Unfortunately, Diabetes is very common and thus the large number of sufferers to whom assistance must be provided directly impacts the viability of many proposed diabetes treatment plans. One solution which remains unhindered by the volume of diabetes patients is video games. A video game can be replicated many times and thus is suitable for distribution amongst large numbers of people. Video games can also be designed in such a way that they are able to dynamically reconstruct content in response to a number of user specified properties, thus allowing the gameplay experience to change to represent the circumstances and specific issues facing a player (Booth 2009). This report details the construction of a prototype video game "proof of concept" which demonstrates the feasibility of creating a serious video game to teach people about effective diabetes management. The report also outlines a set of game mechanics which can be used as an effective representation of Type 1 Diabetes in a video game. The video game proof of concept was produced using the Unity 3D engine.

2 Serious Video Games, Educational Games and Gamification

Traditionally, a video game consists of a rule based system with which the user interacts for their own enjoyment. These rules which make up the core video game interactions are referred to as game mechanics. The focus of the video game is entirely placed upon the user's enjoyment, which usually is achieved by overcoming challenges, although more recently some video games have achieved this by allowing the player some form of self expression, such as the extremely popular video game Minecraft, in which players build their own worlds, buildings, mining systems and industries.

Educational video games have existed since the advent of video games themselves. We use the term "Educational Game" here to refer to a specific style of video game common to early educational video games and children's learning games. We define the term as a game where the rule based system which forms the core of the video game relates to knowledge. For example, there is geographic knowledge in the core of the popular *Where in the world is Carmen San Deigo?* series, or there is skill based knowledge, such as algebra or mathematical skills, in other children's games. Users must complete challenges using these skills, thus the game reinforces gained knowledge and encourages education. This form of video game is very common in the educational space (sometimes referred to as an edutainment game) and is distinct from other genres of video game. When dealing with diabetes, it is very challenging to accurately express the informa-

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tion required for a patient to improve their symptoms management in this traditional format. Medication and treatment information cannot be reduced to a series of truisms and maintain its accuracy.

A serious video game is one that is designed with a primary purpose other than the players enjoyment, and is most commonly found as a simulation game. It is sometimes very difficult to distinguish between a serious video game and a normal video game. Consider the example of SimCity, a popular city simulation game released by EA in early 2013. SimCity can be clearly viewed as a video game yet can potentially be employed as an urban planning tool. Other examples of game which appear to be both serious and not include the popular video game Arma 2 which is used by the United States Military for combat training and simulation. The serious game Fold-it is possibly the most well known serious game - it allows users to experiment with protein folding in a puzzle solving environment. Players are able to determine the folding pattern of a key protein involved in the replication of the HIV virus, which is included in the video game as a solvable puzzle. Foldit players sometimes outperform state of the art computational algorithms (Khatib, Cooper, Tyka, Xu, Makedon, Popović, Baker & Players 2011). Serious games feature far more complex game mechanics than an educational game - players are expected to learn to understand the system being modelled by the video game through experimentation.

3 Related Works

This area is not an unexplored one; a large number of educational video game have been developed, including a significant number targeting diabetes education. Projects such as the "Escape from Diab" aim to encourage those who play video games to exercise more and monitor their food consumption more closely, while some other research groups are attempting to introduce gamification into diabetes medication systems (Thompson, Baranowski, Buday, Baranowski, Thompson, Jago & Griffith 2010).

In the videogame the "Escape from Diab", the focus of the project is to encourage consumption of low energy density foodgroups such as fruit and vegetables and to encourage physical activity amongst obese youth. The project attempts to change ingrained behaviours of youth through a process of gradual change in mediators such as skill levels, knowledge and self esteem, which in turn is expected to result in a change in behaviour. The Escape from Diab experiments with a number of different behavioural theories such as social-cognitive theory, self-determination and the Elaboration Likelihood model. These models were used to guide game development decisions and were incorporated where possible with game development guidelines to develop and entertaining and engaging game (Thompson et al. 2010).

Similar projects have been undertaken in the past, such as the historic SNES video game "Captain Novolin" in which the titular character is a superhero who also suffers from type 1 diabetes (Frieberger n.d.). The player must manage the glucose levels of the player character, Captain Novolin and fight enemies which appear visually similar to fast food. The game was sponsored by the Novo Nordisk company - a pharmaceutical group which distribute the Novolin brand of insulin. The effectiveness of the Captian Novolin game at improving diabetes management has not been measured, however investigations into the impact of playing the video game at

the time showed that participants felt more comfortable discussing their diabetes with friends and family (DeShazo, Harris & Pratt 2010).

Several projects have taken a different approach and attempted to use gamification in conjunction with blood glucose measurement tools. Didget is one such system (Klingensmith, Aisenberg, Kaufman, Halvorson, Cruz, Riordan, Varma, Pardo, Viggiani, Wallace et al. 2011). Consisting of a blood glucose monitor which functions as an attachment to the popular Nintendo DS handheld gaming platform. The Didget device comes with a selection of minigames which require that the player to take their own blood glucose level as a gameplay element. Additional minigames can be unlocked as a reward for frequently using their glucose monitoring device. An evaluation study carried out in 2011 found that participants who were using the Didget system found it to be motivating and helpful for building good blood monitoring habits (Klingensmith et al. 2011).

Left 4 Dead 2 is not an educational video game. It does, however, include a "Director" - an artificial intelligence capable of redesigning the game world to present new and interesting challenges to the player (Booth 2009). This can take the form of moving item pickups and ammo, to altering the weapons available to the player. Most importantly, it can change the enemies the player must fight to create dramatic tension at key moments and ensure the player is constantly engaged with the game. Such a system could easily be extended to dynamically determine the challenges a player faces based upon their own medical history, allowing a game to be tailored automatically to the player's particular medical requirements.

4 Advantages of Video Games Over Other Media

Video games as a form of interactive medium have several significant advantages over other forms of diabetes education. One advantage which can be easily seen and potentially will have the most impact is the easy replication of the product. Tens of thousands of diabetes sufferers can be provided with a copy of a video game for no additional cost. In addition to this, it is known to researchers that providing customized and tailored assistance to patients can significantly improve the quality of their engagement with support programs. Video games can easily be configured to support this customization through dynamic content placement and visual adjustments. For example, a patient with an allergy to seafood could receive a video game with a predetermined configuration which alters the spawn points of food to have less seafood, or to include specific game missions which deal with managing allergies in the contexts of diabetes. This form of dynamic content and configuration is not available in any other medium. Some other ways in which video games are an ideal medium to use when educating patients about Type 1 diabetes relate to the motivation patients feel to play a video game. Video games are incredibly enjoyable and can be made to appeal to a wide range of people, and provide constant positive feedback for patients when they play the video game. It is hoped that this motivation can improve the users engagement with the video game.

5 Feasibility of Video Games as Educational Tools

Video games have a long history as educational tools, dating back to early video games such as *Where in the world is Carmen San Deigo?*. Their effectiveness as educational tools has been established by a number of studies (Rosas, Nussbaum, Cumsille, Marianov, Correa, Flores, Grau, Lagos, López, López et al. 2003) (Brown, Lieberman, Gemeny, Fan, Wilson & Pasta 1997) (Dondlinger 2007). Furthermore, the use of video games for diabetes education has been explored and found to be an effective tool for education about symptom management (DeShazo et al. 2010). We believe additional effectiveness remains untapped and that a more cohesive integration of the educational components of the game and the gameplay elements, similar to the integration of orbital mechanics in Kerbal Space Program and boolean logic in Minecrafts redstone system, will be a more effective method for imparting knowledge to the player. Video games are certainly not a silver bullet and have been unable to influence children in some areas (DeShazo et al. 2010) we believe that video games are a worthwhile and viable education tool. Additionally, commercial video games have an incredible ability to motivate people to play them (Kirriemuir 2002) which provides an extremely effective method for indirectly educating people about in game concepts (Egenfeldt-Nielsen 2006).

6 Video Game Design

This project draws inspiration from the video game Bioshock, in which users are required to manage a resource called EVE. EVE can be used to perform special powers, and is restored by consuming items found in the environment. In order to complete the challenges presented to players in Bioshock, players must effectively manage their EVE levels. By replacing the resource management techniques used to manage EVE with those required to manage blood glucose levels it is hoped that players will learn to use these techniques with a similar level of effectiveness, and then be able to transfer these skills and knowledge to managing real world diabetes symptoms.

Additionally, the player character will experience hyperglycemic and hypoglycemic episodes should their glucose resource exceed or drop below certain thresholds. When this happens, the player character will provide certain cues to the player which indicate that an episode is about to occur. The cues provided to the player will match symptoms which indicate that a hypo/hyperglycemic episode may occur, such as tiredness and lethargy. The player can always see their glucose level relative to the high or low thresholds in the top left of the screen, but it is hoped that by presenting these cues to the player they will begin to associate these feelings and scenarios with the risk of hypo/hyperglycemic episodes and be able to act accordingly.

This style of education is different from that explored by other, similar research and commercial projects. The goal of this project is to provide Type 1 diabetes sufferers with a risk free means to experiment with the management of their symptoms in the hope that the knowledge gained through this experimentation can be adapted to real world scenarios. We will achieve this through two mechanisms:

1. Providing a way of experimentation where players are free to consume different forms of food in different quantities, self medicate with insulin

and partake in physical activity. It is hoped that players will gain an understanding of how food, insulin and exercise interact to effect blood glucose levels through this unstructured interaction system.

2. Provide a series of scenarios which relate to real world scenarios in which diabetes management may be particularly challenging. It is hoped that by providing these scenarios we will be able to expose players to challenging scenarios and thus equip them to deal with these scenarios in the real world.

As opposed to the explicit inclusion of diabetes content in the projects discussed in the related work section above, this project has a more implicit inclusion of diabetes related content. The goals of the game designers are not readily apparent to the user. We believe that this will encourage more experimentation from users. Additionally, we believe that by integrating blood glucose management as a game mechanic players will be forced to master the skill to progress through the game. This game has been targeted at young adults between 18 and 25 due to the high uptake of video games within that age sector.

7 Blood Glucose Levels as a Resource System

A desired outcome for this video game was to provide players with some experience managing the glucose levels of a character in the hope that these management skills will be transferable to real world scenarios. For this knowledge transfer to be feasible, there must be a correlation between game actions and real world actions. In practice, this means that any and all in-game actions a player can take to manage their blood glucose levels must convey all important information relating to the equivalent real world action. Additionally, the relative effectiveness of different actions must be accurately represented in the video game to prevent one particular action or set of actions becoming a dominant strategy. The presence of a dominant strategy will mean that players do not experiment with all possible actions but instead reuse the same sequence of actions - an undesirable outcome. This process of ensuring the viability of different techniques in video games is colloquially known as "balancing". With this in mind, we identified a number of actions which form the core of diabetes management techniques based upon current research and medical practices. These actions were then simplified to produce elements which can be easily understood and then introduced into a video game environment. Through several iterations of playtesting, a roughly balanced set of actions were produced. These include physical activity - represented as a slight drain on the players glucose levels and by a large drain for using special powers - food consumption, which increases the characters glucose levels gradually, and insulin consumption, which can reduce the characters glucose levels.

8 Diabetes Game Mechanics

Based upon user evaluations, current medical practice for diabetes treatment and information about the disease itself (Hanas 2007) we have identified the following set of game mechanics which we believe can be used to form a model of diabetes in a video game.

- A resource representing blood glucose levels

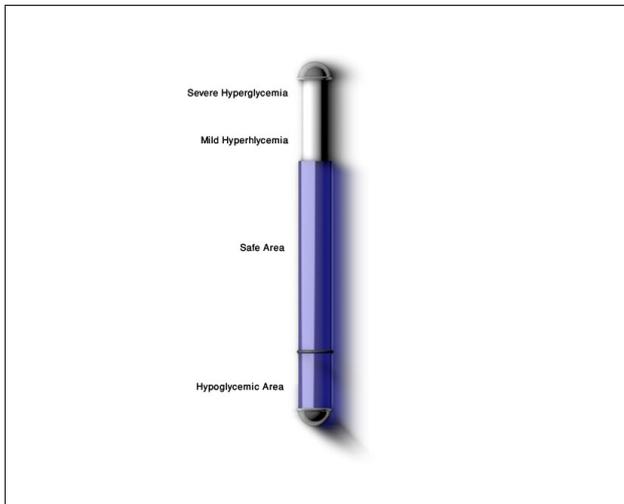


Figure 1: Concept Art for the Glucose Resource Bar

- This resource should be increased by consuming food
 - This resource should be decreased by consuming insulin
 - This resource should be decreased by performing physical activity.
- A large variety of foods differing in quantity, glycaemic index and carbohydrate content.
 - A number of scenarios which challenge the players mastery of this resource system.

Furthermore, we propose that the inclusion of these game mechanics will result in players being more informed about, and having a greater understanding of, their own diabetes symptoms based upon the response to similar systems in other commercial video games.

9 Prototype Development

In order to facilitate rapid development, the video game prototype was produced using a free game engine called Unity 3D. Unity 3D is highly popular and well supported toolkit, and it is hoped that by using an existing engine that later development will be made easier due to the popularity of Unity 3D and the lack of support requirements. The game currently supports a number of features, the most significant of which are listed below.

- The ability of the player and enemies to use and fire weapons. Weapons damage their targets which then die.
- The ability to consume food / other health items to restore health and glucose levels.
- The ability to consume insulin to reduce the players current glucose levels.
- The ability to walk, run, jump, and use special powers which consume glucose. This is the main way in which hypoglycemic episodes are induced.
- Automated pathfinding using an implementation of A*. This is used to assist enemy navigation and movement.
- Simulated Hypo/Hyperglycemic episodes.

- A HUD showing glucose levels and health.

The video game contains a simple level suitable for demonstrating the effectiveness of the game mechanics being employed and as such is populated predominantly with temporary or procedurally generated content. Levels were initially designed with much denser content, however this distracted playtesters from the gameplay mechanics.

A prototype was produced featuring a small amount of gameplay and was used to test users responses to the video game and the mechanics representing the diabetes game mechanics.

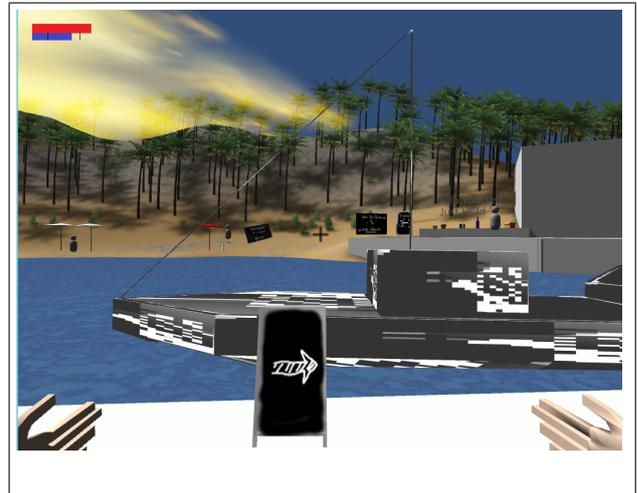


Figure 2: A screenshot of the games introduction sequence.



Figure 3: A screenshot of a combat sequence.

10 Prototype Evaluation

During the development of the prototype, a small sample of playtesters were used to examine the viability of the diabetes game mechanics. This viability related to how easy users found it to understand the diabetes game mechanics, how flexible the diabetes game mechanics were, and how much of an impact the diabetes game mechanics has on the gameplay of the prototype. A playtesting session usually lasted for 5-10 minutes and consisted of a user playing the



Figure 4: A screenshot showing the visual representation of a hypoglycemic episode.



Figure 5: A screenshot showing some of the food available in the proof of concept.

video game while being observed by a developer. After a playtesting session, the video game would be adjusted based upon the performance of the playtester and the playtest repeated. Playtesters were changed frequently to ensure that a wide variety of viewpoints were examined. A total of 12 playtesters were used, all aged between 19 and 25 years of age. The purpose of this play testing is two fold validation of the game as a playable, enjoyable video game is sought and this is assessed primarily through observation of the playtesters to determine how they interact with the game and thus identify any issues with game mechanics, level design or control schemes. More importantly, some indication of how effective the game is at conveying concepts relating to diabetes management is needed. In order to determine the impacts that the game had on participants knowledge levels, participants were asked a series of questions relating to diabetes management, specifically focusing on suitable meal composition for diabetics, before and after playing the game. After playing the game, participants were able to rank foods based on their carbohydrate content (as represented in the game) and were able to construct meals more effectively.

11 Evaluation of Health Impacts

The purpose of this application is to develop a greater level of understanding in players of how glucose levels are impacted in scenarios represented in the game. It is thus critical to determine how players respond to the application and as such a formal evaluation of the applications impact on diabetes management should be undertaken. An effective evaluation would require that a selection of participant with type 1 diabetes of varying genders and ages play the video game over a small period of time. The abilities of the participants to manage their diabetes symptoms should be measured before and after using the video game. Measurements should relate to the content portrayed in the video game, specifically blood glucose management, calorie counting, portion and meal sizing and exercise levels. These can be measured by investigate the levels of glycated haemoglobin in test participants, as well as surveys and interviews.

12 Future Work

There exists a clear continuation of this work - the development of a full scale video game production suitable for distribution and testing. There are a number of ways this video game could be developed. The prevalence of mobile devices has resulted in the development of a large mobile gaming market. This market has limited technical capabilities and is not swayed by impressive graphical effects, resulting in a resurgence of 2D games. It is quite possible that a 2D game aimed at mobile devices would be a viable and effective medium for developing a diabetes education video game. However, mobile games require short interaction periods and require create control schemes due to the lack of hardware controls, potentially complicating development. Conversely, it is possible to develop a large scale, high cost and production quality video game aimed at personal computing and console "gamers". This market segment is easier in some ways to develop for as the control schemes are far more standardized and players have longer interaction sessions with the video game, potentially allowing for a greater impact on participants in terms of behavior modification. There is also a possibility of developing a modification for an existing video game. Several video games currently on the market include extensive modification support and tools which would significantly reduce the costs of developing a modification. The cost of developing a modification to an existing game is significantly lower than that of creating a game from scratch, however it requires that users who wish to play the modified game must purchase a copy of the game, limiting distribution. Thus, games which are already commonplace are an ideal target for this practice. Games such as Minecraft and The Elder Scrolls: Skyrim are easy to modify and highly popular, making them potential candidates for modification. A modification to an existing game would require far less time and resources to develop than a bespoke game, in particular less time requirements for developing game content. Modifications to make these games educational already exist (Short 2012) and have been shown to be a viable tool for creating educational games compared to the development of an entire game from scratch.

The development of a modification to either Minecraft or The Elder Scrolls: Oblivion or The Elder Scrolls: Skyrim is recommended as this would allow for a working product to be obtained with a much lower cost than developing a whole game. For the



Figure 6: A screenshot of a working elevator constructed in Minecraft using "Redstone" - a form of boolean logic gates (RSTmastery 2012)

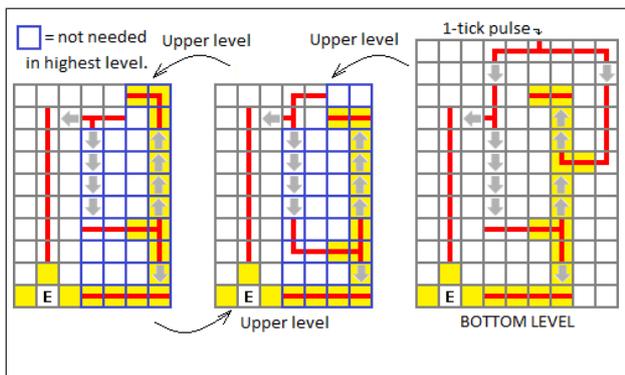


Figure 7: The schematic Diagrams developed by users to explain how to create another minecraft elevator (Minecraft 2013)

purposes of evaluating the effectiveness of the game mechanics identified above, the issues incurred by developing a modification and not a stand alone product are easily overcome, making this practice a viable area for future research into educational video games.

13 Conclusion

We have identified a need to improve symptom management of Type 1 Diabetes and shown that video games can be an effective tool for improving symptom management. We have further identified a set of game mechanics which we believe can serve as a viable model of diabetes in a video game and produced a proof of concept video game to demonstrate these game mechanics. Furthermore, we have identified the development of a modification for the popular video games Minecraft or The Elder Scrolls: Skyrim as potential areas of future research.

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