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Original Article

The Use of Videogames, Gamification, and Virtual Environments in the Self-Management of Diabetes: A Systematic Review of Evidence

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Abstract

The use of videogames in healthcare interventions is gaining popularity, but there is still a gap in the understanding on how these types of interventions are used for the management of diabetes. The purpose of this review is to examine published research on the use of videogames for diabetes management. With the increased use of mobile technology, the review was expanded to understand whether games, gamification, and virtual environments can be used for diabetes self-management. Out of the 307 articles identified, only 10 articles met the inclusion criteria of the study. The duration of most studies was short, with small sample sizes. All interventions targeted behavioral changes examining risk reduction of diabetes-related risk and promotion of healthy behavior among study participants. Videogames appeared to be helpful tools for education in some interventions, whereas gamification and virtual environments increased extrinsic motivation and provided positive reinforcement. This review concludes by discussing the potential of using videogames and gamification for the self-management of diabetes.

Introduction

Diabetes is a chronic metabolic condition that is especially costly for individuals diagnosed with it.[1] Complications that may arise from diabetes include heart disease, blindness, and renal failure. Regular monitoring of the condition and securing optimal glycemic control through effective self-management practice are critical in reducing micro- and macrovascular complications due to the disease.[2]

Playing videogames has been shown to foster extrinsic motivation and increase positive emotion.[3] Linking this to the sphere of health behavior, serious videogames can be a promising novel avenue that seeks to entertain the user while attempting to elicit some form of change in behavior. Such games may be perceived as only being entertaining, which perhaps explains the gap in the number of clinical studies. However, serious games are developed with a specific purpose rather than purely for entertainment. Serious games can be designed to modify user attitudes, perceptions, knowledge, and skills[4] and requires tailoring to a targeted sociodemographic group.[5]

Gamification has been described as the ''use of game design elements in non-game contexts.''[6] It leverages on a person's desire for achievement, competition, collaboration, self-expression, learning, and altruism. The process itself would be to equate activities in nongame contexts with ''points'' and provide external rewards (e.g., badges, leadership board placement, cash incentives) for reaching point thresholds.[7] The idea of gamification is to make a task feel more like a game, thus encouraging the users to engage in the activity to achieve the desired outcomes.

Some of the issues with diabetes management is that people with diabetes display negative attitudes, coping difficulties, and low motivation toward self-monitoring and regimen adherence.[8,9] One novel way to address this issue introduces elements from game-based approaches or ''gamification'' into diabetes initiatives, such as for self-monitoring and diabetes education. By gamifying mundane responsibilities such as taking blood glucose readings, the person may be more motivated to complete such tasks. Similarly, rather than presenting information about diabetes healthcare behavior, gamification involves learning in an engaging manner.

This study extends the concept of gamification to virtual environments (VEs), showcasing a novel platform that allows individuals to tap into their innate desire to socialize, interact, and express themselves online. Within the VE, a multisensory, interactive, and three-dimensional environment is created for a specific purpose, making the experience

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game-like yet retaining aspects of the real world. These VEs have been shown to augment traditional care in the management of diabetes[10] and allow patients with diabetes to ''attend'' group sessions, learn about lifestyle change, and gain social support. Therefore, VEs offer unique opportunities to reach out to populations with diabetes[11] in a cost-effective method.

There has been a steady increase in the use of technology for the management of diabetes. A majority of the studies focused on the glucose monitoring process—such as allowing patients to upload their data so that healthcare providers may adjust their medication and dosage.[12,13] Technology interventions were observed to be effective and versatile in facilitating the management of the condition[14,15] and support the resultant changes in lifestyle.[16]

With increasing interest in the use of games for health care, the objective of this study is to review the literature that focuses on the use of videogames, gamification methods, and VEs for day-to-day self-management of people with diabetes. The three types of interventions share a common goal of using various techniques to engage and motivate people to achieve healthy behavior. Videogames and VEs are technology-based interventions, whereas gamification is an approach of applying game mechanics and game design techniques to engage and motivate users to achieve their goals. In order to measure the outcomes of the interventions, the studies reviewed will be compared across behavioral, knowledge-based, biological, and psychological dimensions.

Materials and Methods

Research questions

Three research questions (RQs) guided the design of this study. These are as follows: (RQ1) What are the characteristics of videogame, gamified application, or VE studies for the management of diabetes? (RQ2) What are the targeted behaviors for these interventions? (RQ3) What are the key findings from the studies?

Data sources

We searched four databases (PubMed, Web of Science, Scopus, and PsychINFO) on October 31, 2014 using the key words of diabetes with ''gamifi*'' OR ''virtual reality'' OR ''virtual environment'' OR ''video gam*''OR ''mobile gam*'' OR ''computer gam*'' in the key word search. The asterisk (*) was used in order to expand the search to include terms such as ''games,'' ''gaming,'' ''gamification,'' etc. We also confined the searches to only subheadings, abstracts, title, and key words with a limit to the publication date between 2000 to 2014. Searches were confined to English language journals, and dissertations were excluded as access to the abstracts contained insufficient information to be used as evaluation.

The inclusion criteria were as follows: (1) The study was focused on people with diabetes in managing their health conditions. (2) At least one videogame, VE, or gamified approach was used as the primary intervention. (3) The study included qualitative or/and quantitative measures. (4) The study was an original article and not a review of other studies.

The publications shortlisted were measured against the 22-item Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for cohort studies[17] for the measurement of studies in epidemiology. The checklist aims to strengthen the reporting of observational studies by researchers. Incomplete and inadequate reporting of research often hampers the assessment of merits and weaknesses seen in the literature. The STROBE checklist is highly endorsed and consists of a collaborative international initiative of epidemiologists, methodologists, statisticians, researchers, and journal editors. Two authors measured against the checklist and shortlisted 10 publications, which met an average of 17.9 out of 22 quality criteria of the STROBE framework. One publication was removed, as it did not meet even half of the items on the checklist.

The unit of analysis of this article is the intervention or project. If the same intervention was featured in more than one publication, the primary study was selected for this review.

Data extraction

The authors extracted the data from the articles using predetermined tables that were entered into an Excel® (Microsoft, Redmond, WA) spread sheet for further analysis. The data extracted from the studies included (1) author and year of publication, (2) description of the study, (3) theoretical background of the intervention, (4) intervention platform, (5) research design (study type, duration of study, sample size, age), (6) measured outcomes (target behavior, knowledge, self-efficacy, biological, psychosocial), and (7) key outcomes.

Target behavior for change is based on the American Association of Diabetes Educators' AADE7™ Self-Care Behaviors to measure behavior change as a desired outcome for diabetes education.[18] The AADE7 consists of seven primary goals, and two authors categorized the studies separately and sorted out any disagreement on the shortlisted studies through mutual agreement.

Results

RQ1: Characteristics of interventions

The search identified 307 articles (Fig. 1), and 10 studies met all the inclusion criteria. Four studies were based on videogames,[19–22] three studies used VEs,[23–25] and three studies used principles of gamification for the management of diabetes.[26–28]

Three studies reviewed used a randomized control trial (RCT) design.[19,22,25] Five were quasi-experimental,[23,24,26–28] one was a qualitative focus group discussion,[20] and one study was of an independent measures experimental design.[21] In addressing RQ1, a summary of the reviewed studies' characteristics is presented in Table 1.

Platform. Three studies adopted the Second Life program as a medium for intervention.[23–25] Two used mobile phones.[20,27] One study used a humanoid robot called ''Nao,''[26] one used modified exercise cycles with a videogame attachment,[19] one used the Nintendo® (Kyoto, Japan) Wii™,[22] and one developed an Flash videogame.[21] The final study tested the effects of the glucometer in conjunction with the Nintendo DS™.[28]

Study methodology. Of the studies reviewed, five studies were quantitative,[19,21,22,25,28] four mixed methodologies,[23,24,26,27]

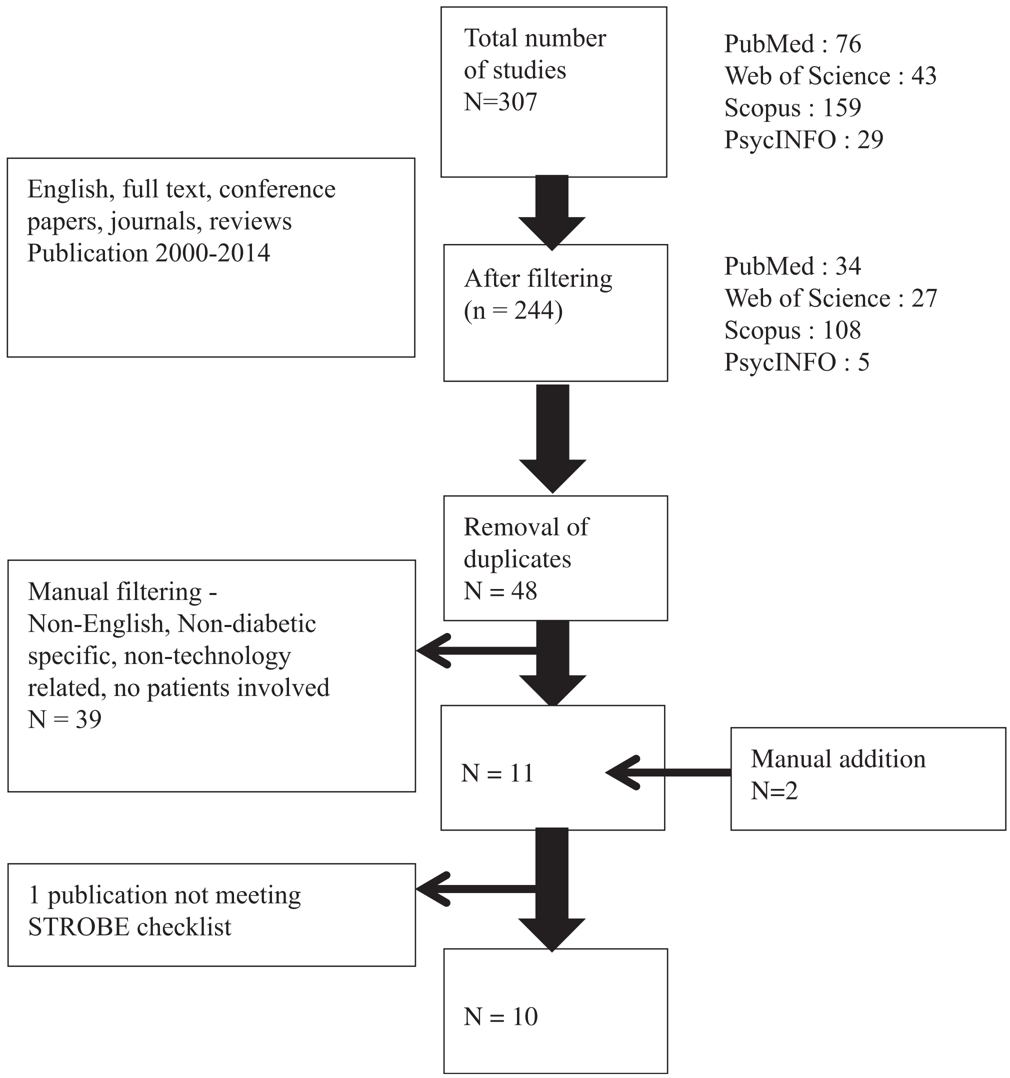

FIG. 1. Flow diagram of search results. STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.

and one was qualitative.[20] A shared feature across the quantitative studies was measures of satisfaction and acceptability. There were only three studies in those reviewed that used RCTs.[19,22,25]

Duration. Duration of the studies ranged from single 10–30-minute sessions for videogames and up to 6 months for more immersive conditions.

Sample size. Sample sizes for a majority studies reviewed were small, having fewer than 50 participants.[19–21,23,24,26,27] Only three studies had sample sizes above 50.[22,25,28]

Age. Four studies focused their interventions on children, youth, and young adults, with ages ranging from 5 to 24 years.[21,26–28] The remaining studies recruited adult and elderly participants, with individuals ranging in age from 38 to 88 years.[19,20,22–25]

Study attrition rates. Dropout rate statistics were not available for most studies.[19–21,23,24,26,28] One study had 2 out of 20 participants not completing the intervention,[27] one had 44 out of 220 dropping out,[22] and another had 5 out of 89 dropping out of the study.[25]

RQ2: Targeted behavior

The targeted behavior section in Table 2 summarizes key findings addressing RQ2. To standardize behavioral outcomes, shortlisted studies were compared against behavioral outcomes set by the AADE7. Table 2 also summarizes the original authors' findings and methodologies used in the respective studies.

Four studies encouraged ''healthy eating.''[20,21,23,24] Five studies sought to motivate participants to ''be active.''[19,22–25] Three studies had a focus on improving blood glucose ''monitoring.''[23,27,28] Three studies stressed the impact of and directly encouraged ''taking medication.''[21,23,24] Four studies[21,23,24,26] promoted ''problem-solving'' skills. All the interventions investigated in this study were aimed at behaviors associated with ''reducing risk.'' Furthermore, the majority of the studies ($n=9$) also advocated ''health coping'' behavior.

Table 1. Description and Characteristics of Studies Meeting Inclusion Criteria

Reference (year)	Description of study	Theory	Platform used (type of intervention)	Study type	Duration of study	Sample size (dropout rate)	Age (years)
Anderson-Hanley et al.[19] (2012)	Exploratory on the neuropsychological effects of exercise among older adults with diabetes and feasibility of using exergaming as a viable exercise		''CyberCycle'' exergame (videogame)	Quantitative	3 months	20 (NA)	60–88
Blanson Henkemans et al.[26] (2013)	Assessed the effects of an educational play with a personalized robot on the enjoyment, motivation, and acquisition of health knowledge of children with diabetes	Self-Determination Theory	''Nao'' the Robot (gamification)	Mixed	9 weeks	5 (NA)	8–12
Cafazzo et al.[27] (2012)	Adolescents with type 1 diabetes were provided the ''bant'' application for the iPhone and a Bluetooth glucometer for automated reading transfer to the application. Routine health behaviors and actions were rewarded in using iTunes gift cards.	Behavior Change Theory	iPhone (gamification)	Mixed	12 weeks	20 (2)	12–16
DeShazo et al.[20] (2010)	Game design and usability of three mobile phone games developed for the delivery of diabetes education were investigated. The games were then refined after focus group discussions and field-tested.	Health Communication Theory and Education Theory	Mobile phones (videogame)	Qualitative	10–30 minutes	11 (NA)	Average 38
Fuchslocher et al.[21] (2011)	The development and initial testing of a Flash-based videogame called ''Balance'' focusing on food and insulin intake. An implicit version of the game not alluding to diabetic management was also tested, to address concerns of adolescent reactance against diabetic management.	Social Learning Theory	Computer (videogame)	Quantitative	15-minute session	20 (NA)	11–16

(*continued*)

Table 1. (Continued)

Reference (year)	*Description of study*	*Theory*	*Platform used (type of intervention)*	*Study type*	*Duration of study*	*Sample size (dropout rate)*	*Age (years)*
Johnson et al.[23] (2014)	Feasibility and efficacy of participation in a digital virtual environment (Second Life Impacts Diabetes Education and Self-Management) for diabetes self-management and support were evaluated in a sample of individuals with diabetes.	Social Cognitive Theory, virtual environment theories	Second Life (virtual environment)	Mixed	6 months	20 (NA)	39–72
Kempf and Martin[22] (2013)	A randomized control tested how the regular playing of an exergame, ''Wii Fit Plus,'' over the study's duration affected metabolic control, weight, cardiometabolic risk, physical activity, and quality of life of participants with type 2 diabetes.		Nintendo Wii gaming console (videogame)	Quantitative	12 weeks	220 (44)	50–75
Klingensmith et al.[28] (2013)	The acceptability and performance of a blood glucose meter that was coupled with a gaming system were assessed in a sample of children, adolescents, and young adults with type 1 diabetes.		Didget glucomonitor coupled with Nintendo DS Lite (gamification)	Quantitative	3–5-day testing phase	147 (NA)	5–24
Ruggiero et al.[24] (2014)	The acceptability, usage, and preliminary outcome of a virtual world (''Diabetes Island'') were examined in a sample of low-income African American individuals with type 2 diabetes.	Social Cognitive Theory	Second Life (virtual environment)	Mixed	6 months	41 (NA)	Average 55
Rosal et al.[25] (2014)	A randomized clinical trial designed to test the feasibility and comparative effectiveness of a virtual world versus a face-to-face diabetes self-management group intervention	Social Cognitive Theory, evidence-based practice, cultural tailoring	Second Life virtual world (virtual environment)	Quantitative	8-week program; 4 month follow-up	89 (5)	Average 52

NA, not applicable.

Table 2. Measurement, Targeted Behaviors, and Key Findings of the Study

Reference (year)	Instruments	Targeted behavior (AADE7)[a]							Measured outcomes			Key outcomes
		1	2	3	4	5	6	7	Knowledge	Biological	Psychological	
Anderson-Hanley et al.[19] (2012)	Neurological Evaluation of Executive Function (Color Trails 2, Stroop Test, Digit Span Backwards)		×				×	×			Cognition and executive function	Game-based virtual reality enhanced exercise in older adults with and without diabetes. Exercise was also seen to improve cognition in older adults, with a stronger effect on those also suffering from diabetes.
Blanson Henkemans et al.[26] (2013)	Mind Youth Questionnaire, "Funness" Questionnaire, Diabetes Knowledge Questionnaire					×	×	×	Knowledge about diabetes		Self-efficacy	Improvements in child health literacy in an enjoyable manner using a "personalized" robot
Cafazzo et al.[27] (2012)	Interviews, Self-Care Inventory, Diabetes Family Responsibility Questionnaire, Diabetes Quality of Life for Youth Instrument			×			×	×		HbA1c	Social support, self-efficacy, quality of life	Increase in the daily frequency of blood glucose measurements by 50 percent with high satisfaction (88 percent) ratings. Improvement in exercise but not statistically significant. No significant change in quality of life
DeShazo et al.[20] (2012)	Focus group discussion, questionnaire to assess user attitude and self-reported experiences	×					×		Knowledge about diabetes			9 out of 10 testers reported learning about nutrition while playing the game. All testers felt that the nutritional information was relevant to them.
Fuchslocher et al.[21] (2011)	Game Enjoyment Scale, Adapted Self-Efficacy Scale, Locus of Control Scale	×			×	×	×	×			Self-efficacy	Participants who played the game with diabetic characters had a higher enjoyment level but no statistically significant difference in self-efficacy and internal locus of control in both groups.
Johnson et al.[23] (2014)	Focus group discussion, Perceived Usefulness Scale, Perceived Ease of Use Scale, Diabetes Empowerment Scale-Short Form, Modified Assessment of Diabetes Knowledge measure, Summary of Diabetes Self-Care Activities, perceived support for diabetes management, presence questionnaire, copresence questionnaire	×	×	×	×	×	×	×	Knowledge about diabetes	HbA1c, blood pressure, weight, BMI	Social support, copresence, self-efficacy	High scores on rated usefulness and ease of use with regular log-ins. Self-efficacy, social support, and foot care behavior had significant improvement. Small sample size restricted statistical significance of otherwise clinically meaningful trends.
Kempf and Martin[22] (2013)	Problem Areas in Diabetes questionnaire, Short Form-12 health survey, World Health Organization-5 Wellbeing Index, Center for Epidemiologic Studies Depression Self-Report Depression Scale (German)		×				×	×		HbA1c, cardiometabolic risk factors, diabetes-dependent impairment	Quality of life, subjective well-being, depression	The intervention group significantly improved HbA1c and fasting blood glucose. Weight and BMI also were significantly reduced. Diabetes-related impairment was lessened. Increases in mental health, subjective well-being, and quality of life were documented. Similar results were observed in the control group after provision of intervention.

(*continued*)

Table 2. (Continued)

Reference (year)	Instruments	Targeted behavior (AADE7)[a]							Measured outcomes			Key outcomes
		1	2	3	4	5	6	7	Knowledge	Biological	Psychological	
Klingensmith et al.[28] (2013)	Healthcare professionals' evaluation of subjects' comprehension of instructional materials, preloaded meter with simulated glucose result to measure parent/guardian comprehension of interface, satisfaction surveys			×			×	×		Glucometer readings	Self-efficacy	The majority of participants agreed the Didget system would motivate them to test blood glucose, practice better blood glucose management, and reduce frustrations with blood glucose monitoring. High satisfaction ratings by healthcare professionals (94 percent), who felt that it solved a problem, fulfilled a need, and was a good motivator for proper blood glucose management
Ruggiero et al.[24] (2014)	Summary of Diabetes Self-Care Activities, Environmental Barriers to Adherence Scale, fat-related Diet Habits Questionnaire, Diabetes Empowerment Scale-Short Form, Diabetes Distress Scale, intervention acceptability questions	×	×		×	×	×	×	Knowledge about diabetes	HbA1c, BMI	Self-efficacy, empowerment, diabetes-related distress	Intervention showed significant impacts on BMI, diabetes-related distress, global and dietary environmental barriers to self-care and subscales of physical activity and dietary intake. Feedback was consistently positive, and log-in patterns were regular.
Rosal et al.[25] (2014)	Verbally administered scales: Center for Epidemiologic Studies Depression Scale Self-Report Depression Scale, self-efficacy for diabetes management, Medical Outcomes Study Social Support Survey, Perceived Stress Scale, Rapid Estimate of Adult Literacy in Medicine, Short Form-12, experience with computer and Internet measure, participant satisfaction questionnaire		×				×	×		HbA1c, blood pressure, total cholesterol, weight, waist circumference, BMI	Self-efficacy, depression	Virtual world intervention slightly superior to face-to-face intervention in promoting physical activity. HbA1c and depressive symptom reductions were greater for face-to-face intervention.

[a]AAD7 descreiption: 1, healthy eating (making informed and appropriate healthy food choices, eating times, and weight management to achieve optimal blood glucose levels); 2, being active (engaging in appropriate levels of exercise and physical activity); 3, monitoring (daily self-monitoring of glucose level to assess food, physical activity, and medication affect their blood glucose level); 4, taking medication (to be knowledgeable about each medication information and effect on oneself); 5, problem solving (to be able to use their problem-solving skills to make rapid, informed decision about food, activity, and medication); 6, reducing risk (learning to understand, seek, and regularly obtain an array of preventive services to reduce the effects of risk associated with the condition); and 7, healthy coping (helping the individual's motivation to change behavior and setting goals and guiding individuals through multiple obstacles).

BMI, body mass index; HbA1c, hemoglobin A1c.

RQ3: Key findings

Because of the heterogeneity of the studies, we extracted the findings and measured them against four facets of outcomes in RQ3: (a) behavioral, (b) knowledge and self-efficacy, (c) biological, and (d) psychological. Table 2 describes the instruments reported by the authors, which we measured against the four outcomes and key findings.

Comparison of key findings

All studies measured some form of behavioral outcome (Table 2). Participants' knowledge on diabetes was a key focus and outcome measure in four studies.[20,23,24,26] The primary biological measure of glycated hemoglobin levels was featured in half of the studies reviewed.[22–25,27] One study evaluated participants' cognitive and executive functions,[19] one study used glucometer readings,[28] and one study included cardiometabolic risk factors and diabetes-dependent impairment.[22] Secondary outcome measures such as body mass index, weight, blood pressure, total cholesterol, and waist circumference were used by three studies.[23–25] Two studies included psychosocial measures, evaluating social support,[23,27] and Johnson et al.[23] included an evaluation of copresence, a sense of others' presence in relation to the self. A majority of reviewed studies also had other miscellaneous outcome measures, including participants' self-efficacy, quality of life, and well-being (Table 2).

Intervention-specific findings

All studies attested to the feasibility and potential of game-based directives in bettering the lives of individuals with diabetes. The four studies[19–22] with videogame interventions observed the following: (1) game-based virtual reality enhanced exercise in older adults, also increasing levels of cognition for individuals with diabetes[20]; (2) participants learned more about nutrition while playing mobile games[21]; (3) participants recorded greater enjoyment when a game protagonist shared their condition[22]; and (4) participants saw enhancements in glycated hemoglobin levels, fasting blood glucose, weight, body mass index, and diabetes-related impairment as well as mental health, well-being, and quality of life.[22]

Three studies used virtual world interventions. One[23] recorded significant improvements in self-efficacy, social support, and foot care behavior of participants post-intervention, and another[24] found impacts on body mass index, diabetes-related distress, barriers to self-care, physical activity and dietary intake, with the study of Rosal et al.[25] revealing that virtual world interventions were more effective compared with face-to-face interventions in promoting physical activity. The latter study, however, also found that glycated hemoglobin levels and depressive symptoms were greater reduced by face-to-face intervention.

The last three studies in the review used gamification principles. Health literacy of children was seen to improve when learning was facilitated by a personalized robot,[26] which made the participants interested in interacting with the robot. The rewards system of iTunes® (Apple, Cupertino, CA) credits led to greater patient engagement, especially in performing routine behaviors.[27] The Didget™ (Bayer HealthCare LLC, Diabetes Care, Tarrytown, NY) system,[28] which rewards users with points that can used in videogames when users take their blood test, saw a majority of participants and healthcare professionals attest to its value as a blood glucose monitoring aid.

Discussion

This review synthesized evidence on using videogames, gamification, and VE interventions for diabetes management. Of the 307 articles identified, only 10 articles met the inclusion criteria. Four studies used videogames as their intervention, three used virtual reality environments, and three studies adopted principles from gamification and relevant theory. Given the state of technology and the popularity of the medium in entertainment, the number of studies that investigated videogames in the context of diabetes management was much lower than anticipated. However, findings from all the studies suggest that the use of videogames, gamification, and VE appears to have some positive effects toward the self-management of diabetes.

Games for health change

Serious videogames provide promising avenues that seek to entertain while attempting to elicit behavioral change. Such games are tasked with modifying user behavior and knowledge by inserting the procedure into the process of playing the game, or by embedding concepts into the story of a game for risk reduction.[29] Two studies[19,22] adopted the former method, via ''exergames'' that introduced the behavior to be internalized (physical activity) directly as an aspect of the game. On the other hand, Fuchslocher et al.[21] used the latter method, with one group of participants playing as a protagonist with diabetes who required management of insulin and dietary intake. Another casual mobile game study[20] did not fall clearly into either category as proposed by Baranowski et al.,[29] although the applications were favorably accepted for their informative value. Therefore, videogames appear to be more helpful for increasing knowledge rather than for eliciting behavioral changes. The effects for behavioral changes were observed to be short term rather than long term and are consistent with the meta-analysis findings by DeSmet et al.[5]

Three studies reviewed[23–25] embedded their interventions in the Second Life virtual reality system. Second Life is a simulated multimedia environment that allows the creation of interactive avatars (graphical self-representations) that inhabit a virtual world.[11] Studies that used Second Life observed positive effects in the lives of participants (Table 2). However, the small sample size of two studies[23,24] was a restriction in drawing strong conclusions. All three studies reviewed demonstrated the feasibility, usability, and quick acceptance of virtual world interventions through the high participant satisfaction and interest rates.[23–25]

Promoting health behaviors through games

Healthy behavioral habits such as blood glucose monitoring are perceived as mundane and routine tasks by people with diabetes. This study found that the novelty of even a generic rewards system may have been enough to motivate participants to effectively learn and practice effective blood glucose monitoring behavior. The adoption of game elements for serious purposes extrinsically motivates the practice of target behavior by the provision of external rewards.

The challenge shifts to internalizing these extrinsically motivated behaviors enough to be assimilated into an individual's sense of self. Internalization has been associated with greater medication adherence in patients with chronic illnesses and improved glucose control in individuals with diabetes.[30] Feelings of volition and empowerment toward management of diabetes as well as supportive relationships with caregivers and health professionals can shift individual goals from extrinsic to intrinsic in nature.

Research gaps

There appears to be a gap in publications that use the RCT, considered the ''gold standard'' of methodological processes. RCTs are often the preferred methodology in clinical trials, allowing for more definitive conclusions to be drawn. Only three of the studies reviewed used the procedure.[19,22,25] Perhaps it is the novelty of the gaming medium that has resulted in such few RCT studies. It is expected that as implementations such as those reviewed become more widely accepted and enter mainstream forums, more robust research methodologies can be used to study them.

Many of the studies that were reviewed also had small sample sizes.[19,20,21,23–27] Therefore, it remained difficult for any statistically significant analyses and results to be drawn conclusively. In addition, the intervention lengths for the studies were less than 6 months,[19,20–22,25–28] making interpretation of long-term effects challenging. Only VE studies were longer in duration,[23–25] but relatively small sample sizes do not necessarily translate to generalizability of findings. Dropout rate statistics were not assessed in a majority of the studies[19–21,23,24,26,28] as most had either short durations (less than a day) or flexible participation requirements.

One of the common issues in these interventions is the decline in user participation over time. This was attributed to the poor upkeep of content,[23] which should be fluid and constantly renewed. With the culmination of the studies, there appeared to be no intrinsic value for participants to continue their participation. This saw a decline in usage patterns, especially log-in instances for the VE studies.[23–25] This is observed to be consistent with studies that found that the effects of game design elements change over time, diminishing in the long term.[31,32] Similarly, a meta-analysis of serious digital games for the promotion of a healthy lifestyle found that long-term effects were maintained for knowledge but not for behavior.[5] A prominent novelty effect might be a critical confounding factor with the use of game design elements for the promotion of specific behavior.

A mediating factor in maintaining rates of use might be found in the social aspect of the interventions. Virtual communities, for example, allow for the creation of ''third places,''[33] allowing for informal cohesion away from work and home life. This could be a primary motivating factor to encourage continuous participation within a serious game-based intervention.

Patients' adherence to healthy behavior for chronic illnesses such as diabetes remains one of the biggest challenges for healthcare professionals. Self-monitoring of health behavior is especially crucial for chronic conditions, as proper control and maintenance negate symptom progression and worsening of the disease. A majority of the studies reviewed games used, gamification, or VE interventions as an educational tool, rather than a direct means to increase self-monitoring behavior. Only two studies[27,28] had interventions where the actual practice of self-monitoring behavior was inculcated via gamification processes. Therefore, behavioral intentions geared toward continued use[34] should be considered for future research.

Medication adherence is the foundation of effective diabetes care and management. However, the current study did not find any research specifically targeting medication adherence as part of the behavioral change process. Interventions such as those from Johnson et al.[23] and Ruggiero et al.[24] facilitated medication adherence through information provision but did little to actively encourage the behavior, and Fuchslocher et al.[21] alluded to the importance of balancing insulin levels via medication. However, the authors did not have any direct measures as to how their interventions might have affected rates of adherence. Given the importance of medication adherence, future research should seek to address this concern.

Limitations

Despite our rigorous attempts to locate all relevant articles, a possibility exists that certain articles were missed or that publication biases led to overall underreporting of studies. Our specified key word search might not have been as efficacious because of these reasons. Moreover, the low number of relevant publications, low sample size, and the heterogeneity among the studies make drawing strong conclusions from the studies a challenging process. Despite these limitations, our analysis framework provides readers with an important understanding of the gaps within the current literature and provides future directions for research in this area.

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