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Serious games for health: An empirical study of the game "Balance" for teenagers with diabetes mellitus

Alberto Fuchslocher *, Jörg Niesenhaus, Nicole Krämer

Department of Computer Science and Applied Cognitive Science, Faculty of Engineering, University of Duisburg-Essen, Forsthausweg 2, 47057 Duisburg, Germany

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ABSTRACT

In addition to a broad range of different application areas, health games differ in the level of abstraction of the game's message or goal and the way to achieve game benefits. Most games focus on teaching knowledge or prevention topics. Furthermore, some games focus on strengthening motivation of patients to attend a specific medication or to change their daily behavior in order to live healthier. In this paper we present the health game "Balance", developed to optimize the self-management of teenagers with diabetes mellitus type-I. Two versions of the game were implemented: A version explicitly referring to diabetes and an implicit version of "Balance" with no diabetes content in order to reduce diabetes related reactance among juveniles. In a between-subjects experimental study with a clinical sample the two versions were compared. Results demonstrate, contrary to expectations, that the explicit game version yielded higher game enjoyment than the implicit version.

1. Introduction

A serious game is a specific type of game whose primary purpose goes beyond pure entertainment by teaching knowledge or training skills [1,2]. Serious games are strongly connected with the term "game-based learning" which describes the application of games for teaching competences and skills in a selected area of knowledge or the informal learning while playing a game [3,4]. A huge advantage of a serious game compared to conventional forms of education is to foster high intrinsic motivation [5] and a positive emotional experience [6]. Serious games are used for different purposes in a wide range of application areas like education, advertisement, scientific research, military training and health care. Despite the considerable amount and variety of developed serious games, only a few studies have been conducted to measure the games' degree of efficiency in achieving the implied added value beyond the entertainment [7,8].

Serious games for health (or "health games") are games with a focus on health care, physical and mental fitness. In most cases they are not commercial products but offered free by health care institutions like insurances, medical institutes or foundations. Popular application areas of health games are nutrition, physical training, education and prevention [2].

Health games as well as commercial games with no relation to health care can also be employed in order to positively influence patient's treatment compliance, since treatments can often be painful and unpleasant. For instance, distraction, by means of engaging burn-injured patients in a virtual game activity, has showed to significantly reduce perceived pain during bandage change [9]. Furthermore, health games in combination with biofeedback treatment have revealed to be a successful approach for treating children with dysfunctional voiding and obstipation [10]. In addition, in a different study an increase in the training intensity of spinal cord injury patients could be accomplished when a health game interface was employed that was especially developed for the training [11]. A further detailed research review about the effectiveness and the different application areas of health games is given by Kato [12].

Among the numerous applications of health games, some of them are directly focused on strengthening motivation of patients to attend a specific medication or to change their daily behavior in order to live healthier. A game developed to strengthen the motivation of patients to attend medications is "Re-Mission". In this game the player is put in the role of a nanobot in order to fight cancer cells allocated in the patient's organism. A clinical study [8] showed that the game intervention significantly improved treatment adherence and cancer-related self-efficacy of teenage and adolescent patients who were undergoing cancer therapy. Besides "Re-Mission" several other games have been developed that address motivational aspects of chronic diseases. One that focuses diabetes is "Packy and Marlon" [7], which puts the players in the role of young elephants who have a diabetic disease and have to control their blood sugar level in order to stay fit for their adventures. As a result of playing "Packy and Marlon" for a 6-month

* Corresponding author. Tel.: +49 203 379 1293x1420x2482.
E-mail addresses: alberto.fuchslocher@uni-due.de (A. Fuchslocher), joerg.niesenhaus@uni-due.de (J. Niesenhaus), nicole.kraemer@uni-due.de (N. Krämer).

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period, participants showed an improvement in diabetes-related self-efficacy, communication with parents about diabetes, and a decrease in unscheduled urgent doctor visits compared to the control group who played a videogame containing no diabetes-related content [7]. Another approach to improve the self-management of teenagers with diabetes is offered by the game hardware "GlucoBoy", which can be used together with the mobile game consoles Game Boy Advance and Nintendo DS. The GlucoBoy features a glucose meter, which translates the blood sugar level into game points that can be used to play different games provided by the hardware. Although the games do not refer to the diabetic disease the games may motivate to take blood samples on a regular basis.

2. Problem statement

Chronic diseases like diabetes pose several challenges to patients' self-care, especially in the target group of kids and teenagers. Since no cure for diabetes has been discovered, disease treatment is primarily focused on controlling patients' blood glucose level by regulating food intake and insulin injections in order to avoid long term complications like blindness, kidney disease or amputations.

Diabetes treatment of children and adolescents is especially difficult because of age group related resistance to behavioral restrictions. Therefore practitioners concur, that effective diabetes self-management among juvenile patients can hardly be achieved by conventional schooling or motivational techniques [13–15]. A practical and effective way to mediate and reinforce successful diabetes self-care could best be achieved by engaging the target group in an enjoyable activity (e.g. computer games) which at the same time implicitly conveys educational diabetes self-management techniques. A health game that is designed accordingly might thus increase intrinsic motivation and reduce reactance.

As stated earlier, the idea to use games for health care communication and education is not new and has been used for several other purposes like the optimization of self-management process of diabetes diseased patients. The game Packy and Marlon addresses the self-management process but does not offer characters the teenagers can identify with. The GlucoBoy impressively shows the integration of hardware into the self-management process but misses to provide a connection between the abstract glucose points gathered through the blood samples and the relevant health related topic. Therefore, the goal of our newly designed health game "Balance" is to directly address the target group of teenagers and to integrate the self-management process with its challenges and dangers in the overall gameplay.

3. Developed game

The game "Balance" was developed at the University of Duisburg-Essen with aid of medical scientists and psychologists of the LMU Munich child hospital in order to assure the adequate mediation of diabetes related self-management. A first prototype was implemented with Adobe Flash and optimized by professional game developers in order to match the quality standards needed for the clinical study. Currently in development is also a Microsoft XNA version of the game for further research with a broader audience and different input devices.

"Balance" is a jump'n'run game (also called "platformer") which refers to a very well-liked game genre within the teenage target group. The jump'n'run genre is characterized by jumping to and from suspended platforms or over obstacles. The player's mission in Balance is to free his/her friends who were captured by strangers. Therefore, the player has to travel through different locations in order to find and free his/her friends while being confronted by several obstacles and agents. In addition to the challenges provided by the level architecture, the player has to control his/her blood sugar level by eating food and taking insulin. This game based self-care has a direct impact on the game mechanics and the gameplay. If the player has a low blood sugar level he/she gets slower and is not able to fulfill all given tasks. Vice versa a very high blood sugar level is also critical for his/her health. Therefore, the player has to find the right balance of consuming food and insulin. While the food can be collected during the game level, insulin is provided through the player's inventory. As the game progresses, the complexity of the level design increases by offering the player a more unbalanced variety of "food" and "insulin" game objects in order to generate more difficult choices how and when to consume the objects. During the course of the game the jump'n'-run challenges become tougher by changing obstacles size and the movement speed of agents. This does not only have an impact on the required player skills concerning the avatar controllability but also on the challenge to attain an optimal blood sugar level in order to be able to overcome the presented game obstacles.

Based on operant learning principles [16] implemented, players' successful self-care is reinforced through experienced positive consequences such as game score and playing mechanics (avatar controllability). Specifically, two different forms of reinforcement were employed to enhance diabetes related diabetes self-care: positive reinforcement by means of high scores (if diabetes self-management is adequate) and negative reinforcement by the decrease of the avatar's controllability (if diabetes self-management is neglected or poorly accomplished).

In order to minimize reactance among adolescents, additionally an implicit game version was programmed. In the explicit version, the player is directly confronted with the avatar's diabetes disease within the introduction of the characters, the game's story and the gameplay. The implicit version has no such clear references to diabetes and replaces the blood sugar regulation with a temperature regulation analogy. In this metaphoric version of the game the player collects red potions to raise his/her temperature and uses blue potions to lower his/her temperature. The overall gameplay experience is identical in both versions of the game by only substituting the visual representations of the glucose meter, the insulin and the food (Fig. 1).

We expected that a successful self-regulation in the game positively influences players' experienced self-efficacy regarding diabetes self-management. Perceived self-efficacy consists of beliefs that one is capable of carrying out a desirable behavior, bringing about desirable events, and avoiding undesirable ones [17]. The role of self-efficacy for the performance of specific diabetes self-care and health related behavior in general is of prime importance. Accordingly, people who have high self-efficacy related to carrying out specific positive health behaviors are more likely to have a healthy life style and to seek and follow medical advice when ill [18]. As the self-efficacy performance of a certain behavior is linked to the conviction of being able to carry out that certain behavior, diabetes self-management internal locus of control was also expected to be positively influenced by playing the game versions.

Relying on conducted empirical research, children tend to be highly attentive to role characters that are similar to them or that appear in media genres like cartoons and video games [19]. Therefore, diabetes management self-efficacy should be positively influenced by players' perceived similarity to the game character. The underlying mechanism can best be explained in terms of social learning theory [20] and its influence on self-efficacy. According to this theory, a person experiencing self-efficacy regarding a certain behavior (e.g. diabetes self-care) will be positively influenced by a role model (e.g. game character), if desirable outcomes of role model's behavior are observed (e.g. reinforcement by high score and game mechanics) and perceived similarity between observer and role model are given.

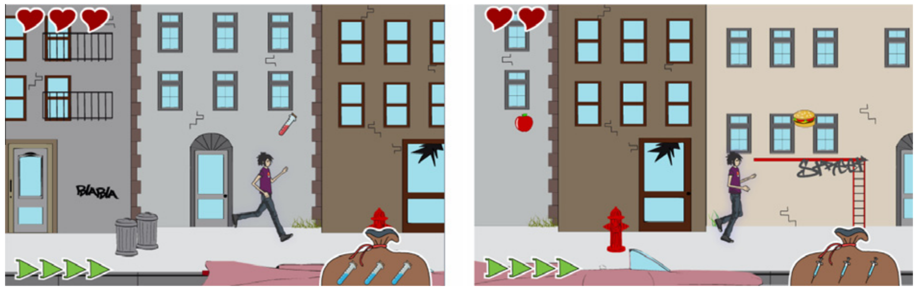

Fig. 1. Explicit version (left) and implicit version (right) of the game "Balance".

4. Experimental study

The study was designed to explore possible differences between the implicit and explicit health game version regarding game enjoyment, perceived similarity to game character, diabetes related self-efficacy and locus of control. Participants were recruited with the cooperation of pediatric endocrinologists from local hospitals. Invitations for study participation were directly sent to the parents. In the invitation, the study purpose was explained and instructions to not reveal the study purpose to their children were given to the parents. Correspondingly, adjunct to this invitation a letter for the children was sent, in which children were invited to test a game developed for hospitals usage with the aim to bridge waiting periods when attending medical examinations. The cover story was necessary in order to minimize the danger of the children guessing the hypothesis and to avoid a "diabetes disease priming" when facing the explicit and particularly the implicit game version. Appointments for study participation were individually arranged via telephone or email. The experiment took place at the Elizabeth Hospital in Essen and at the University in Duisburg. Participants were compensated with 10€ and the possibility to take part in an IPod lottery.

The study was a between subjects experiment in which children with diabetes mellitus type-I were randomly assigned either to the explicit or the implicit game version. The experimental procedure consisted in playing the game during a single session for a 15 min interval followed by a questionnaire with two parts. In the first part of the questionnaire participants evaluated the game according to its enjoyment, acceptance, likeability and immersion in the game story on a 6-point rating scale. Additionally, likeability and perceived similarity to the game character were assessed. In the second part of the questionnaire, self-efficacy (adapted scale from Schwarzer and Jerusalem [21]) and locus of control with regard to the diabetes self-care [22] were also measured on a 6-point rating scale. Afterwards, participants were asked about their media consumption (e.g. "How often do you play PC-games") and demographic characteristics. The debriefing was conducted at the end of the study.

5. Results

The sample ($N = 20$) is composed of 12 boys and eight girls with diabetes mellitus ranging between the ages of 11 and 16 ($M = 13.1$; SD = 1.83) years. 19 of 20 participants reported to play computer games regularly and for 1.38 h a day on average. Specifically, 30% of the sample reported to play 1–2 days a week, while 35% and 30% of all participants reported playing 3–4 days and 5–7 days a week, respectively. Furthermore, 18 of 20 children and adolescents possessed an own computer or video console. No preferences for specific game genres were found (e.g. Action and Adventure, Jump'n'Run, Sport-simulation, Strategy, Role-game), only educational software was disliked on average. There was no statistical difference between treatment conditions concerning the average amount of playtime. Due to the small sample size no significant statistical differences between groups were observed on any assessed dependent variable. Therefore Cohen's effect size d was computed in order to determine whether the observed mean differences between the tested game versions imply a meaningful effect.

To analyze the influence of game version on game evaluation, both game versions were compared with respect to enjoyment and acceptance. Children in the implicit game condition ($M = 4.11$; SD = 1.45) as well as children in the explicit game condition ($M = 4.63$; SD = 1.09) with diabetes related content enjoyed playing the game [$t(18) = .922$; $p = .369$]. Cohen's effect size d analysis indicated a small effect ($d = .034$) suggesting the superiority of the explicit game over the implicit game version regarding game acceptance and enjoyment. Further analysis revealed a significantly negative relation between participants' age and game enjoyment for the diabetes related game version ($r = -.719$; $p = .001$) but none for the implicit health game version ($r = -.206$). This suggests that the explicit version – although it was in general more liked than the implicit game version – was the less enjoyed the older the participants were (Fig. 2).

In a subsequent analysis, differences between game versions regarding children's perceived similarity to the game character were examined. In general, eighty percent of the participants reported having some similarity to the game character. No significant difference between the implicit ($M = 3.1$; SD = 1.32) and the explicit ($M = 3.7$; SD = 0.89) game version was found [$t(18) = 1.865$; $p = .189$]. However, simple effect analysis revealed a noteworthy medium effect ($d = .064$), implying that participants experienced a higher similarity to the game character when the character was presented as having the same medical condition. A closer inspection of the data revealed a highly significant interrelation between perceived similarity to game character and its likeability for the explicit ($r = .736$; $p < .001$) but not for the implicit game version ($r = .498$).

In order to check the effect of game version on diabetes related self-efficacy, mean ratings were submitted to a t-test. The analysis revealed no significant difference between both game versions [$t(18) = .397$; $p = .537$]. Cohen's d effect size analysis revealed a small effect ($d = .017$), indicating that diabetes related self-efficacy was slightly higher in the explicit than in the implicit game version ($M = 5.13$; SD = 0.54 vs. $M = 4.96$; SD = 0.67; respectively). In addition, differences between game versions in regard to diabetes associated internal locus of control were examined. No statistical difference between the implicit ($M = 4.43$; SD = .622) and the explicit ($M = 4.88$; SD = 0.78) game version was found. However, Cohen's effect size d analysis exposed a notable medium effect ($d = .045$), suggesting a higher health game effectiveness of the explicit over the implicit version on diabetes self-management related internal locus of control.

Based on social learning theory accounts, a positive interrelation between participants' perceived similarity to game character

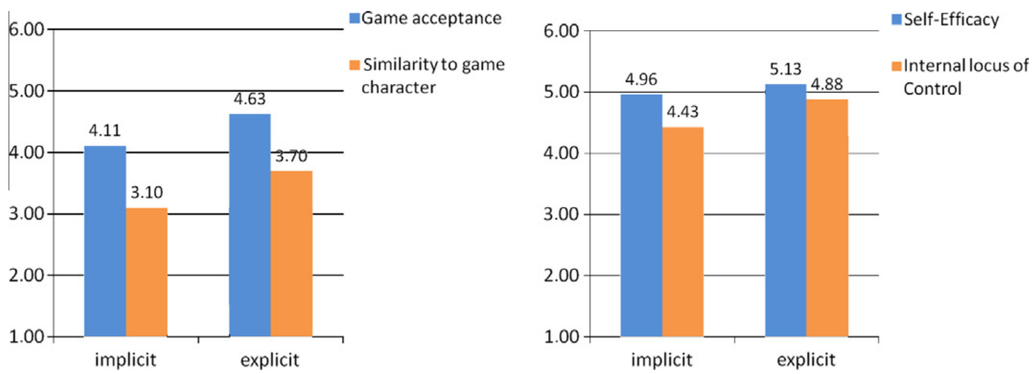

Fig. 2. Mean comparison for the explicit and implicit game version. All depicted variables were assessed on a 6-point rating scale. High values represent high scores on the assessed variables.

and diabetes self-efficacy was expected. In congruency with the above mentioned theory, data analysis revealed a significant statistical correlation between self-efficacy and participants' experienced similarity to the game character ($r = .466$; $p < .05$). Despite participant's higher perceived similarity to game character in the explicit compared to the implicit game version, the results of a regression analysis exposed no moderating interaction effect between game version and perceived similarity to the game character on diabetes self-management related self-efficacy ($b = .032$; $t = .146$; $p = .886$).

6. Conclusion

In order to minimize juvenile reactance towards diabetes associated issues an implicit health game version for the promotion of self-care behavior was developed. Instead of diabetes content, a temperature analogy and its regulation was addressed. The main aim of the present study was to examine the efficacy of the developed implicit health game for diabetic adolescents with regard to diabetes self-efficacy reinforcement. A parallel version of the game, in which diabetes content was directly addressed, served as comparison. Contrary to expectations, the explicit game version was better evaluated than the implicit version with regard to game enjoyment. In line with this finding participants' perceived similarity to game character, diabetes related self-efficacy and internal locus of control was higher in the diabetes game version than in the implicit version. Analogous to social psychology findings [23], game character likeability increased with participant's perceived similarity to the character. Therefore the game character with the diabetes medical condition probably was liked more in the explicit condition due to its higher perceived similarity.

Apparently, the possibility to identify with a game character also suffering from diabetes can be more beneficial than an implicit game version that tries to prevent reactance by not addressing the health relevant content. In accordance with this interpretation, health games designers should allow players to create and modify their game character in order to enhance health game effectiveness. However, the exact causal relations between game effectiveness and participants' perceived similarity are still open and will have to be addressed in detail in further studies. It is, for instance, possible that the superiority of the explicit over the implicit game version regarding its enjoyment and effectiveness could have been elicited by further factors like e.g. participants' perceived higher game meaningfulness when diabetes content was addressed. Alternatively, the advantage of the explicit over the implicit game version might also have been caused by a facilitated integration of experienced game based self-care into the players' cognitive representation of real diabetes self-care when diabetes content is addressed. In accordance with this explanation, psychological research findings suggest that the encoding of specific learning content is facilitated when the learner is able to associate it to existing mnemonic contents [24]. In congruence with this finding, context effects are known to booster information recall when processing and recalling of certain information take place under the same contextual circumstances [25]. Therefore, it is possible that the presence of diabetes context in the explicit game version facilitated the encoding of diabetes-management procedural knowledge, leading to a subsequently stronger activation when self-efficacy concerning diabetes self-regulation was assessed. This could have led to higher perception of diabetes related self-efficacy in the explicit compared to the implicit game condition.

As stated before, a further explanation can be derived from social learning theory. The perceived similarity between participants and game character might have facilitated vicarious learning processes and as a consequence enhanced the diabetes self-efficacy stronger in the explicit than in the implicit game condition. Altogether, based on study results no ultimate conclusion can be drawn with regard to the factors accounting for the superiority of the explicit diabetes-related over the implicit temperature analogy game. Future studies should target the different explanations in more detail and should also rule out additional methodological problems. Here, for example, future studies should employ other alternative metaphors for the implicit version since the temperature regulation analogy might have been oversimplified.

Due to the employed experimental design, no predictions in regard to the temporal persistence of the observed effects on diabetes self-regulation can be made. However, it is all the more astonishing to see that already a 15-min gaming interval yielded differential effects depending on the specific condition. Therefore we assume that a longitudinal study, in which participants play the game at home for a longer period and consecutive measurements of game evaluation and perceived diabetes self-management related self-efficacy are done, would deliver stronger results. However, assessed short-term changes in perceived diabetes self-efficacy are a necessary precondition for long-term changes to occur. Furthermore, the aim of the present study was primarily to test possible existing differences between the implicit and an explicit health game version in regard to game enjoyment and effectiveness, and less to investigate if the observed changes in perceived self-efficacy of diabetes self-management are stable over time. In order to address this research question, a control group with children playing a non health related PC game would have to be employed which we plan to do in further studies.

Certainly, a major limitation of this study can be seen in the small sample size. The low attendance of participants points towards difficulties in recruiting a sample exclusively consisting in children and adolescents with diabetes mellitus. Not only was participant's medical condition a prerequisite for study attendance but also participant's age (11–16), resulting in an additional constraint due to the fact that the young participants depended on their parents in terms of mobility. Furthermore, a two-step flow of communication was necessary for participant's recruitment in order to attain parental approval for including their child in the study and in order to not reveal the study purpose to children. Additionally, a plausible explanation for the low attendance can be seen in patient's time-consuming medical treatment and the high density in medical appointments, which could have led to a low motivation to attend to a further "clinical" appointment. Apparently, the offered compensation and lottery incentive for study attendance were not high enough to motivate participants to take part in the study. Therefore, higher compensation for parents and children should be taken into account when planning an experimental study with participants of a specific population.

As mentioned before, due to the small sample size no significant differences between the game conditions were found. Since results of a post doc analysis revealed a statistical power of less than 50%, no ultimate conclusions about the superiority of the explicit game version over the implicit game can be driven. Therefore further research, with a larger sample size and an additional control condition, is needed before effects regarding diabetes health game content on diabetes self-efficacy and internal locus of control can be generalized.

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