ENGAGING CHILDREN IN DIABETES EDUCATION THROUGH MOBILE GAMES

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ABSTRACT

Traditional methods for diabetic education rely heavily on written materials and there is only a limited amount of resources targeted at educating diabetic children. Mobile games can be effective, evidence-based, and motivating tools for the promotion of children's health. In our earlier work, we proposed a novel approach for designing computer games aimed for educating children with diabetes and applied our design strategy to a mobile Android game (Mario Brothers). In this paper, we report the findings of a preliminary evaluation study (n = 12) conducted over 1 week. The initial results showed that the children found the game engaging and improved their knowledge of healthy diet and lifestyle.

KEYWORDS

Games, diabetes, game design, evaluation, self-management, mobile health.

1. INTRODUCTION

Addressing diabetes is a priority for several major reasons: (1) the number of people diagnosed with diabetes is increasing (estimated to be over 240,000 New Zealanders[1]); (2) the prevalence is increasing rapidly (between 5-10% each year since 2005); (3) it is the major preventable cause of costly and debilitating renal failure, lower limb amputation, and avoidable blindness; and (4) it is a major contributor to inequalities in life expectancy (Ministry of Health, 2008).

Children with diabetes in New Zealand currently receive medical care from a physician-coordinated team of nurses, dieticians, and health psychologists with a special interest in diabetes. This approach is resource-intensive and potentially could benefit from an inexpensive, popular new mode of delivering diabetes health-related education. Existing research evidence supports the use of videogames to promote health-related behaviors. A randomised controlled trial, which provided health behavior information and support in the form of a videogame, helped children aged 10–12 years consume more fruits and vegetables (Baranowski et al., 2011). A systematic review of interactive multimedia interventions to educate children about their health demonstrated potential to improve children’s health-related self-efficacy, which could in turn enable them to become more competent on complex topics such as dietary behaviour change discussions (Raaff et al., 2014).

Playing games with mobile devices has become increasingly popular both in the development of games and in the field of research. The use of smartphones and tablet computers may offer opportunities to engage young people during inactive times between visits to the healthcare professionals, tests, or treatments by providing interactive health education modules (Greysen et al., 2014). Mobile technologies offer the potential for a new phase in the evolution of technology-enhanced learning. As the current research points out (e.g. Chai et al., 2014), meaningful learning could take place when learners are engaged in activities that allow for experimentation, conversation, collaboration, and reflection. Using mobile games for exploring new ways of learning has been shown to be very promising. Mobile gaming could be very well used in creating

[1]New Zealand Ministry of Health, http://www.health.govt.nz/your-health/conditions-and-treatments/diseases-and-illnesses/diabetes, Accessed in July 2016

authentic and engaging activities that combine teaching and gaming (Lieberman, 2012). Informal learning coupled with games can provide a foundation for innovation when applied to more formal learning situations.

Driven by the initiative of the Adult & Pediatric Diabetes Psychology Service of New Zealand, research has been undertaken to design and develop proactive mechanisms for diabetes education. To enhance children's learning about their condition, we chose to focus on exploiting interactive features of computer games to deliver education knowledge through immersive and situational learning. As a result, we embarked on developing a novel game design for teaching children how to manage their diabetes. We then applied the design ideas to an open source 2D game (Mario Brothers), developed a mobile version of the game and proposed several heuristics designed for subjective evaluation of educational mobile games (Chen, 2011; Baghaei, 2016). In this paper, we report the results of a pilot study conducted with 12 children to determine the effects of playing the mobile game 1) on engaging children and 2) on enhancing their knowledge of healthy diet and lifestyle. We hypothesize that game-based support will enhance the diabetes health-related knowledge, which in turn can stimulate and facilitate the conversation of the children with health-care providers about their self-management practices.

The rest of the paper is structured as follows. Section 2 explains the research question and the main idea of our research. The discussion of the modified mobile Mario Brothers game is outlined in Section 3. Section 4 describes the study and reports our findings. Finally, Section 5 concludes the paper and highlights future research opportunities.

2. DESIGN OF MOBILE GAMES FOR DIABETES EDUCATION

2.1 Research Questions

The main aim of this project is to investigate how we can effectively embed diabetes knowledge in a computer game to engage children for immersive learning. Two research questions are, therefore, investigated: 1) will engagement with the mobile game result in gaining greater knowledge of healthy diet and lifestyle? 2) how engaged are the participants with the game? We hypothesised that the participants will enjoy playing the game and that game-based support will enhance the diabetes health-related knowledge, which in turn can stimulate and facilitate the conversation of the children with health-care providers about their self-management practices.

2.2 Design Strategies

To address these questions, the very nature of computer games needs to be carefully examined. The key concept that is frequently utilized to explain the level of engagement in a computer game is that of "flow", first introduced by (Csikszentmihalyi, 1990). Many researcher consider flow as the state of intensive involvement. It is widely believed that flow is the key to the success of an educational game. According to Malone (1982), several conditions are likely to induce the flow state. Among them, a few conditions are of particular importance for designing diabetes education games (Chen, 2011):

C1. The activities in a game should be structured so that the level of difficulty of the game can be adjusted to match children's diabetes knowledge.

C2. The activities in a game should provide concrete feedback to children so that they can tell how well they perform and perhaps what they need to do to perform better. In particular, the performance of the game should be closely related to children's skill of managing their diabetic condition.

C3. The activities in a game should present a variety of challenges such that children can obtain increasingly complex information about different aspects of managing their diabetic condition.

It can be argued based on Malone's conditions that, instead of aiming for a gaming experience that superficially conceal the educational purpose behind fun activities, a careful design of the structure of the game is highly desirable. Specifically, the game structure should contribute to the flow and subsequently the creation of an active learning environment.

Among all types of games, it appears that simulation and role play games are most likely to satisfy these requirements. Simulation and role play games are the most popular types of games. In fact, learning through direct experience, which is enabled by simulation and role play, has been consistently demonstrated to be

more effective and enjoyable than learning through "information communicated as facts". Guided by Malone's conditions, efforts have been made to compare and select suitable games as the basis for our quest towards tackling the research question. Many open-source games were studied in respect to their educational value. The Mario Brothers game was finally selected for our game design since it enjoys a good match with the three conditions (i.e. C1, C2, and C3). The Mario Brothers game is open source and has long been considered as an engaging game for children thanks to its structured design with varied levels of difficulties. Thus, condition C1 is satisfied. The game has built-in feedback mechanisms that allow children to explore various game-play strategies through proactive interaction within a simulated environment. It hereby satisfies condition C2. In addition, the Mario Brothers game presents a variety of challenges through its stage-based design. It is easy to embed increasingly complex knowledge about living with diabetes at different game-playing stages. Thus the game agrees well with condition C3 and is suitable for providing an enduring and fun-filled learning experience.

All these reasons confirm the suitability of the Mario Brothers game for our research. Although our implementation of the education features was based on this game, we believe that the design strategies as explained below are generic enough to be applied to more education games. It is worthwhile to mention that these strategies can be considered as natural consequences of Malone's conditions.

- The first strategy is what we call the *Structure Enhancement* (*SE*). This means that the inclusion of education features should enhance rather than weaken the game structure. For example, adding education features to a game should contribute to the creations of a series of fine-grained difficulty levels so that children can gain new knowledge gradually as they progress from one level to another.
- The second strategy is the so-called *Feedback Enhancement (FE*). Namely education features should embody themselves in the form of knowledge-rich visual feedbacks. The triggering of these feedbacks is likely to be situational and is subject to certain properties of the game character. Feedbacks can assume various forms, with message boxes, and on-screen performance indicators being a few examples.
- The third strategy is termed the *Challenge Enhancement* (*CE*). According to this strategy, education features in a game should bring more challenges to be faced by children while they play the game. This is because challenge encourages proactive knowledge discovery and therefore enhances engaged learning. We found that one good approach is to consider a stage-based game design. In this way, simple education features will be embedded in early stages of a game. On the other hand, complex features will be reserved for later stages of the game to facilitate progressive learning.

The three design strategies above have been applied to modify the Mario Brothers game, described further in the next Section. There are perhaps many other game design strategies that could be explored when designing education games. For example, a good education game should enhance the reward provided to children when a learning target embedded in a challenging task has been accomplished. This and other possible design strategies will be investigated in our future research.

3. GAME MODIFICATION FOR DIABETES EDUCATION

Driven by the three design strategies, namely *SE*, *FE*, and *CE*, modifications have been made to incorporate educational features into the mobile Mario Brothers game (see Figure 1). In line with the fundamental principles of role play games, the main character of the game, named Mario, is assumed to have type I diabetes. The health problems faced by Mario become the health problems to be solved by the game player. The ultimate goal of the game is to save a princess who is locked in a castle. To achieve this goal, Mario needs to manage his diabetes and maintain a healthy condition while fighting against a variety of evil guards during multiple stages of the game.

It is expected that, as children progress through stages of the game, they will gradually learn the skills to remain healthy by eating healthy food, having regular exercise, and injecting suitable amount of insulin when needed. *SE*, *FE*, and *CE* have been extensively utilized to support effective learning in the game. Feedback is given both in textual format (e.g. "*Mario's blood sugar level is well below the normal range he needs to eat something!!"*) and visual format, i.e. blood sugar level changing colour from green to orange (warning) or red (critical). Below we discuss some representative examples of using the proposed strategies.

ISBN: 978-989-8533-61-6 © 2017

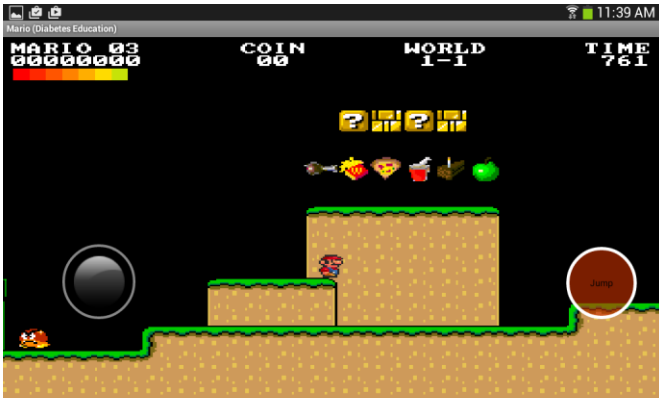

Figure 1. The screenshot of the Android mobile version - Diabetic Mario should maintain his blood sugar level (shown at the top) while trying to save the princess.

Example 1: Managing Mario's healthy condition, especially his blood sugar level, is designed as a main challenge at every stage of the game. If Mario's blood sugar level goes outside a healthy region, children's effort to rescue the princess will fail. To emphasize the importance of the blood sugar level, an indicator is placed at the top left corner of the game screen. In line with *FE*, the indicator as shown in Figure 1 is designed to change its colour whenever Mario's blood sugar level goes up or drops down. The way that the blood sugar level changes is determined by many factors, including playing time, the amount of exercises Mario had such as walking and jumping, and any food consumed by Mario.

Example 2: The modified Mario Brothers game is designed to help children learn the right skills to cope with their diabetic condition. As illustrated in Figure 1, choices regarding food consumption or insulin injection will pop up occasionally when Mario's blood sugar level deviates to a certain degree from the healthy level. According to *SE*, the options essentially represent fine-grained challenges since children need to make right choices through eating healthy food or injecting suitable amount of insulin in order to continue playing the game. The choice is to be made based on Mario's health condition and the progress of the game. The level of difficulty is adjusted to match the player's knowledge.

For the purpose of behavioural analysis, children need to login with their user name in order to play the game. Password is not required as this might pose problem to some children, especially those at very young age. Many game-playing activities, such as the amount of food consumed, the amount of insulin injection, and the amount of exercises, will be recorded in the system log. The log will help us find out whether children's skill of managing blood sugar levels will improve after playing the game for some time.

4. PRELIMINARY EVALUATION

A pre-post pilot study was conducted with the modified mobile version of Mario Brothers in 2015. Eligible participants were 12 children aged 9-13 years (6 females, 6 males), recruited from the greater Auckland area through community advertisements, schools and word of mouth. For the purpose of this study, participants were not required to have diabetes mellitus, nor had to have any particular experience playing video games of any time. The study was approved by the University of Auckland Human Participants Ethics Committee (Ref 013217). Participation in the study was entirely voluntary. Interested participants were given a participant information sheet to read, and completed written informed consent at baseline data collection.

Assessments were conducted at baseline and one-week after (post-intervention). At each time point, participants filled out a health-related questionnaire concerning their diet, physical activity, and lifestyle choices. Following the baseline assessment, participants were loaned a Samsung tablet for one week so they could play the mobile game in their free time if/when they wanted to. For the purpose of this study, participants were required to login with a unique user ID. The game automatically logged all the interactions, including when and for how long they played each time, which choices they made, how much feedback they received etc. At the end of the week, we collected the tablets and asked them to fill out the health-related questionnaire again, followed by a survey with closed and open questions about what they thought of the game.

4.1 Evaluation Metrics

The main objectives of this study were to determine the effect of playing the mobile game on enhancing children's knowledge of healthy diet and lifestyle. We also wanted to know whether children found the game engaging over the period of one week. Thus, the change of users' knowledge of healthy diet and lifestyle as well as their engagement with the game were our dependent variables.

To measure lifestyle knowledge enhancement, we used the health knowledge questionnaire developed by Saksvig and colleagues (2005) , based on previous work from the CATCH Health Behaviors Program (Edmundson, 1996) and the Kahnawake Schools Diabetes Prevention Program (Macaulay, 1997). The questionnaire aims to measure change in diet and physical activity psychosocial constructs in children over time. We used a set of questions measuring health-related knowledge (i.e. diet, physical activity, and diabetes) and adjusted the wording of some items to reflect the New Zealand context (e.g. for the originally developed item "Do people in Sandy Lake get more exercise or physical activity today than they did 30 years ago", Sandy Lake was replaced by Auckland).

The questionnaire consisted of 21 items about diet and exercise, each with four answer options and took approximately 10 minutes to complete. A sample question was:

Which one is the healthiest choice for supper (tick one only)?
1) lamb meat and macaroni soup, baked crumpet, water
2) hot dogs, french fries, jelly, fizzy or soft drink (e.g. Coke, Sprite, Fanta)
3) 2 minute noodles, chips, fruit juice
4) I don't know

To measure engagement, we analysed the number of times they played the game over the course of one week, amount of time they spent per session, average number of feedback messages they received etc. The acceptability/perceptions of the game questionnaire was developed by the research team for the purpose of this pilot study. Both questionnaires/surveys were pilot-tested in a small sample (n = 2) of children of the same age as those to be recruited to ensure reading comprehension of the items. Additionally, a research assistant was in place during the completion of the questionnaires, should reading or vocabulary explanations be necessary.

4.2 Results

We analysed the interaction logs recorded on each tablet during the 7-day period participants played the game (Table 1). On average, our participants played the modified Mario Bros game for 22.2 times over the 1-week period, spent 12.3 minutes in average on each session and were shown 38.6 feedback messages (box textual and visual). Out of all participants, two completed all seven levels of the game and the rest completed at least up to level 4. See Table 1 for more details.

Table 1. Analysis of User Interaction Logs.

Users ID	Number of sessions	Total number of feedback provided (textual & visual)	Average number of feedback shown per session
11	24	555	23.125
10	22	774	35.18
6	25	868	34.72
3	21	330	15.71
5	52	4355	83.75
7	42	3468	82.57
8	5	160	32
13	9	295	32.77
14	24	529	22.04
15	16	962	60.12
16	9	217	24.11
17	17	307	18.06
Average	22.2	1068.33	38.68

The analysis of the Health Knowledge Questionnaire (Table 2) shows that the confidence of the participants increased from pre to post event with respect to selecting healthy eating choices (pre = 66% to post = 77%) and initiating regular exercise habits (pre = 62% to post = 66%). The average score on the post-health questionnaire was higher than the pre-test score for all categories. More studies are needed to examine the effect of playing the game on children's knowledge and confidence over a longer period of time.

Table 2. Pre and Post study statistics.

	Average		**s.d.**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Questions related to Healthy food choices	66%	77%	24%	16%
Questions related to Exercise	62%	66%	22%	32%
Overall	65%	73%	12%	13%

Overall, the game was viewed as a good and fun experience by the players. Subjective evaluation of the data showed that the participants enjoyed playing the game. They also believed that it would have added educational value, as it involved players in problem-solving and decision-making, by requiring them to balance food and exercise to keep Mario's blood sugar level (displayed throughout the game) within the optimal levels.

5. CONCLUSIONS & FUTURE WORK

This work aimed to exploit the popularity of mobile games in an attempt to impact diabetes health-related knowledge of children. We proposed and described the design, implementation and preliminary evaluation of Diabetic Mario Bros, a mobile game intended to engage and motivate children to adopt a healthy lifestyle, which would enable them to take increasing control of their condition.

The contributions of this work were: 1) proposing a novel game design for teaching children how to manage diabetes 2) applying the proposed design to an open source 2D game and developing a mobile version 3) evaluating the effect of playing the game on enhancing children's knowledge of healthy diet and lifestyle and 4) analysing the participants' interaction logged over a period of one week. The results showed that the participants enjoyed playing the game. Interacting with the game for a week also enhanced children's diabetes health-related knowledge, which in turn can stimulate and facilitate the conversation of the children with health-care providers about their self-management practices. However, there were a few limitations in terms of players' competence and health background. The current version of the game does not take the history of the player into account and all users are presented with the same challenges regardless of their gaming experience.

The core research effort going forward will focus on effects on engagement and health knowledge changes as a result of personalisation technology in computer games. Personalising the game according to players' preferences and abilities can sustain their engagement in the long-term and encourage them to use and explore all features supported by the system. In addition, for the purpose of this study, participants were not required to have diabetes mellitus, nor had to have any particular experience playing video games of any time. For the next evaluation study, we will be recruiting children with type I diabetes.

We will also further analyse the player interaction data logged on each tablet, such as number and nature of the daily sessions over the course of the week to see whether food items they picked changed as they kept playing the game. Some of the food options the participants were presented with were: APPLE, BANANA, MEAT, PIZZA, CARROT, MILKSHAKE and CAKE. We would like to investigate the number of times a healthy food choice was made after blood sugar level jumped up and compare that with the number of sessions each user played the game and the number of textual and visual feedback messages they received. Our hypothesis is that the more they played, the healthier food choices they made. Full analysis of the interaction data will also allow us to think in terms of what motivates a participant to play a health educational mobile game and how that motivation can be sustained over time. We believe our research paves the way for the systematic design and development of full-fledged computer games dedicated to diabetes education in the future.

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