Power Defense: A Video Game for Improving Diabetes Numeracy

Abstract
Adolescents with T1D often have poor control of their disease. With the knowledge that the current generation appreciates and learns more from interactive approaches to teaching, we have developed Power Defense, a highly interactive video game aimed at improving one particular skill associated with managing diabetes – numeracy. Diabetes-related numeracy encompasses the ability to understand and interpret results and then appropriately apply the results to the management of diabetes. Power Defense employs the principals of experiential learning and includes both implicit and explicit methods for teaching the player the necessary diabetes numeracy skills.

Author Keywords
Serious games; video game-based learning; adolescent diabetes; diabetes numeracy; type 1 diabetes.

ACM Classification Keywords

General Terms
Design, Human Factors.
Introduction

Type 1 diabetes (T1D) is a chronic medical condition that is usually diagnosed in childhood and it has no cure. Children and teens with T1D need to engage in numerous tasks on a daily basis to keep their blood sugars well controlled in order to prevent serious short- and long-term complications associated with high blood sugar levels including blindness, heart disease, and kidney problems. They need to measure their blood sugar levels at least four times daily and require insulin injections each time they eat. Diabetes-related numeracy is the ability to understand and interpret results and then appropriately apply the results to the management of diabetes.

In adult studies, low numeracy skills has been shown to be an independent factor in predicting poor control of diabetes and worse long term outcomes. The problems are further compounded with children and adolescents who typically resist any behavioral restrictions leading to difficulties in diabetes self-management [1]. Furthermore, management of diabetes and diabetes numeracy in particular, is typically conveyed to children and adolescents using "traditional teaching methods" (e.g., pamphlets, books, etc.). However, traditional teaching-and-learning environments are often quoted by children and adolescents (i.e., the millennial generation) as "boring" and they do not address the unique learning needs of this generation who prefer to be actively involved in the teaching process [2]. This high level of interactivity that millennials seek is not easily captured in traditional learning environments. However, the more recent use of simulations through virtual reality and videogames have been noted as a highly effective means of promoting interactivity and active learning [3].

Given the issues associated with educating adolescents with T1D about diabetes numeracy and self-management, and the potential benefits inherent to video games, we have created a developmentally appropriate interactive, and engaging video game, Power Defense, aimed at improving numeracy in adolescents with T1D. We have successfully tested the usability of Power Defense (alpha testing) on a small subset (eight) of our target population (adolescents with T1D). The testing involved an exploratory period where participants used (played) the game individually and then completed a questionnaire. Generally, the majority of participants found Power Defense easy to use, intuitive, fun, and capable of conveying useful educational material regarding diabetes numeracy skills. We will be evaluating the impact of this video game on numeracy skills and health outcomes in this population.

Background: Diabetes-Related Games

Ketones Attack

Ketones Attack [4] is an asteroids style game (top-down shooter), where the player must shoot all sugar cubes on the screen with an "insulin gun". The insulin gun is charged by picking up insulin that randomly appears on screen. When too many enemies hit the player, the player loses (dies).

Diabetes Dash

In this game, the player must direct their avatar left and right to catch falling food and insulin [4]. The goal is to balance their blood sugar level by collecting the correct amount of food and insulin. Food is consumed only when an insulin shot is collected, making it possible to eat large quantities of food without it affecting your blood sugar.
The Diabetic Dog Game
Diabetic Dog Game [5] is a game wherein the player is charged with the task of taking care of a diabetic dog. There are many things that the player can do, including walking the dog, feeding the dog, and giving the dog insulin. The player must walk the dog or inject insulin to lower the dog’s blood sugar level and feed it to raise it. If the player neglects to take proper care of the dog, they lose the right to take care of the dog.

Packy & Marlon
This 2D platforming game was released in 1995 for the Super Nintendo, and is designed to improve self-care among children and adolescents with diabetes [6]. Before each level, the player must check their blood glucose level and inject insulin by pressing the “A” button (no calculations are required). Next, the player must navigate platforming areas, collecting as much food items as possible, while avoiding enemies that quiz the player on diabetes if touched.

The Magi and the Sleeping Star
This is a 3rd person action adventure game, in which the main character must maintain their blood glucose level to gain access to amazing powers [7]. The player can pause the game at any time to use food that restores their characters health, but the user must also inject the appropriate about of bolus insulin to obtain the “ideal” level. Once the ideal level is obtained, special abilities are unlocked, and the player can defeat bosses. While this is a high quality game, there is a very evident segmentation between the educational content and the game play, forcing the player to stop playing the game in order to manage their blood sugar.

The Power Defense Game
Overview
In collaboration with diabetes experts and education researchers at the Hospital for Sick Children in Toronto, Canada, we have created an innovative and interactive game (called Power Defense) for improving numeracy in adolescents with type 1 diabetes (T1D). Power Defense is based on the popular tower defense subgenre of real-time strategy games. Tower defense games offer simple game-play mechanics, they are fun and challenging and this has led to a large number of casual tower defense gamers [8]. In a tower defense game, the player “buys” and “strategically” places defensive towers throughout their area (typically a maze). Towers fire automatically upon approaching enemies and for each enemy a tower destroys the player earns points. If enough enemies are destroyed, the player wins the round and accumulates further points. However, if the enemies reach the end of the player’s area, the enemy wins the round. The player can use the earned points to “purchase” further towers or upgrade existing ones [8].

In Power Defense, the player is given control of a reactor-based power base station (represents the person with T1D) that stores energy (represents “blood sugar level”) and it is their responsibility to maintain this power station by balancing the amount of energy allowed into it. Players are provided with various tools at their disposal to do so, including four types of towers (each with its own “cost” and capabilities), “real-time coolant” (represents short acting insulin), and “daily super coolant” (represents long acting insulin). The station has a power output meter (represents “blood sugar level”), which must be kept at the optimal level between four and seven thousand units.
During an "attack wave", energy entities (represent food) try and reach the base station. The goal is for the player to survive as many waves of energy attacks as possible, while keeping base station's power output level within the acceptable range. Power is obtained from the advancing energy entities; the power of any energy that reaches the base station is added to the base station's power level. The player positions their available towers around their base station, in an attempt to limit the number of energy that actually reach the base station. The challenge is to let enough energy make it to the base while not to letting in an excessive amount.

If the base station power level becomes too high it will overload, and must be shut down for repairs. If power levels are too low, the base station shuts down and must be restarted. The base station gradually loses energy over time, and must have energy coming into it to maintain its level. Towers also drain the power output level. To maintain the station within its optimal output range, the player is given "coolant" to inject into the base station reactor if the output level is too high. Calculations for the amount of coolant to inject or the amount of "energy" to let in must be performed in real time similar to calculations performed by patients with diabetes for managing their blood sugar levels. If the output level is dangerously low the player can use a "Jumpstart" which offers a rapid energy boost to the base station. When the power level falls below a pre-set threshold, the game play area starts to blur, and this blurring effect increases as the level keeps dropping. Should the base station power level go below one thousand five-hundred, or go above fifteen-thousand then the player will have to re-start the level.

A screenshot illustrating a sample game-level with the base station, towers, and enemies is provided in Figure 1 while a sample game-play video demonstration is available from the following URLs:

http://www.youtube.com/watch?v=iKUSfBRv_JI
and
http://www.youtube.com/watch?v=KMqm6WSStE0

The score for each level is based on how much time the player was able to maintain the energy level of the base station within optimal range. In Power Defense, the relevant diabetes numeracy skills we wish to impart to the player is done so primarily implicitly. To enhance transfer of knowledge and skills to real life diabetes management we also incorporate explicit methods of learning in the form of a "game within a game": at certain points in the game, depending on specific user actions, the player is presented with diabetes-specific
questions which if answered correctly, are awarded accordingly and if they answer incorrectly, they are provided with the correct answer and appropriate explanation. An example is illustrated in Figure 2 where the user is provided with a nutritional label and asked a specific question about it. In this example, they are asked how many grams of carbohydrates the entire package contains and provided with a set of four potential answers which they must choose.

![Figure 2. Sample question screenshot.](image)

The waves of energy are organized into days, and at the start of each day the player has several decisions to make. The first is to decide whether to increase, decrease, or keep the same amount of super coolant. This will affect the rate at which towers drain output as well as how much power output is added when energy enters the power station. Next, the player is given options to spend their Tower Points (an in-game currency offered as a reward for various actions). The player can spend them on Free Towers, which work like regular towers except they have no drain on output. There is also the option to purchase jumpstarts (which provide a small, instant boost to output). Alternatively, the player has the option to "wager" his or her tower points. Wagering allows the player to bet points, which they are then prompted to answer a question; should they get it right, they receive double the points they wagered and if they answer incorrectly they lose the points they bet. Once the player has adjusted super coolant and spent all tower points, they are able to start the next day.

**Discussion**

Through an iterative and step wise approach that involved focus groups with medical experts exploring key diabetes numeracy concepts and alpha testing with T1D patients, we have developed Power Defense, an innovative video game that addresses diabetes related numeracy. Power Defense implicitly and explicitly addresses core elements of diabetes numeracy skills. Preliminary (alpha) testing conducted with a small subset (eight) of our target population (adolescents with T1D) has revealed that Power Defense easy to use, intuitive, fun, and capable of conveying useful educational material regarding diabetes numeracy skills. Power Defense employs various educational strategies to enhance learning and transfer of knowledge and skills to actual diabetes self-management.

Video games are popular and should be explored as a method for enhancing patient diabetes education. The development of an educational video game must be based on input from experts in the field of diabetes,
education, and technology development and most importantly must be based on the learning needs and desires of the target population.

We have subsequently recently begun testing the effectiveness of Power Defense with a pre-post intervention study (approved by the Hospital for Sick Children Research Ethics Board). Participants (adolescents with T1D), have played Power Defense on three separate occasions within a short period of time and then return after 1 month to play the game a final time. Numeracy skills, quality of life, and A1C levels (a blood test that measures average blood sugar control) are measured pre and post video game intervention.

Power Defense is unique as it implicitly and explicitly educates patients, through a video game, skills that they need to manage their chronic illness. The use of video games in health care and patient education is limited. The results of our study will help inform our current education practices for adolescents with T1D.

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