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Evaluating Mobile Games for Diabetes Education

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Abstract: Mobile games can be effective, evidence-based, and motivating tools for the promotion of children's health. Traditional method for diabetic education relies heavily on written materials and there is only a limited amount of resources targeted at educating diabetic children. In our earlier work, we proposed a novel approach for designing computer games aimed for educating children with diabetes. In this paper, we apply our game design to a mobile Android game (Mario Brothers). We also introduce three heuristics that are specifically designed for evaluating the mobile game, by adapting traditional usability heuristics. The results of a preliminary evaluation study, conducted for a week, showed that the children found the game engaging and it helped enhanced their knowledge of healthy diet and lifestyle.

Keywords: games, diabetes, game design, evaluation, self-management, mobile health

1. Introduction

In light of the increasing numbers of people with diabetes (estimated to be over 208,000 New Zealanders in 2011, up 9.7% from 2010 and therefore potentially up to 229,000 in 2012[1]), addressing diabetes is a priority for three major reasons: (1) the prevalence is increasing rapidly (between 5-10% each year since 2005); (2) it is the major preventable cause of costly and debilitating renal failure, lower limb amputation, and avoidable blindness; and (3) it is a major contributor to inequalities in life expectancy [1].

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. There has been enough qualitative research to suggest that video games have helped children between the ages of 10-12 make healthier diet and physical activity choices [2]. 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 [3]. Tablet computers may offer opportunities to engage patients during inactive times between visits to the health care professionals, tests, or treatments by providing interactive health education modules [4].

Playing games with mobile devices is a recent development and has become increasingly popular both in the development of games and in the field of research. A good gaming experience requires a lot from the user interface. It should be convenient, reliable, and usable so that the player can concentrate on playing the game and enjoying it instead of struggling with the user interface. In addition, the game design itself has a huge impact on the gaming experience. If the rules or game world contains implausible features, the players can be easily offended or frustrated and quit playing. In addition, the heuristics for evaluating games in mobile context are qualitatively different from traditional playability heuristics.

[1] New Zealand Ministry of Health, http://www.moh.govt.nz/moh.nsf/indexmh/heha-importance, Accessed in May 2015.

A number of usability heuristics have been proposed for digital games by several researchers in recent years:

- The initial set of heuristics proposed by Malone [6] in 1980 categorized into three types: challenges, fantasy, and curiosity.
- Clanton [7] then proposed fifteen principles for video games in 1988. The main purpose this set of heuristics to examine whether or not the game design facilitates user interest.
- Federoff [8], later on, proposed a list of forty heuristics that focused on gameplay, engagement and storyline elements.
- Desurvire et al. [9] proposed heuristics in four categories; game-play, game-story, game-mechanics and game-usability.
- Korhonen & Koivisto [11] proposed twenty-nine heuristics categorized in terms of 'Game-Usability', 'Game-Mobility' and 'Game-Play'. 'Game-Play' defines a user's interaction with other objects in the game. 'Game-Mobility' defines how easily a player is involved in the game's venue and how it behaves under unclear conditions. 'Game-Usability' covers a player's interaction with the game's world and with other players. In another study, the authors proposed a new category consisting of eight heuristics for multiplayer games. These heuristic were found to be effective in identifying playability problems in multiplayer mobile games [11].
- Schaffer [12] introduced heuristics for Game-Usability. Schaffer divided his heuristics into five categories: General, Graphical User Interface, Gameplay, Control Mapping, and Level Design.
- Pinelle et al. [13] proposed a new set of ten heuristics that covered usability aspects. Later on, Pinelle et al. introduced an additional ten usability heuristics for multiplayer gaming [14].
- Ibrahim et al [15] highlight certain educational playability heuristics for measuring the experience obtained by the players during a game.
- Soomro et al. [16] proposed a further ten playability heuristics for mobile games.
- Shoukry et al [17] proposed a detailed set of sixty three attributes to evaluate the Mobile Educational Games in fifteen categories.

Having reviewed the heuristics for the evaluation of video games for the last 20 years, we realised that most of the heuristics proved very generic and valid only for high level issues in the games. In addition, some were not validated. In heuristic validation, each heuristic is evaluated according to its relevance in designating usability problems ([22], [23], [24], [25]). Furthermore, the size of heuristic sets is also an important factor.

Driven by the initiative of the Adult & Paediatric Diabetes Psychology Service of New Zealand, research has been performed to design and develop proactive mechanisms for diabetes education. As widely known by researchers and clinical psychologists, children who are learning about their diabetic condition will need to learn to cope in a variety of different situations. In view of this, we decided to focus our research on exploiting interactive features of computer games to deliver education knowledge through immersive and situational learning. As a result, we embarked on developing a game design for teaching children how to manage their diabetes [5]. In this paper, we applied the design ideas to an open source 2D game (Mario Brothers), developed a mobile version of the game and conducted a pilot study 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 remainder of this paper is organised 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 presents the proposed heuristics for evaluating the game and reports our findings. Finally section 5 concludes the paper and highlights future research opportunities.

2. Design of Mobile Games for Diabetes Education

According to Kirriemuir [18], there are two key themes common to the development of games for education: (1) the desire to harness the motivational power of games in order to "make learning fun";

and (2) a belief that "learning through doing" in the form of games offers a powerful learning experience. The first theme is broadly criticized in the literature. As pointed out by Rieber et al. [19], games should not be treated simply as educational "sugar coating", making the hard work of learning easier to "swallow". Instead we have to consider both the motivational and more importantly the cognitive power of games.

In view of this, rather than focusing primarily on motivating children, the idea of "learning through doing" demands much greater attention. Designers and developers of educational games used to assume that children do not enjoy learning. On the contrary, research evidence clearly indicates that learning can be enjoyable experiences for children especially when they have a sense of their own progression and where the learning is relevant and conducted in a meaningful context.

As many researchers believe, the real educational value of a computer game should be exemplified by its ability of creating a playful learning experience for children through experimentation, progressive exploration, trial and error, imagination, role play, and simulation. Therefore, a game designed to satisfy these criteria might stand for an ideal platform for education. Based on this understanding, it is clear to see that learning in a computer game should be purposely structured through a series of exploration tasks so that children can discover essential diabetes knowledge in a progressive and experimental manner. The main research question that accompanies this goal comes directly into sight: *how can we effectively embed diabetes knowledge in a computer game to engage children for immersive learning and what is the best way of evaluating its effectiveness?*

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 [20]. 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 [21], several conditions are likely to induce the flow state. Among them, a few conditions are of particular importance for designing diabetes education games [5]:

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). Some main reasons of our choice include:

1. The Mario Brothers game 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.
2. The Mario Brothers 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.

3. 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.
4. The Mario Brothers game is open-source. A Java version of the game is available for free modification. The game can be easily migrated to different computing platforms including mobile systems. For this study, we went with Android platform. We believe that mobile games can bring diabetes education to more children anytime and anywhere.
5. The Mario Brothers game has been a popular game for children for decades. Children's and even their parents' familiarity with the game means short learning curve and perhaps wide acceptability.

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 [5].

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 progressively 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 conducted to incorporate education 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.

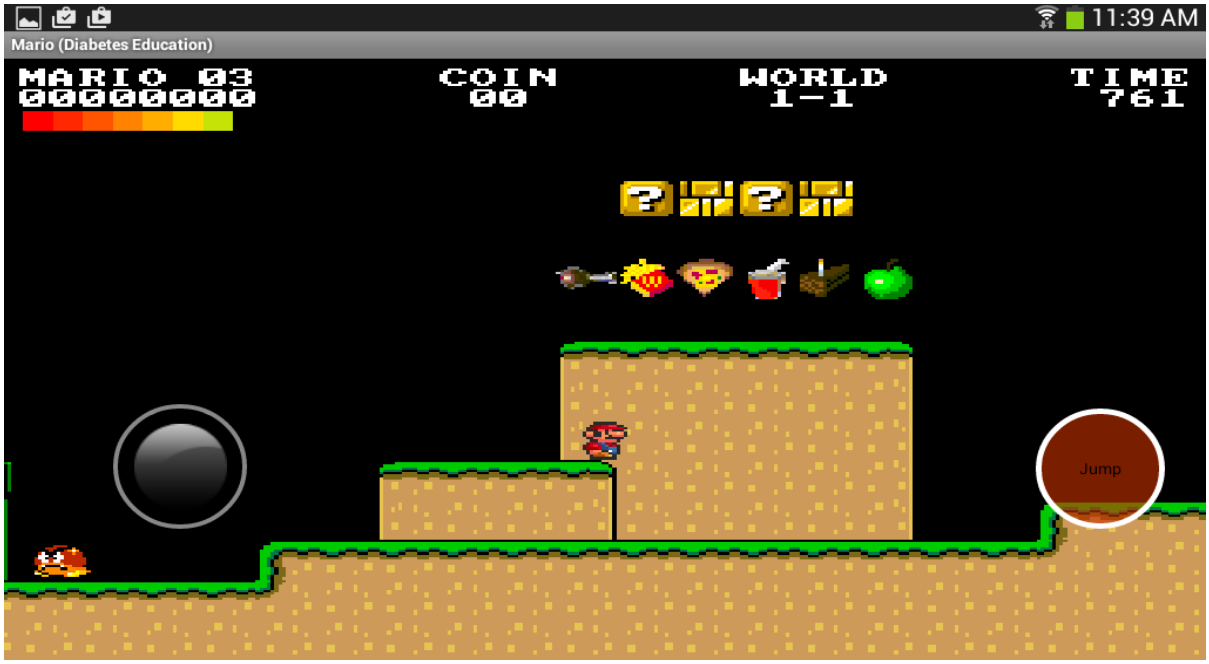

Figure 1. The screenshot of the Android mobile version - Diabetic Mario should maintain his blood sugar level (shown at the top) while trying to save the princess.

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. Below we discuss some representative examples of using the three strategies.

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 diabetes knowledge.

Example 3: The challenge of maintaining appropriate blood sugar levels increases as children progress through different stages of the game. In association with CE, at early stage of the game, a small set of recommended food or insulin injection will be provided when Mario has abnormal blood sugar level. At later stages of the game, the challenge increases and children need to choose among a large variety of food and need to decide the right amount of insulin injection. To make this job even tougher, choices will not pop up automatically. Children need to pay constant attention to Mario's blood sugar level while playing the game. Whenever the blood sugar level becomes abnormal, they must bring up the choices menu manually to control the health problem.

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 pilot study was conducted with the modified mobile version of Mario Brothers in February & March 2015. The main objectives of this study were to determine the effects of playing the mobile game 1) on engaging children and 2) on enhancing their knowledge of healthy diet and lifestyle. These two factors were our dependent variables.

To take part in the study, 12 children aged 9-13 years were recruited in the greater Auckland area. The study was approved by the University of Auckland Human Participants Ethics Committee. Participation in the study was entirely voluntary. The participants filled out a health-related questionnaire about diet, exercises and lifestyle choices. They then borrowed a tablet for one week so they could play the mobile game in their free time if/when they wanted to. 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 about what they thought of the game.

To determine how engaging the game was, we studied different factors. Educability was an important factor for this study, however, one cannot achieve that, if the game does not meet other requirements such as usability and playability. We, therefore, chose three heuristics, *Usability*, *Educability*, and *Playability*, from the study of literature to evaluate the game prototype.

The *usability* aspect of the heuristics covers such factors as audio-visual elements, screen layout, terminology used in the content, navigation, controls offered, feedback management and the help features.

Table 1: Heuristics used for Usability of the game

Usability	GU1	Audio-visual representation supports the game
	GU2	Screen layout is efficient and visually pleasing
	GU3	The player understands the terminology
	GU4	Navigation is consistent, logical, and minimalist
	GU5	Control keys are consistent and follow standard conventions
	GU6	The game gives feedback on the player's actions
	GU7	The player cannot make irreversible errors
	GU8	The player does not have to memorize things unnecessarily
	GU9	The game contains help

The *playability* is a crucial factor in deciding how engaging the game is and whether or not the user comes back to playing the game. It includes elements as game controls, game goals, how progress is made, rewards structure, game mechanics and storyline.

Table 2: Heuristics used for Playability of the game

Playability	GP1	The game controls easy to use
	GP2	The game provides clear goals or support player-created goals
	GP3	The player sees the progress in the game and can compare the results

	GP4	The players are rewarded and rewards are meaningful
	GP5	The players in in control
	GP6	The first-time experience is encouraging
	GP7	The game story supports the gameplay and is meaningful
	GP8	There are no repetitive or boring tasks
	GP9	The game is consistent
	GP10	The player does not lose any hard-won possessions

The *educability* aspect takes care of how much of learning has taken place, though domain specific. This is evaluated in terms of several display mechanisms (e.g. the blood-sugar indicator), confidence achieved (e.g. easy to control the blood-sugar levels) and application of the knowledge (e.g. managing one's own diet as a result)

Table 3: Heuristics used for Educability of the game

Educability	ED1	The blood-sugar indicator easy to understand
	ED2	Easy to control the blood-sugar level
	ED3	Seeing Mario going through the blood-sugar level changes, you feel confident about managing your own diet
	ED4	The game helped understand how blood-sugar level changes

4.1 Results & Discussion

The effectiveness of the game mainly depended on how engaging and educational it was. Figure 2a shows the responses to the *usability* factors. In addition to audio-visual features that support, they expected visually pleasing screen in terms of colour, lay out and the resolution of the animations. There wasn't any terminology used as the game provides the visual representations. The players found the navigation to be consistent, logical, and minimalist. However, any small error meant starting the game right from the beginning, which attracted most criticism. As a result the scores for items GU6 & GU7 were relatively low (see Figure 2a). Some players suggested that there should be new ways to control game characters such as voice interaction with game characters.

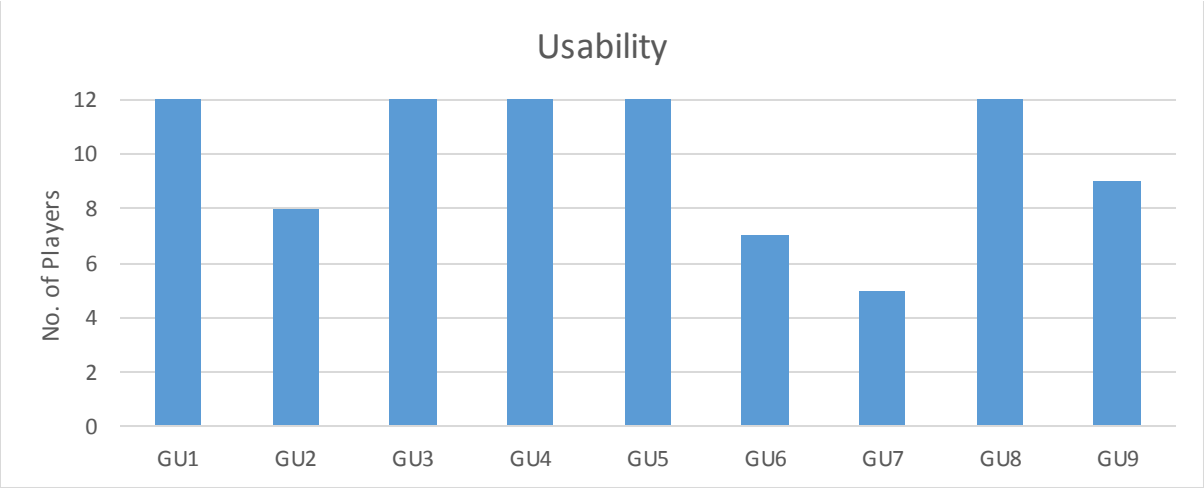

Figure 2a. Responses to the *Usability* heuristics

The results of the playability heuristics, especially the low scores for GP5, GP6 & GP8 (see figure 2c) were due to the fact that the players had to restart the game at Level 1 each time they played. The current version of the mobile game does not remember the player's previous achievement. Achieving all the seven levels of the game needed to be done in one session, which was not realistic for a number of players especially given their gaming experience.

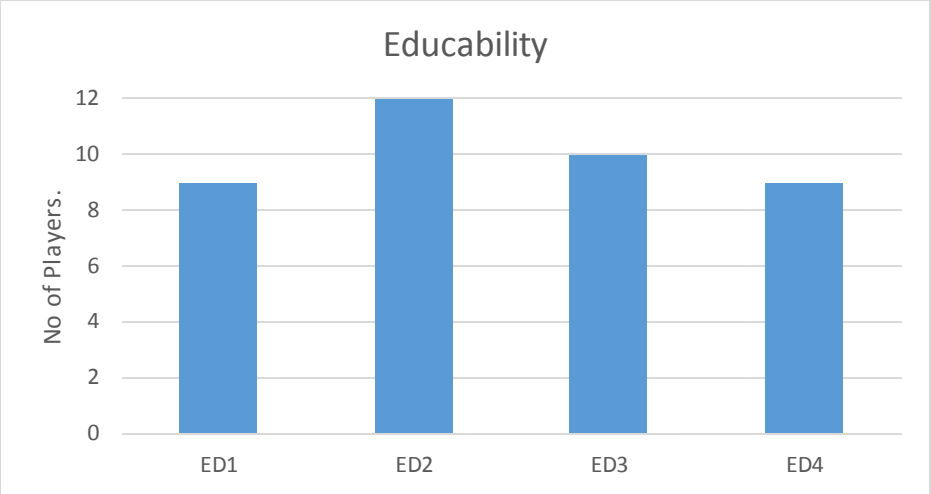

Figure 2b. Responses to the *Educability* heuristics

Based on the results of the study (Figures 2a-2c) and current literature (e.g. [15]) a game should have the following characteristics for any educability:

- The content of the game should be accurate, graphically detailed and predictable.
- The players should feel that they are in total control of the game
- The game should respond to players' actions in a consistent, immediate, challenging and exciting way.
- Transmit different stimuli to activate and engage players during playing time.
- The game should make players feel that they are part of a creative and dynamic community.
- It should accelerate learning times and focus on reinforcement of players' skills and experience.
- It should increase players' retention levels.
- It should present suitable and effective content for players of all levels.

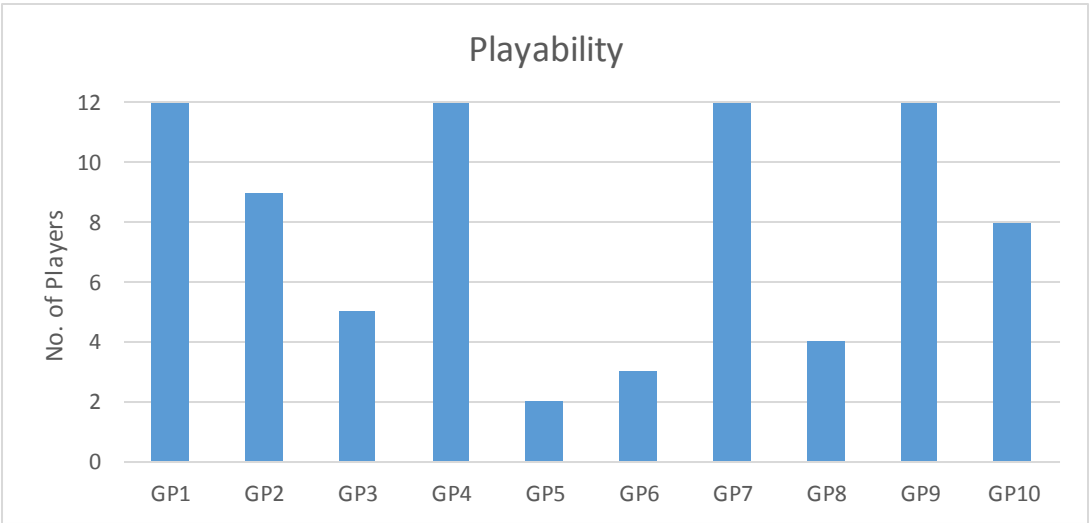

Figure 2c. Responses to the *Playability* heuristics

To determine whether playing the game for a week had any effect on enhancing their knowledge of healthy diet and lifestyle, we gave them a health-related questionnaire at the beginning of the study (pre-test), they borrowed a tablet and played the game for a week (whenever they wanted) and filled out the health questionnaire again at the end of the study (post-test). The health questionnaire consisted of some multiple-choice questions about diet and exercise that took about 10 minutes to complete. Sample questions were:

What are moderate to vigorous physical activities (tick one only)?

1) ***activities we do sitting down***
2) ***physical activities that give our bodies a workout***
3) ***physical activities we do for only 5 minutes***
4) ***I don't know***

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***

Table 4 presents some general statistics about the study. The average mark on the post-health questionnaire was higher than the pre-test mark for all categories:

Table 4: Some statistics about the study

	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%

5. Conclusions & Future Work

A novel mobile game was developed for teaching children how to manage their diabetes using the proposed design strategies. The initial results from an evaluation study showed that the participants enjoyed playing the game and believed that it would have added educational value. It also showed that playing the game for a week enhanced children's health-related knowledge.

The results thus far are encouraging in that the game is engaging and is promoting a sense of healthy lifestyle. Further work includes: 1) addressing the feedback received from the pilot study to enhance the game prototype, 2) analysing the interaction data logged on the tablets which would allow us to gauge the extent to which the game design successfully embeds enjoyable experiences and meaningful learning outcomes, 3) personalising the game according to players preferences and abilities and 4) evaluating the effectiveness of the proposed game with children with diabetes for long-term behavioural changes and increased knowledge of diabetes. 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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