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SYMPOSIUM

Integrative Gaming: A Framework for Sustainable Game-Based Diabetes Management

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Abstract

Obesity and diabetes have reached epidemic proportions in both developing and developed nations. While doctors and caregivers stress the importance of physical exercise in maintaining a healthy lifestyle, many people have difficulty subscribing to a healthy lifestyle. Virtual reality games offer a potentially exciting aid in accelerating and sustaining behavior change. However, care needs to be taken to develop sustainable models of employing games for the management of diabetes and obesity. In this article, we propose an integrative gaming paradigm designed to combine multiple activities involving physical exercises and cognitive skills through a game-based storyline. The persuasive story acts as a motivational binder that enables a user to perform multiple activities such as running, cycling, and problem solving. These activities guide a virtual character through different stages of the game. While performing the activities in the games, users wear sensors that can measure movement (accelerometers, gyrometers, magnetometers) and sense physiological measures (heart rate, pulse oximeter oxygen saturation). These measures drive the game and are stored and analyzed on a cloud computing platform. A prototype integrative gaming system is described and design considerations are discussed. The system is highly configurable and allows researchers to build games for the system with ease and drive the games with different types of activities. The capabilities of the system allow for engaging and motivating the user in the long term. Clinicians can employ the system to collect clinically relevant data in a seamless manner.

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Introduction

Games and virtual reality represent an intriguing opportunity for addressing the needs of chronic disease management and prevention. Diabetes management requires long-term behavior change. Games provide environments that seek a patient's attention, participation, motivation, and retention, and offers dynamic adaptation. They provide a natural, easy, and fun-to-use interface, seamlessly integrating recreation and disease management. From a clinical perspective, games can address several unmet needs. First, games can address issues with compliance. As the treatment for diabetes is long-term, clinicians often struggle with teaching the patients the value of compliance and how to maintain compliance. Games can help address educational needs and allow clinicians to keep track of patients through online monitoring of gameplay, scores, etc. Second, games can

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Abbreviations: (app) application, (BDNF) brain-derived neurotrophic factor, (UDK) Unreal Development Toolkit, (VO_2 max) peak oxygen uptake

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provide engaging environments to encourage exercise. Third, games can be employed to encourage proper nutritional practices. We discuss previous work in each of these domains to identify the opportunities and challenges of employing games.

Games Focused on Teaching Compliance

Games can be an effective aid in educating children and young adults about diabetes management.[1] Several video games have been designed to teach children and young adults about the need for compliance to a treatment regime.[1–3] Aoki and colleagues[4] employed games designed for traditional computers and a gaming console (Nintendo® Game Boy Advance) to educate patients on diabetes management. Researchers developed three games: Tamagoya (egg breeder), Tantei (detective), and Magic Room. In Tamagoya, game players feed insulin or food to an egg and get an egg to exercise for a simulated week. After a week, the egg hatches with a chicken whose visual appearance and behavior is a result of the care that the patient provided to the egg before hatching. This type of game persuades the user toward appropriate behavior by providing a visualization of effects of good/bad behavior practices. In Tantei, game players control a virtual detective who has type 1 diabetes mellitus and is chasing a criminal. The detective has to stop during the chase to maintain plasma glucose levels by consuming food or insulin. Feedback on current glucose levels is given through a heads-up display on a corner of the screen. During predefined stages in the game, users have to answer a quiz centered on knowledge of diabetes management. This game provides users with visualization of their behavior as effects on the virtual detective. Further, it also provides users a means to test and apply their knowledge about type 1 diabetes mellitus. The Magic Room game gives user a task (in this case, build structures with bricks), while maintaining plasma glucose levels in control through proper nutrition. Magic Room focuses on food intake and teaches intricacies of high glycemic versus low glycemic index food. This game is aimed to inculcate appropriate nutritional behavior practices. The researchers tracked the usability of the game, degree of entertainment, and clinical usefulness. Users showed positive reflections on all these parameters as reported through a self-assessment questionnaire. The authors concluded that games could be employed successfully for initial educational interventions.

A study by Smith and colleagues[5] showed that self-monitoring and feedback through glucometers and photographs of behavior and activities of patients can provide a persuasive framework for sustaining continuous compliance and self-reflection. The study augmented data from glucometers with digital photographs that patients carried to record their activities to discuss with their health care providers. The qualitative study for a period of 4–8 weeks showed that such a system was generally beneficial for patients and clinicians to modify behavior through reflection although no quantitative analysis was performed. Further, there were no data reported on long-term adherence to these tools, but it was reported that behavior change with this intervention was cyclical and lapse and relapse both occurred. While the system did not present a gaming paradigm, it could be easily extended to a gaming paradigm wherein picture-taking and glucose readings have an incentive and scoring system associated with them.

Another study focused on the need for personalization of interfaces and games for diabetes patients.[6] The study did extensive interviews, observations, and shadowing with diabetes patients and showed that any system for compliance and education needs to be highly personalized and user-centered. This is an important result for design of any game or system for compliance, exercise, or nutrition.

Games for Exercise

Goodyear and Kahn[7] explored the effectiveness of exercise as a treatment for both insulin-dependent and noninsulin-dependent diabetes mellitus. They explored the biochemical basis of how exercise and insulin affect rate of glucose uptake. The paper argued that insulin-based treatments and exercise follow different signaling pathways and that exercise can be beneficial for patients with insulin resistance. Several papers show that short-term glucose uptake is significantly improved by exercising and glucose control over the long term reduces risk of major complications such as eye disease by 76%, kidney disease by 50%, nerve diseases by 60%, cardiovascular disease risk by 42%, and nonfatal heart attack, stroke, or death risk by 57%.[8] However, there is mixed evidence on whether exercise can actually lead to sustained overall glucose control. This suggests that exercise needs to be performed continuously as part of the management regime of diabetes patients and it needs to be sustained over long periods of time.

This need for sustained adherence to an exercise regime makes persuasive interventions and games an ideal method to motivate users. There have been several reported efforts in employing games for exercising. Southard and Southard[9] showed that games can be employed for increasing physical activities in children through a collaborative game called MetaKenKoh driven by pedometers and a cloud-based information analysis and sharing system. They showed that both healthy and overweight subjects increased activities over the 1-week period of the experiment. Oliveira and Oliver[10] aimed to encourage runners to meet their goal by musical feedback on their progress, a visual interface to give progress feedback, and a competition mode to compete with other runners on a mobile device. It was shown that adding the persuasive elements of feedback and competition improved the exercise times by 45%. This result emphasizes the importance of competitive gaming, visual feedback, and exercise measurement.

Consolvo and colleagues[11] developed a mobile phone-based game to motivate users to exercise. Their system was designed as a social gaming system wherein subjects shared their walking statistics with other participants on a smart mobile phone. A simple study showed that the group that shared their results with other participants met their goals of exercising significantly more times than the participants who used the game system individually ($p < .05$). In a similar vein, Mueller and colleagues[12] presented a framework wherein exertion interfaces (defined as systems that demand physical exertion) could be designed to address three core concepts of (1) exertion, (2) sociality, and (3) engagement that provide meaning to the activities of the user. The authors argued that exertion should be linked with activities that give users the perception of accomplishing something and sociality should be encouraged by designing collaborative scenarios. These provide users with engagement and meaning, and games can be ideal method of meeting these requirements.

An important research component of exercise and game-related research lies in validating that sensors used in the games can predict energy expenditure. Traditionally, energy expenditure and exercise efficiency is measured through sophisticated means such as peak oxygen uptake (VO_2 max).[13–15] These measures have been validated and provide researchers and clinicians with a reliable measure. However, games traditionally use sensors such as accelerometers and gyrometers and in some cases pedometers. Chen and colleagues[16] showed that movement measured using accelerometers at the hip and wrist could be used to predict energy expenditure accurately in diabetes patients. This is an important result that suggests the validity of employing these sensors for monitoring exercise and its impact on patients. In another study, Sorenson and colleagues[17] showed that VO_2 max could be estimated by monitoring heart rate. This means that by monitoring movements and heart rate, it is possible to estimate energy expenditure in a game.

In summary, motion and activity sensors coupled with persuasive framework can offer a means to enabling sustained exercise. Using gaming and its core tenets, it is possible to offer diabetes patients fun and engaging means to exercise while collecting clinically relevant data.

Games for Nutrition

One area of research in gaming and diabetes has focused on using games as an educational tool pertaining to nutrition. Corbett and colleagues[18] developed a gaming system to teach didactic information about nutrition. The authors showed that nutrition basics could be successfully taught using games. However, long-term retention of the principles was not studied. A study by Aoki[4] also showed similar results with their games on nutrition (Magic Room).

Another direction of research lies in real-time analysis of nutrition wherein users are allowed to monitor their nutrition on demand and real-time feedback is provided. Pollak and colleagues[19] developed an iPhone application (app) that allows users to take photographs of their daily food consumption and receive feedback on their food habits and trends through a game-based format. The system showed a positive impact. The system required human observers rating the food pictures rather than an automatic algorithm to analyze image contents to predict nutrition-related variables such as calorie content. There has been some work in development of the automated algorithm and results are encouraging.[20] In a similar vein, there are several apps available for smart phones that lets users self-report their nutrition intake and receive feedback on their habits and behavior.

Another important research area from a persuasive perspective lies in development of celebratory technologies. Grimes[21] argues that most technology for nutrition that gives feedback is corrective in nature. It tries to alter behavior radically rather than engaging users by celebrating their positive habits. This approach is novel from a persuasive perspective and may represent an intriguing direction in gaming that traditionally focuses on competition and strict performance measurement with little in terms of motivation.

In summary, there are several reported attempts at games for diabetes management. These experiments have yielded encouraging initial results and several insights into how persuasive frameworks such as games can be employed for chronic disease management. First, games can provide an adequate mechanism to augment conventional didactic face-to-face diabetes education as well as increasing physical activity. Second, personalized management can increase the effectiveness of games. Games naturally lend to providing competitive environments that can be a motivator for increased physical exercise. Real-time feedback of nutritional intake can be a powerful aid and games can serve as an effective means of encouraging existing good habits of users.

While games in general are seen as an attractive option for chronic disease management, games also suffer from key limitations. Games generally have a short shelf-life and often the cost of developing them can far outweigh the benefits of games in the long term. In order to sustain interest in games, it is important to change the games regularly and develop new scenarios that require additional resources, and personalization has not been handled effectively in almost all experiments reported. These factors are often a large barrier in games providing a sustainable clinical option. This is also one of the reasons why there is a dearth of data on long-term viability of games.[22]

Integrative Gaming: A New Paradigm for Serious Games for Diabetes

One way to address the limitations of games as a clinical intervention is to follow an app store model. Started by Apple®, an application store or app store has become *the modus operandi* of providing users with interesting applications on a common hardware/software platform. Based on the principles of micropayments, individual vendors provide applications on a common platform and users can buy an application of choice. This model has proven to be very beneficial for providing users with a variety of choices and provides a sustainable platform. It provides personalization for users who can choose what they like. The individual applications can be built according to specifications, and offer competition and didactic education and encourage health-promoting behaviors through incentives within the application design. To allow for this type of model, there is a need for unified gaming software and hardware that can support gaming-based clinical interventions. This platform would be based on available computational resources such as personal computerss, gaming platforms such as Xbox®, PlayStation®, or Wii®, and provide middleware to allow measurement and improvement of clinical outcomes from the games.

To address this need, an integrative gaming paradigm is proposed. The core idea of an integrative gaming system is that it links various activities a user is supposed to perform such as measuring glucose levels, taking insulin, performing exercises, and conducting problem-solving, through a game-based storyline. **Figure 1** shows the overall prototype design for our integrative gaming unit. In this design, a central unit links a variety of exercise equipment together into a single unit. A patient can start with any exercise equipment and then move in a counterclockwise or clockwise manner through the different exercises. In a competitive mode, multiple patients can circle through the system. Flat screen televisions give users visual feedback on their performance by providing a persuasive game scenario. We chose the design to be attractive to motivate the users to use the system and perform the exercise. It was also designed for a gym-like setting but can be adopted to have a smaller form factor and a single screen setup for homes. At home, the system is designed to function off a standard laptop, desktop computer, or gaming console. Our gaming system has the ability to be configured to allow gameplay with any type of exercise. The exercise equipment could be a treadmill or any equipment for cardiovascular training. In this prototype, every exercise can be visualized as a stage of a game where the story of the game links all the activities in a single cohesive unit. Sensors on the patient or exercise equipment help record movement, heart rate, oxygenation levels, etc., and drive the games. An important design choice was that the transitions between exercises would actually provide an opportunity for cognitive exercises. While there is very little reported on the value of cognitive exercises in overall exercise adherence within the context of diabetes, research shows that exercises that combine

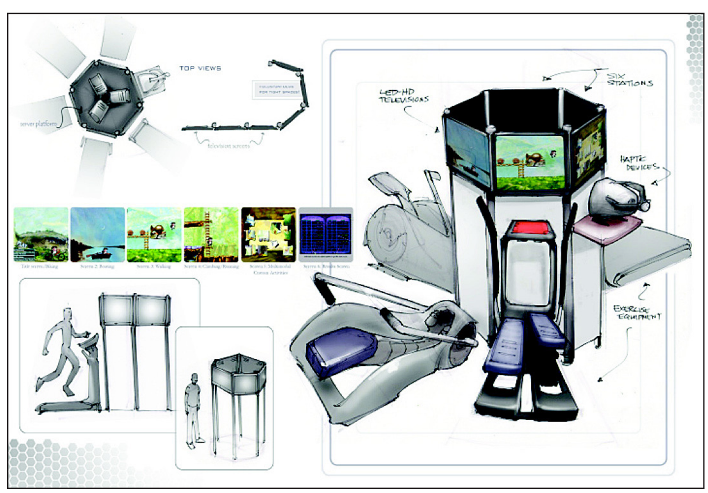

Figure 1. Integrative gaming prototype design.

cognitive and physical dimensions can be more engaging and motivational.[23] In fact, recent experiments on the impact of exercise on cognitive function have shown encouraging results that both resistance training and cardiovascular training increase brain-derived neurotrophic factor (BDNF), a molecule that increases neuronal survival, enhances learning, and protects against cognitive decline.[24] This impact of exercise on increased BDNF has been shown in humans[25] and evidence clearly points to the close relationship between physical exercises and cognitive function. Our proposed system is aimed to leverage this positive relationship and also provide data to further elucidate the relationship between cognitive exercise and physical exercise. This system is analogous to circuit training but with persuasive elements to encourage exercise and measure cross-platform performance of the patient.

Figure 2 shows the actual prototype that was designed. The patient wears movement sensors on their legs, hands, and head and is moved to the cross-country skiing exercise unit. The patient also wears a wireless heart rate sensor. The movement sensors we employed were Movea Sensors® (Movea Inc., Grenoble, France), which are wireless integrated accelerometer, gyrometer, and magnetometer sensors and provide data on the movement of joints where the sensors are placed. Heart rate was measured by Wireless Pulse Oximetry (Nonin Medical Inc., Plymouth, MN) from Alive Technologies. In the first design, we implemented the following game scenario.

The patient is welcomed to an exercise themed around sustainability. In the first stage of the game, the patient walks or runs on a treadmill to power an airplane that is carrying cans to the recycling plant nearby.

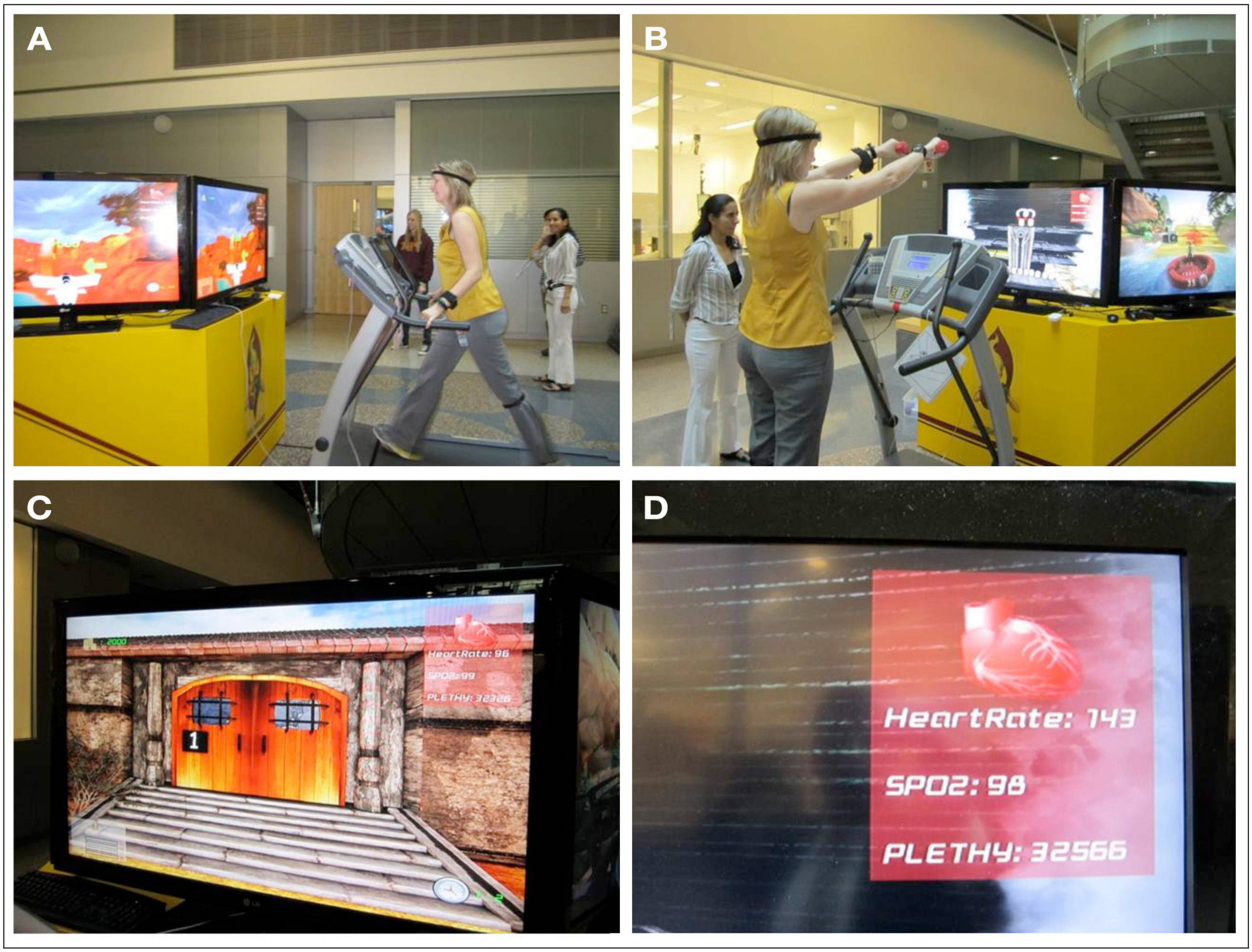

Figure 2. Exercise prototype. **(A)** Subject using treadmill for first stage. **(B)** Subject using dumbbells for third stage. **(C)** Screenshot of digitspan test. **(D)** Feedback of physiological information during the game.

The walking or running offers physical exercise. To add the dimension of upper body exercise, the user has to control the direction of the plane by moving his or her head left or right to guide the direction of the plane. As the plane moves through the terrain, the patient gains virtual currency by reaching for coins. When the patient reaches the factory, she or he opens the gates by repeating numbers that show randomly on the screen. This is integration of the digit span test, which is a cognitive exercise and attention measurement exercise.[26] It provides a break from the exercising but keeps the engagement levels high and provides clinicians with information on cognitive engagement and performance that may be relevant in designing further interventions. Inside the factory, the patient holds stretchable exercise bands or dumbbells, takes cans from the bag they brought on the plane, and places them in receptacles that appear at different locations and heights. This exercise focuses on the patient's upper limbs and provides stretching and upper body exercise. At the end of this stage, the patient has to open the door to the next stage by performing a mental rotation task wherein shapes appear on the screen and have to be matched to their rotated counterpart. This is again a cognitive exercise[26] meant to offer engagement and also measurement of the cognitive capabilities of patients. Once the new stage of the game is opened, the patient's goal is to crush the collected aluminum cans to make a recycling bin or metallic toy from the material. The patient crushes the cans by a karate chop from the left hand, a karate kick, and then another karate chop from the right hand. At the end of the game session, a metallic toy is generated from the crushed cans; its size represents the quality of exercise achieved during the session.

In this manner, the patient goes through stages that provide multiple ways to get exercise. The game provides scores for both the individual stages and the entire exercise session. All the stages of the game can be played on a single screen, allowing multiple users to compete with each other on the same game simultaneously on different screens. The system can integrate an initial stage wherein a user is requested to input their glucose levels from a glucometer, which would enable a user to have multiple options in the game. For example, a good glucose score may enable a user to get a bonus in the game or use a better plane to fly. Similarly, automated or self-reported food reports can provide incentives and coaching within the game context.

A key feature of the developed system is that developers can easily change individual stages of the game. We employed the freely available Unreal® Development Toolkit (UDK), (Epic Games, Cary, NC) to develop games. The kit is free for noncommercial use but requires revenue-sharing for commercial use. There are several gaming scenarios available for the UDK platform, and the library allows for easy integration of sensors and exercises with the already designed scenarios. Further, the system can be set to shift with ease between different forms of exercises that are linked with a story. For example, in the first stage, the plane could be flown by biking rather than running. This type of configurability gives users the ability to exercise according to their preference on a particular day. The clinician simply has to select an activity to drive a stage of the game. It is also important to note that the system does not need development of specialized exercise equipment but can leverage existing equipment.

The system can offer user personalization through three mechanisms. The first mechanism is the adaptive framework wherein the game engine monitors the progress of a patient in games over multiple uses and then adapts the difficulty level of the game to the current ability level of the patient. For example, in first stages, coins become increasingly hard to gather if the patient over multiple trials can complete a task below a certain time threshold and above a certain average heart-rate threshold. As the aim of the system is to allow individuals to get physical exercise and an elevated heart rate, our systems continuous adaptation motivates the individual to increase their physical stamina and exercise. The second mechanism lies in affordance built into our system. Affordance in human computer interaction refers to a system providing multiple methods of accomplishing an action. This in essence gives users the choice of accomplishing exercise by multiple means. As we have mentioned before, our proposed system can be easily adapted to different types of exercise. The wearable computing platform (movement sensors and heart rate sensor) can be employed to measure exercise on any platform that allows for high levels of configurability. The third mechanism in our proposed framework centers on giving users the choice of different difficulty levels. At the beginning of each stage, the user is offered a choice between an easy, medium, and hard level of the game. For example, in the easy iteration of flying the plane through the Grand Canyon stage, the user has to go through a course that has 15 coins and roughly takes approximately 5 minutes to complete, but in the medium stage, the user has to collect 25 coins and the stage takes approximately 10 minutes to complete. This choice sets up the initial difficulty level of a stage and then the adaptive algorithm varies the difficulty within the chosen stage.

While personalization in terms of personalized avatars is not yet included in our system, it is possible to build those features into future version of the games.

The underlying algorithms and data collection system store the data on a cloud-based system. Using the cloud-based system, data are stored in an online repository and is easily accessible by a website. This allows clinicians to have remote access and easy integration into electronic medical records. Reporting and data analysis tools available on the cloud allow for effective analysis of data and enable integration of the physiological information into biosignatures and clinical repositories. This is an important feature of our system and has several implications. We expect that such a system would enable remote data to be collected seamlessly and provide clinicians with continuous information on a patient. We also expect that in the future, such a system would be highly useful in clinical trials where such a system could be employed for continuous monitoring and formative evaluation.

A key feature of our developed system is the cost. The main drivers of the system's cost are the wearable sensors and the software. The software is available for free and sensors such as accelerometers and heart rate sensors are extremely affordable ($20–100 per unit). This allows us to enable a user to exercise with existing equipment or without equipment. For example, a user could run on one point rather than on a treadmill to clear the first stage. Similarly, in the third stage, a user could employ a variety of means to get upper body exercise. The system is scalable to high fidelity representations with use of multiple screens and high-end sensors when needed. This allows for a continuum of exercise equipment from the gym to the home around the same concept of integrative gaming.

Conclusions

Games provide an exciting new avenue for diabetes management. However, it is important to leverage the capability of games in an effective manner. We propose an integrative gaming system that provides a sustainable platform for integrating a variety of games to offer diabetes management. This gaming system can be leveraged by developers and clinicians to offer customizable regimes for their patients. Future work will include validation of this developed system in terms of usability, compliance, and effectiveness. We will also develop additional scenarios of the games and allow for further personalization.

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References:

1. Barry B. Games and activities to teach children about diabetes and nutrition. Diabetes Educ. 1995;21(1):27-30.
2. Brown SJ, Lieberman DA, Germeny BA, Fan YC, Wilson DM, Pasta DJ. Educational video game for juvenile diabetes: results of a controlled trial. Med Inform (Lond). 1997;22(1):77-89.
3. Chiarelli F, Di Ricco L, Catino M, Sabatino G, Verrotti A. Modern management of childhood diabetes: a role for computerized devices? Acta Paediatr Jpn. 1998;40(4):299-302.
4. Aoki N, Ohta S, Masuda H, Naito T, Sawai T, Nishida K, Okada T, Oishi M, Iwasawa Y, Toyomasu K, Hira K, Fukui T. Edutainment tools for initial education of type-1 diabetes mellitus: initial diabetes education with fun. Stud Health Technol Inform. 2004;107(Pt 2):855-9.
5. Smith BK, Frost J, Albayrak M, Sudhakar R. Integrating glucometers and digital photography as experience capture tools to enhance patient understanding and communication of diabetes self-management practices. J Per Ubi Comp. 2007;11(4):273-86.
6. Chen Y. Take it personally: accounting for individual difference in designing diabetes management systems. In: Kalskov K, Petersen MG, editors. Proceedings of the 8th ACM Conference on Designing Interactive Systems; 2010 Aug 16-20; Aarhus, Denmark. New York: ACM; 2010. p. 252-61.
7. Goodyear LJ, Kahn BB. Exercise, glucose transport, and insulin sensitivity. Annu Rev Med. 1998;49:235-61.
8. Cefalu WT. Glycemic control and cardiovascular disease--should we reassess clinical goals? N Engl J Med. 2005;353(25):2707-9.
9. Southard DR, Southard BH. Promoting physical activity in children with MetaKenkoh. Clin Invest Med. 2006. 29(5):293-7.
10. Oliveira Rd, Oliver N. TripleBeat: enhancing exercise performance with persuasion. In: ter Hofte GH, Mulder I, de Ruyter, BER, editors. Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services; 2008 Sep 2-5; Amsterdam, The Netherlands. New York: ACM; 2008. p. 255-64.
11. Consolvo S, Everitt K, Smith I, Landay JA. Design requirements for technologies that encourage physical activity. In: Grinter R, Rodden T, Aoki P, Cutrell E, Jeffries R, Olson G, editors. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems; 2006 Apr 22-27; Montreal, Quebec, Canada. New York: ACM; 2006. p. 457-66.
12. Mueller FF, Agamanolis S, Vetere F, Gibbs MR. A framework for exertion interactions over a distance. In: Spencer SN, Davidson D, Fullerton T, Schrier K, editors. Proceedings of the 2009 ACM SIGGRAPH Symposium on Video Games; 2009 Aug 3-7; New Orleans, Louisiana: New York: ACM; 2009. p. 143-50.
13. Williams CA, Ratel S, Armstrong N. Achievement of peak VO_2 during a 90-s maximal intensity cycle sprint in adolescents. Can J Appl Physiol. 2005;30(2):157-71.
14. Proctor DN, Koch DW, Newcomer SC, Le KU, Smithmyer SL, Leuenberger UA. Leg blood flow and VO_2 during peak cycle exercise in younger and older women. Med Sci Sports Exerc. 2004;36(4):623-31.
15. Armstrong N, Welsman J, Winsley R. Is peak VO_2 a maximal index of children's aerobic fitness? Int J Sports Med. 1996;17(5):356-9.

16. Chen KY, Acra SA, Majchrzak K, Donahue CL, Baker L, Clemens L, Sun M, Buchowski M. Predicting energy expenditure of physical activity using hip- and wrist-worn accelerometers. Diabetes Technol Ther. 2003;5(6):1023-33.

17. Sørensen H, Overgaard K, Pedersen PK. Estimation of VO2max from the ratio between HRmax and HRrest--the Heart Rate Ratio Method. Eur J Appl Physiol. 2004;91(1):111-5.

18. Corbett RW, Lee BT. Nutriquest: a fun way to reinforce nutrition knowledge. Nurse Educ. 1992;17(2):33-5.

19. Pollak J, Gay G, Byrne S, Wagner E, Retelny D, Humphreys L. It's time to eat! Using mobile games to promote healthy eating. IEEE Pervasive Computing. 2010;9(3):21-7.

20. Antonelli A, Cocchi M, Fava P, Foca G, Franchini GC, Manzini D, Ulrici A. Automated evaluation of food colour by means of multivariate image analysis coupled to a wavelet-based classification algorithm. Analytica Chimica Acta. 2004;515(1):3-13.

21. Grimes A, Harper R. Celebratory technology: new directions for food research in HCI. In: Burnett M, Francesca M, Catarci T, de Ruyter B, Tan D, Czerwinski M, Lund A, editors. Proceeding of the 26th Annual SIGCHI Conference on Human Factors in Computing Systems; 2008 Apr 5-10; Florence, Italy. New York: ACM; 2008. p. 467-76.

22. Baranowski T, Buday R, Thompson DI, Baranowski J. Playing for real: video games and stories for health-related behavior change. Am J Prev Med. 2008;34(1):74-82.

23. Kahol K, Nørgaard Jensen C, Smith ML, Dilli S, Johnson K. Integrative rehabilitation through gaming. CyberTher & Rehab. 2010;13(2):30-2.

24. Cotman CW, Engesser-Cesar C. Exercise enhances and protects brain function. Exerc Sport Sci Rev. 2002;30(2):75-9.

25. Rasmussen P, Brassard P, Adser H, Pedersen MV, Leick L, Hart E, Secher NH, Pedersen BK, Pilegaard H. Evidence for a release of BDNF from the brain during exercise. Exp Physiol. 2009;94(1):1062-9

26. Lezak MD. Neuropsychological assessment. 4th ed. New York: Oxford University Press; 2004.