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Contents

Viewpoint

What Serious Video Games Can Offer Child Obesity Prevention

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Abstract

Childhood obesity is a worldwide issue, and effective methods encouraging children to adopt healthy diet and physical activity behaviors are needed. This viewpoint addresses the promise of serious video games, and why they may offer one method for helping children eat healthier and become more physically active. Lessons learned are provided, as well as examples gleaned from personal experiences.

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KEYWORDS

serious video games; children; teenagers; obesity prevention; formative research, qualitative research

Childhood Obesity

Childhood obesity is a worldwide public health issue [1,2], and is associated with adverse health effects in both children and adults [3,4]. Obese children and adolescents are more likely to become obese adults, further exacerbating the public health urgency of this issue [3,5]. Diet and physical activity behaviors, the cornerstones of obesity prevention [6,7], track into adulthood [8,9]. Establishing healthy diet and physical activity behaviors during childhood is an important aspect of obesity prevention. Effective ways to achieve and maintain this goal are needed.

Technology may offer an effective method for encouraging children to adopt healthy behaviors. Technology is pervasive in today's world and influences many aspects of our lives, including how we communicate, educate, and entertain ourselves. Video games are an example; 97% of 12-17 year olds play video games, play multiple genres, and have access to computers and other devices on which to play the games [10,11]. Internet access, including high-speed access [11], has increased, making Internet games more accessible. Evidence indicates the digital divide is diminishing [12], particularly when mobile platforms are taken into account [13,14]. Thus, Internet video games offer a familiar, convenient, and readily accessible channel within which to evaluate obesity prevention programs developed for children and teenagers.

While traditional video games are primarily designed to entertain, a new genre has emerged that seeks to do more. Serious video games, often referred to as games for health when they target health behaviors [15], are showing promise as a method for promoting healthy behaviors to youth [15,16]. Serious video games have the dual goal of entertaining, while promoting behavior change [17,18]. This game genre has the formidable task of achieving a balance between "fun-ness" (ie, components that entertain, such as animation, storyline, sound effects) and "serious-ness" (ie, the components that promote behavior change, such as goal setting, problem solving) [18]. This balance, although sometimes difficult to attain, is essential; too much "fun-ness", the game will entertain, but it will not likely change behavior; on the other hand, too much "serious-ness", and the players will not likely play all levels or episodes of the game (ie, inadequate dose), making behavior change less likely.

Serious Game Components Targeting Behavior Change

There are several components that should be considered when developing serious games for health behavior change. These include interactivity, feedback, characters, story, and sound effects [18,19]. For examples of how features such as these were incorporated into a serious video game, please see Thompson et al [18].

Interactivity

Rather than a didactic presentation of facts or figures, the player is able to interact with and "discover" knowledge and skills, and then immediately apply these to overcoming behavioral obstacles in the game.

Feedback

A serious video game offers a unique opportunity to receive immediate feedback, thus refining, reinforcing, and enhancing newly found knowledge and skills.

Characters

The protagonists model desired behaviors, while the antagonists attempt to "foil" the player's efforts to attain a goal, thus adding challenge and interest.

Story

The story adds intrigue and excitement, and can be designed to "wrap" the behavioral components into the game for a more seamless experience.

Sound Effects

The sound effects convey meaning and direction without words. For example, a ticking clock or fast-paced music can indicate that time is running out or that the player must act quickly.

My colleagues and I have been involved in the development and evaluation of a variety of serious video games and other technology-based interventions for a number of years [20-33]. We have learned many lessons along the way, including the following.

Just Because You Can, Does Not Mean You Should

Think about the behavior you're targeting and the project goal. It may be that another method or approach would be a better fit.

For example, research suggests that video games may not be the best method for enhancing moderate to vigorous physical activity [34,35]. We have seen this in our own work [20,21]. It is highly likely that we have not found the "ideal" method for using technology to promote physical activity. This is an area that needs additional investigation. For example, we are investigating the effect of text messages [33] and avatars created from photographs of the player (ie, self-representational avatars) as ways to promote physical activity to teenagers. It may be that traditional approaches are more effective than serious video games at enhancing physical activity; however, before we give up on technology as a way to promote physical activity, it is imperative that additional methods, such as these and others, be investigated.

Know What You Want Before You Start

Once programming has been completed, it is expensive to make a change. An approach that has worked for us is to know what you want and how the pieces fit together before starting development. For example, first identify the "serious" components that need to be included based on the theoretical framework (ie, content, behavioral procedures) and the targeted behavior (ie, diet, physical activity) [19]. Then negotiate with the design studio about how to structure the game to create a seamless, entertaining experience for the player. We have discovered that following a process similar to this minimizes miscommunication and increases the likelihood that you will be satisfied with the end result [19].

Carefully Assess Your Budget

Serious video games can be expensive to develop [19]. In addition to having an ample budget to cover the costs of development, it is wise to have a contingency budget to cover unexpected issues (eg, technical problems, etc) that may develop. Often, it is not "if" unexpected delays or set backs will occur, but "What do I do now?" when they do. Anticipate and plan for them.

We have seen this in our own technology-based work. Negotiation and open communication with the game design team are essential. Using the approach described above has been extremely beneficial to achieving our research goals within a reasonable budget. For example, in a serious video game promoting fruit and vegetables to youth [31], during discussions with the game design studio, we were informed that flickering torches were possible, but it would be expensive to animate them, which was not feasible given our budget. Through negotiation and communication, we compromised on a lower cost way to animate the torches (ie, overlays versus actual animation), leaving us both satisfied with the outcome. Other issues that need to be discussed with the game design studio are commercialization and intellectual property rights (ie, who owns what) [19].

Partner With Your Target Audience

The importance of research with the target audience to serious video game design cannot be emphasized enough [36]. It is important to understand their perspective before initiating game development. For example: (1) What are their beliefs and attitudes regarding this behavior?; (2) What problems do they face when trying to engage in the behavior?; (3) What type of information do they want, and in what format?; (4) What would a serious video game addressing this behavior need to include?; and (5) equally as important, What should it not include? [32,36]. Alpha testing with them throughout development is also important, for example: (1) Did we get it right?; (2) What changes, if any, are needed?; (3) Do you understand what this is asking you to do?; and (4) Can you do it using the approach presented in the serious video game?. Beta testing to identify technical issues (ie, "bugs" or "glitches") before finalizing the game is also essential. During this phase, be sure to test the serious video game with different operating systems, hardware, browsers, and connection speeds. After the outcome evaluation has been completed, asking the target audience, ("Did we meet your expectations?" and "What, if anything, should we do differently next time?"), would inform the next game you develop. Partnering with the target audience is essential. Partnering with them will help avoid costly mistakes and help ensure the game addresses their needs and interests in an appealing and acceptable manner.

We used this approach when developing a serious video game for elementary aged school children [31]. We first convened an expert panel of 4th and 5th graders, and, over a period of several months, they vetted critical aspects of the serious video game, such as characters, storyline, and behavior change components. Several of the behavioral components involved complicated concepts, such as implementation intentions (ie, plans connected to goal attainment) [37]. Therefore, it was essential to obtain the children's feedback on whether they understood what they were being asked to do and whether they could do what they were being asked to do. Their comments were used to refine the game components as identified above and enhance its developmental appropriateness and appeal. They also participated in a pilot test, which served as a final beta test of the serious video game and its procedures.

Do Not Forget About the Data

A myriad of data can be collected as players navigate through the game, but not all of it may be useful (eg, time spent in the serious video game, which may not be useful if gameplay is discontinued for another activity, such as eating dinner, but the game or Web browser is not closed). Identify in advance what data you want to capture (eg, goals set, goals attained, problems encountered, time needed to attain each level) early in the development process. Talk with the game design studio about the data you need and how you would like these data stored in the back-end database to avoid potentially expensive (or unfortunate) surprises at the end (ie, miscommunications regarding which data were to be collected and/or how they were to be stored). Data security is also an important issue that should be addressed, (ie, How will the data, as well as confidentiality, be protected?).

When we develop technology-based programs, we typically have a discussion with the game design studio well before the end of the programming phase, where we discuss options for data collection, and how the data are stored in the database. We have learned that this process helps to avoid missteps and opens up an important discussion between key players. For example, when developing the serious video game promoting fruit and vegetable consumption [31], we provided the game design studio with a document that identified the data we needed and how the data tables should be formatted, including whether the tables needed to include numbers or words (eg, "choice 2" or "carrots"). We then had a discussion about possible options and came to an agreement about what data would be collected, and what the tables would look like. During this discussion, it was discovered that the game design studio and the research team had very different opinions about how the game play information would be saved. This realization proved to be critical and opened up an extremely important dialogue between the game design studio and the research team. This process made several key points very clear-do not make assumptions; keep the lines of communication open; and be open to alternative ways of accomplishing the same goal-you may be pleasantly surprised by the result.

Developing serious video games is a difficult, time consuming, humbling, and exhausting experience, but it is also exhilarating. When a parent tells you what a difference the game has made in his or her child's life, or the outcome evaluation shows the child not only played all episodes of the game, but modified their behavior, such as eating more fruit and vegetables [21], you realize the potential of this work for child obesity prevention. Will you make mistakes? Yes; like most things in life, there is no iron clad formula for success. But when you get it right, it is invigorating, and you can't wait to start working on the next serious video game. There is nothing like knowing that you made a difference in someone's life, particularly a child's life.

Relax, and enjoy the journey! In my opinion, it's well worth it.

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Conflicts of Interest

None declared.

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Abbreviations

ARS: Agriculture Research Service
USDA: United States Department of Agriculture

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Original Paper

The Cure: Design and Evaluation of a Crowdsourcing Game for Gene Selection for Breast Cancer Survival Prediction

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Abstract

Background: Molecular signatures for predicting breast cancer prognosis could greatly improve care through personalization of treatment. Computational analyses of genome-wide expression datasets have identified such signatures, but these signatures leave much to be desired in terms of accuracy, reproducibility, and biological interpretability. Methods that take advantage of structured prior knowledge (eg, protein interaction networks) show promise in helping to define better signatures, but most knowledge remains unstructured. Crowdsourcing via scientific discovery games is an emerging methodology that has the potential to tap into human intelligence at scales and in modes unheard of before.

Objective: The main objective of this study was to test the hypothesis that knowledge linking expression patterns of specific genes to breast cancer outcomes could be captured from players of an open, Web-based game. We envisioned capturing knowledge both from the player's prior experience and from their ability to interpret text related to candidate genes presented to them in the context of the game.

Methods: We developed and evaluated an online game called The Cure that captured information from players regarding genes for use as predictors of breast cancer survival. Information gathered from game play was aggregated using a voting approach, and used to create rankings of genes. The top genes from these rankings were evaluated using annotation enrichment analysis, comparison to prior predictor gene sets, and by using them to train and test machine learning systems for predicting 10 year survival.

Results: Between its launch in September 2012 and September 2013, The Cure attracted more than 1000 registered players, who collectively played nearly 10,000 games. Gene sets assembled through aggregation of the collected data showed significant enrichment for genes known to be related to key concepts such as cancer, disease progression, and recurrence. In terms of the predictive accuracy of models trained using this information, these gene sets provided comparable performance to gene sets generated using other methods, including those used in commercial tests. The Cure is available on the Internet.

Conclusions: The principal contribution of this work is to show that crowdsourcing games can be developed as a means to address problems involving domain knowledge. While most prior work on scientific discovery games and crowdsourcing in general takes as a premise that contributors have little or no expertise, here we demonstrated a crowdsourcing system that succeeded in capturing expert knowledge.

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KEYWORDS

breast neoplasms; gene expression; artificial intelligence; survival analysis; crowdsourcing; Web applications; computer games; collaborative and social computing systems and tools; supervised learning; feature selection

Introduction

Molecular Predictors for Breast Cancer

Breast cancer is the most common form of cancer in women [1]. It has been studied extensively with genomic technologies, with many attempts to devise molecular predictors of clinical outcomes [2-4] and drug response [5]. If successful, tests derived from these predictors would pave the way toward personalized therapy and better care. While much progress has been made, including several commercially available tests [6], molecular predictors consistently show lower than desirable accuracy, degrade in performance in subsequent validation studies, identify different gene sets in every permutation, and often have no discernable biological rationale [7].

Here, we address the challenge of predicting survival based on gene expression and copy number variation. Given a database of these genomic measurements and associated clinical outcomes, the objective is to produce a classifier that will accurately separate the patients into two classes, those that survive beyond ten years from initial diagnosis, and those that do not. Any such attempt at class prediction based on high-throughput (eg, microarray) data is technically challenging because of the very large number of potential features [8]. Typical datasets provide measurements for tens of thousands of genes, and each gene is a potential predictive feature for use in a classifier. The individual members of optimal feature sets work synergistically, displaying relationships that make the group more useful for prediction as a whole than any individual unit. The space of possible feature combinations is too large to explore exhaustively and, even if it were, the tests available for evaluating feature set quality are not precise. As a result, researchers rely on heuristics and, increasingly, on prior knowledge to identify good feature groups.

Recent gene selection methods are driven by structured prior knowledge in forms such as protein-protein interaction networks [9,10], pathway databases [11,12], and information gathered from pan-cancer datasets [13]. These methods guide the search for predictive gene sets toward cohesive groups related to each other, and to the predicted phenotype through biological mechanism. In doing so, they have improved the stability of the gene selection process and the biological relevance of the identified signatures. These techniques hint at the potential of strategies that marry a top-down approach based on established knowledge with a bottom-up approach based directly on experimental data, but they have not yet produced substantially greater accuracy than other approaches. This may be due in part to a scarcity of relevant structured knowledge with which to compute.

Since the year 2000, more than 166,000 publications related to breast cancer have been added to PubMed [14]. Within that body of literature, and in the minds of those that have created and consumed it, lays a wealth of knowledge relevant to selecting gene sets for survival prediction. Here, we explore a crowdsourcing approach for tapping into that knowledge.

Crowdsourcing

Crowdsourcing processes take tasks traditionally performed by individuals or small groups and reformulate them such that large numbers of people can participate in their completion. There are many instantiations of the crowdsourcing paradigm [15], here we focus on just one, games with a purpose (GWAP) [16]. GWAPs incentivize large scale work by translating the required labor into elements of games. The games are played for fun, for learning, and to aid in achieving the underlying purpose. Popular GWAPs within biology include Foldit for protein folding [17], Phylo for multiple sequence alignment [18], and MalariaSpot for image analysis [19]. Here we introduce a GWAP for genomic feature selection called The Cure.

Our high-level objective is to identify genes that can be used to build improved prognostic predictors for breast cancer. Our hypothesis is that, if aggregated effectively, the collective knowledge, reading, and reasoning ability of a large community could help to identify genes that are useful in constructing robust classifiers, but might be hidden from purely data driven approaches. In striving to achieve that aim, we conducted the study described here to assess the feasibility of the use of an open, online game (The Cure) in capturing pertinent, expert-level biomedical knowledge.

The central questions addressed are: (1) How many people, of what levels of expertise, would play a game oriented around gene selection for breast cancer survival prediction and why? (2) Would it be possible to extract a gene ranking from the results of play that reflected biomedical knowledge? That is, could the game act as a portal for expert-level knowledge transfer? And (3) could the gene ranking captured through the game be used to generate classifiers that perform well in cross-dataset evaluations?

The null hypotheses are that: (1) no one would play, (2) the results of their play would not yield discernible biological knowledge, and (3) any gene ranking produced would be no better than random. Below we discuss the design of the game, and then present results from one year of open play that shed light on each of the questions posed above.

Methods

Game Design

The Cure is a Web application consisting of the pages home, login, board selection, game, and help. The home page provides information about the project and the game, and allows users to either log in or create accounts. Users must create an account to play. During account creation, users must select a username and password, and have the option of entering an email address and answering three short survey questions: (1) “Most recent academic degree?”, (2) “Do you consider yourself knowledgeable about cancer biology?", and (3) "Do you consider yourself a biologist?".

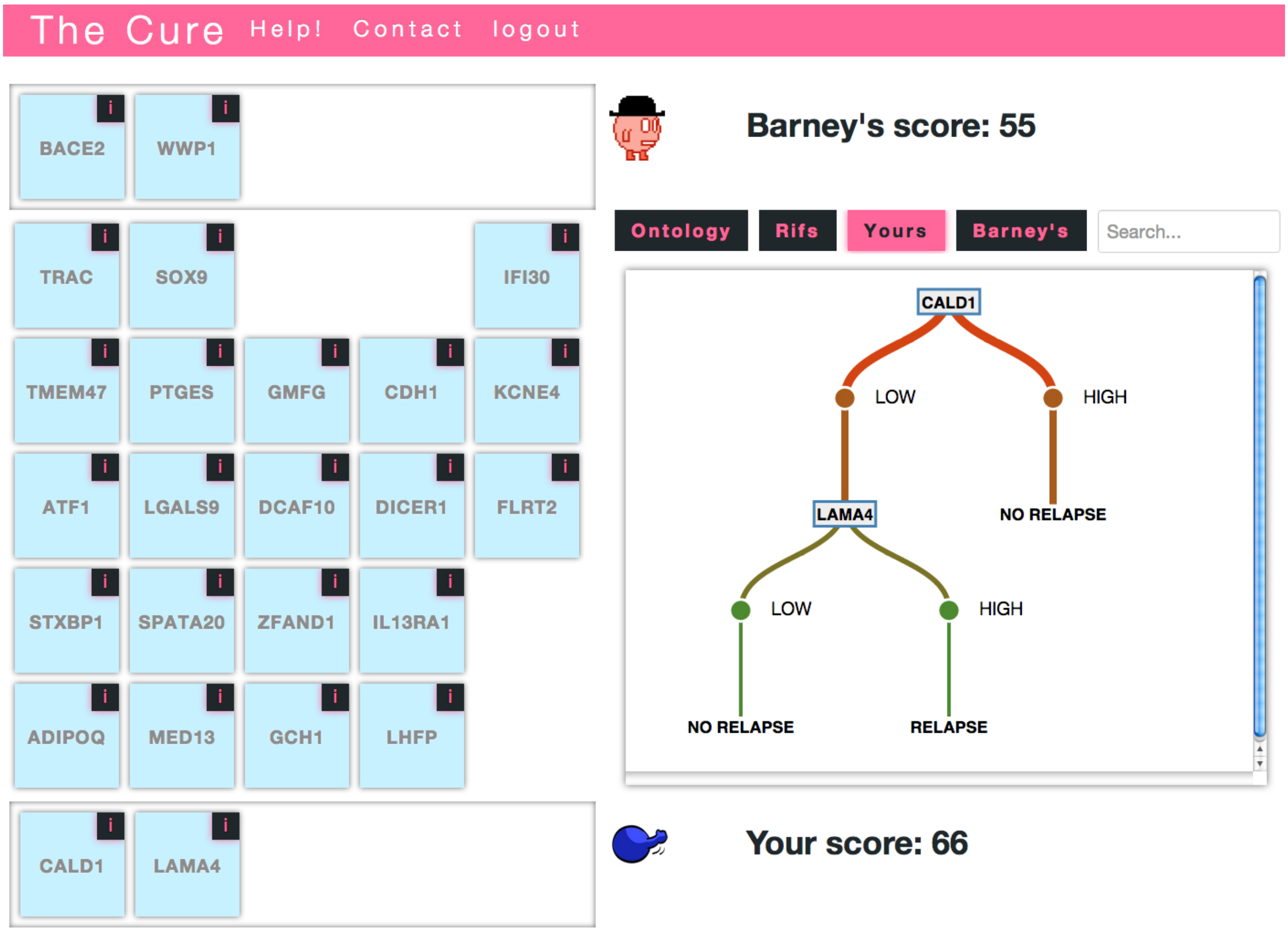
Training

When players first register, they are presented with a training stage that must be passed before they enter the main game area. The training stage consists of four "boards" containing 2 to 4 features common to animals such as "number of legs, breathes air, produces milk, etc". To complete the level, the player must select the features that can best be used to discriminate between mammals and other classes of animal, before the games automated opponent "Barney" beats them to it. This task was chosen as a way to introduce the dynamics of the game, and to get across the idea of feature selection for classification on a straightforward problem.

Game

After training, the player is presented with boards containing 25 different genes (Figure 1 shows an example board). The objective of each game is to choose a set of 5 genes that produces a better decision tree classifier than that of the automated opponent "Barney". The players, the human player and Barney, alternate turns, taking a gene card from the board and placing it in their hand, with the human player always going first. Once a card is taken from the board, it cannot be put back, and the other player cannot take it. The score for the final 5 card hand determines the winner of the game. Note that each time a board is rendered, the locations of the genes are randomized to prevent bias.

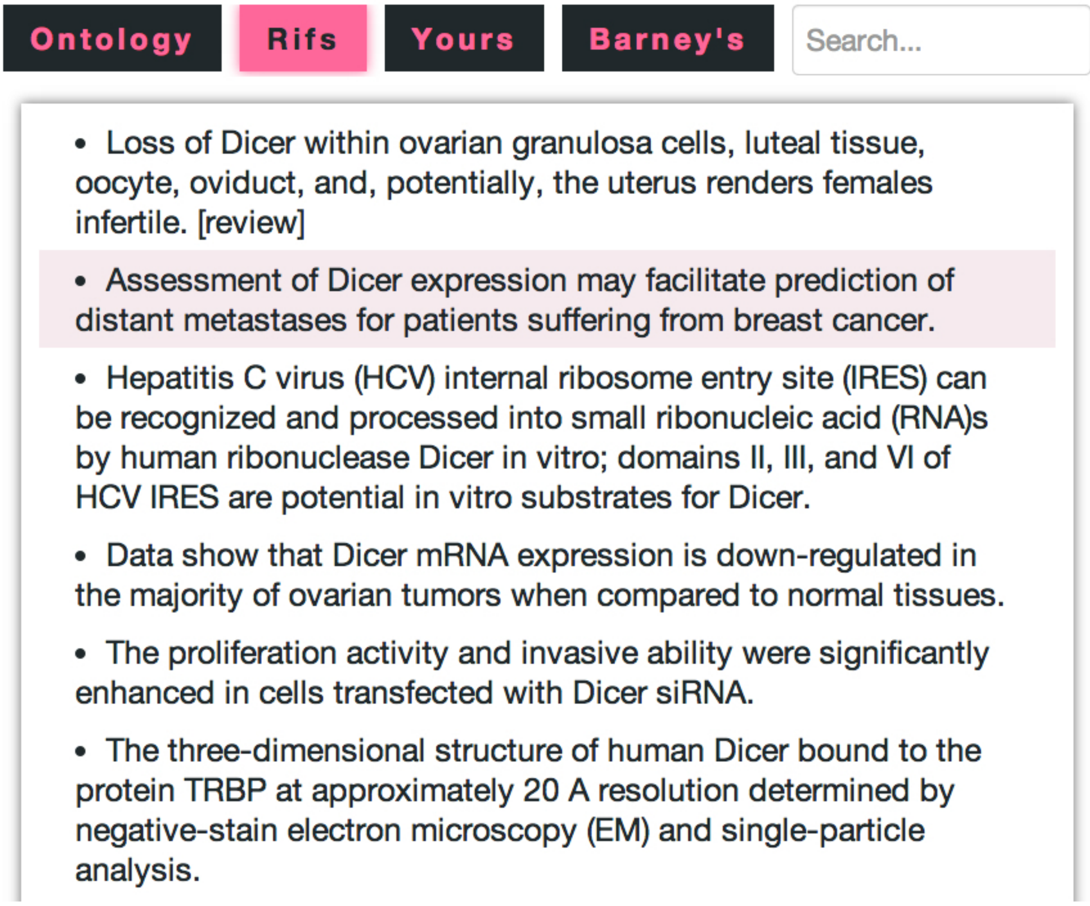
Figure 1. The Cure game. The figure shows a game in progress in which both players have completed 2 of the 5 turns. Players alternate turns, taking a gene card from the board and adding it to their hand. The player with the highest score after 5 turns is the winner. The tabbed display provides gene annotations ("Ontology", "Rifs") and views of decision trees constructed by the system using the selected genes. The scores reflect the predictive power of the selected genes. The system produces these scores by using data associated with the selected genes to train and test a decision tree classifier. The scores are the accuracy of these inferred classifiers.



Gene Annotations

Dragging the mouse over each gene provides the player with information including: (1) a summary description from Unigene, (2) Gene Ontology annotations, and (3) snippets of text related to the gene from The United States National Center for Biotechnology Information's Gene Rifs (Figure 2 shows these tabs). All of the annotations contain hyperlinks that the players can follow for more information. A search interface allows the player to find genes on the board based on the text in their related annotations. Coupled with the player's biological knowledge, this information helps the player make informed guesses about which genes from the board might make the most useful predictors.

Figure 2. The Gene Rifs tab showing information about the Dicer gene. Gene Rifs provide textual descriptions of gene function extracted from abstracts. These can be used to gain insights into the possible connections between the gene and breast cancer prognosis, and thus can help players to intelligently select genes in the game.



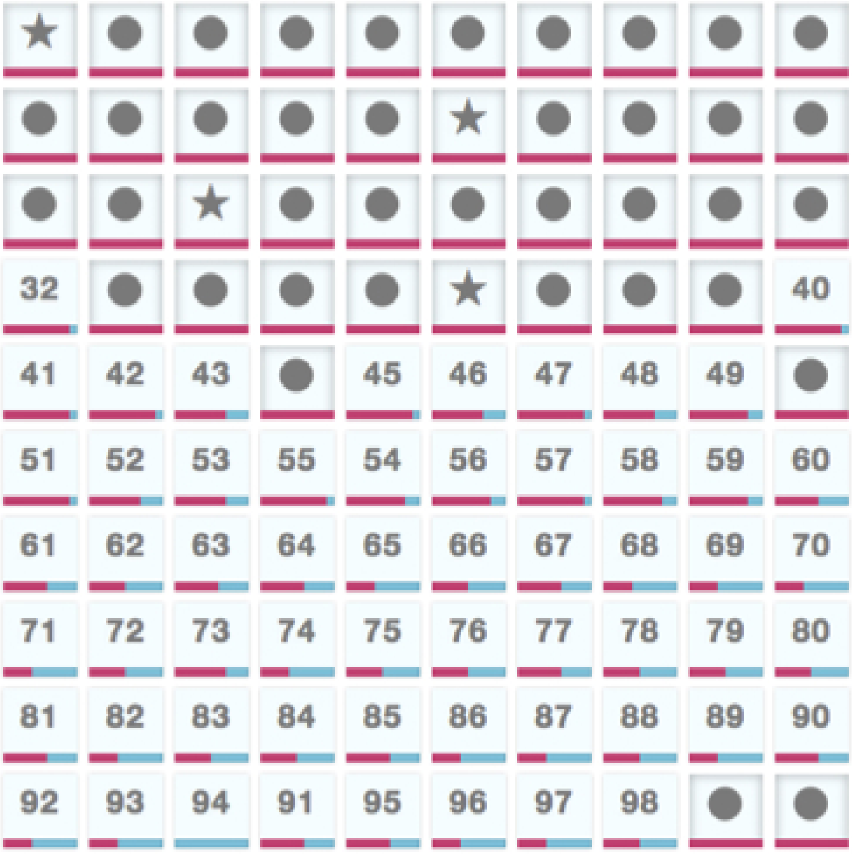
Scoring

Each time a card is added to a player's hand, the game server scores the hand by evaluating the combined predictive performance of the genes it contains. To accomplish this evaluation, the server uses a gene expression dataset containing samples classified with long-term (>10 year) survival status. In each evaluation, the server uses data from just the genes in the player's hand to train and test a decision tree classifier. The score for the hand is the accuracy returned by a cross-validation experiment. In machine learning parlance, this is known as a "wrapper" feature set evaluation scheme [20]. A simplified decision tree created using all of the available training instances, but just the selected genes, is displayed for the player and their opponent (Figure 1 and Multimedia Appendix 1 for additional details on the implementation of the scoring process). If the player loses, they are not awarded any points; they may play the board again or select a different board to play. If they win, their score is determined based on the accuracy of their winning tree. Within each round, player scores are cumulative. The more games they win, the higher their score. The player's score is displayed on the board selection page along with its global rank and the current top 10 scores.

Board Selection

Each round of The Cure consists of a collection of 100 different boards for players to choose from (Figure 3 shows this selection). Each board is composed of a different set of 25 semirandomly selected genes (see Multimedia Appendix 1 for board composition strategies). The boards are arranged in loose order of difficulty, with the easiest boards occupying the lower numbers. The difficulty is assessed based on an estimation of the predictive power of the complete 25 gene set, the more predictive, the easier the board. The goal of the board selection page is to capture both broad and deep coverage of all the boards (and their corresponding gene sets) by the player community. Once a given board has been completed by at least 11 players, it is closed off so that players are forced to select a different board. Any open board can be selected for play. Once a player has completed a particular board, they are not allowed to play it again.

Figure 3. The board selection view. Stars indicate boards the active player has completed, circles indicate boards that have been completed by a sufficient number of different players, and numbers indicate open boards. The pink progress bar indicates how close the community is to finishing the board.



Purpose

The purpose of The Cure is to translate the knowledge of the players, along with their ability to process textual information, into a ranked list of genes for use in the development of predictors for breast cancer prognosis. This translation is enacted when the players select genes in the game. We record the gene selections, and apply aggregation functions to produce gene rankings that reflect the consensus of the player community.

Aggregation Function for Gene Ranking

Each time a player selects a gene in a game, they are indicating to the system their intuition of that gene's relevance for predicting breast cancer survival. That intuition may be based on their knowledge, on inferences drawn from gene annotation information, or solely on random speculation. By aggregating the data collected from many different players across many different games, we tried to eliminate the noise from random clicking and reveal the community consensus with regard to predictive genes.

Given a set of recorded games, our gene ranking method is as follows. For each gene g, we estimate the frequency of selection F(g) as,

$$F(g)=(S(g))/(O(g))$$

O(g) equals the number of times the gene g appeared in a played game. Some genes appear on multiple boards, multiple players play all boards, and all occurrences are counted. S(g) is the number of times the gene was selected by the human player.

We then empirically calculated a one-tailed *P* value for each value of F given O through simulations of random game play. The *P* values indicate the chances of observing a value of S or greater given O, assuming that all gene selections were random. Importantly, they allow for comparisons between genes with different numbers of occurrences. For example, the known apoptosis regulator BCL2 gene occurred in 13 played games (O=13), and was selected in 10 of those games (S=10), thus F for BCL2 was 0.77 with *P*<.001. Our simulations stopped at 10,000 iterations per value of O, hence *P* values below .0001 cannot be reported. On the other end of the spectrum, the AARD gene (of unknown function) appeared in 33 played games (O=33), was selected 3 times (S=3), had an F of 0.09 with *P*=.91. Given any collection of played games, we generate gene rankings based on the estimated *P* values for each value of F. We can thus assemble gene sets based on different groups of games as well as different *P* value cutoffs.

Gene Set Assessments

Quality

Given the gene sets produced by this system, we assess quality by: (1) direct comparison to gene sets used in published predictors of breast cancer survival, (2) gene set enrichment analysis, and (3) classifier accuracy.

Enrichment Analysis

Enrichment analysis is a widely used statistical technique for assessing the functional roles of gene sets based on their annotations. Given a set of genes with annotations such as Gene Ontology or Disease Ontology associations, these tests estimate the annotation terms that are overrepresented in the gene set. For example, a typical high-throughput experiment may identify a set of 100 or more active genes in a given condition. An enrichment analysis can be used to detect if genes related to a functional category, such as the immune response or a disease group such as cancer, are represented in that set of 100 genes more than they would be expected to by chance. By applying enrichment analysis to the gene sets produced by The Cure player community, we can identify whether genes annotated with terms related to breast cancer or other related diseases or processes are being preferentially selected, as we would expect if the players are not choosing randomly. In principle, it could also unearth interesting new categories of genes selected by the player community.

Classifier Accuracy

Finally, we measure the value of the gene sets by using them to construct machine-learning-based classifiers that predict 10 year survival. Given a particular dataset, we eliminate measurements from all genes outside of the set in question, and use the remaining measurements to train and test a predictive model. For the experiments conducted here, we trained support vector machine (SVM) classifiers on gene expression derived datasets, and tested them on independent test sets. We compare the accuracy of the predictors produced using gene sets derived from the game and gene sets used in published survival predictors.

Results

Data From One Year of Game Play

The results presented here are derived from games played between September 7, 2012 and September 5, 2013. In that time, 1077 player accounts were created and a total of 15,669 games were played (including training games). There were 9904 games that were played on the cancer datasets. All collected data except personal player information is available, see Multimedia Appendix 2.

Players and Games Played

Based on the self-reported data collected during registration, the player population was mixed in terms of education, orientation as a biologist, and declared knowledge of cancer. In total, 35.00% (377/1077) of the players had a graduate degree, 28.88% (311/1077) had an undergraduate degree, and 36.12% (389/1077) did not declare any degree. There were 31.94% (344/1077) of the players that considered themselves biologists, while 62.67% (675/1077) did not, with 5.39% (58/1077) not responding. There were 32.96% (355/1077) of the players that declared that they were knowledgeable about cancer biology, 60.35% (650/1077) did not, and 6.69% (72/1077) declined to respond.

Over the course of the year, the number and demographics of players registering per month fluctuated (Figure 4 shows this fluctuation). In the first two months, 36.4% (67/184) and 37% (13/35) of the players who registered had PhDs. After those months, the percentage for the next four months ranged from 16% (4/25) to 18% (15/80), and then fluctuated between approximately 5% and 10% thereafter. We observed two notable spikes in player registrations. The first coincided with the launch of the game, its presentation at Genome Informatics 2012, and its advertisement as part of the Sage Bionetworks DREAM7 breast cancer prognosis challenge. The second, in May of 2013, is likely related to a posting on the popular website i09, which occurred on May 1, 2013 [21].

The total number of games played roughly followed the trends observed for new player registrations. The most games played on a single day were 550, on May 2, immediately after the i09 posting.

The number of games played per player followed a power law, consistent with most studies of the quantity of voluntary contributions in open environments (eg, Wikipedia contributions) [22]. There were 243 players that played more than 10 games, 28 players that played more than 100 games, and the most prolific player (“oneoff64”) that played 718 games (Figure 5 shows these numbers).

Figure 4. New player registrations per month, with academic degree. The figure shows the fluctuations in both the size and the demographics of the player population over time.

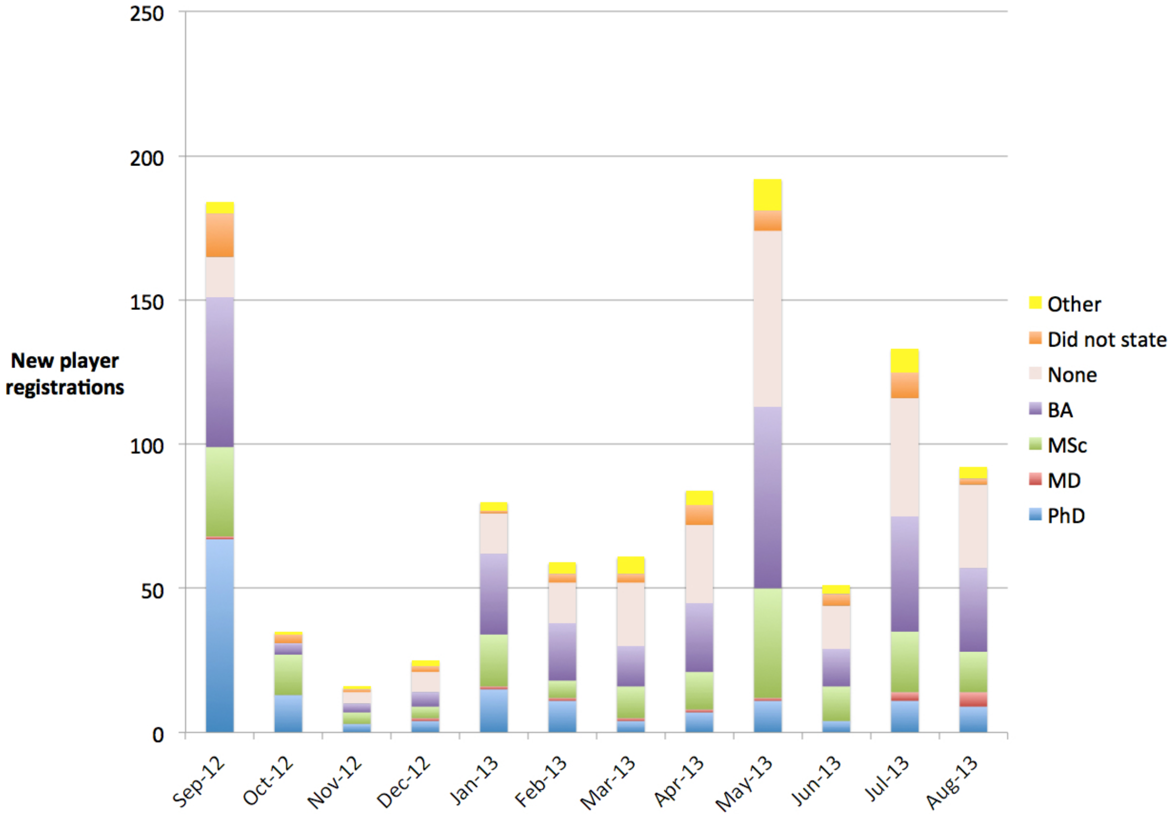
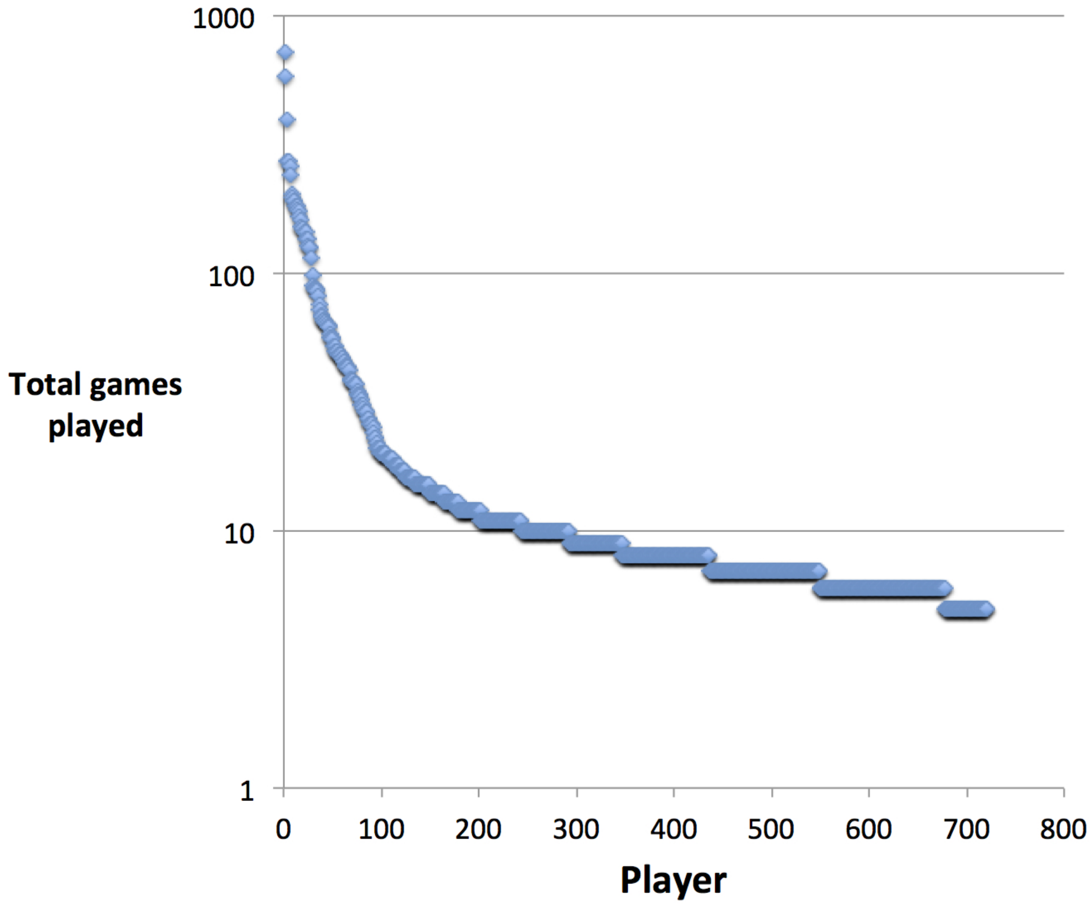


Figure 5. Games played per player. The majority of players only played a few games, while some players played several hundred games.



Gene Set Evaluations

We evaluated three game collections: (1) “all”, (2) “expert”, and (3) “inexperienced”. “All” considers games from all players; “expert” includes games from players that indicated that they had either a PhD or an MD and knowledge of cancer; and “inexperienced” includes just the games played by people without an advanced degree, with no knowledge of cancer, and that were not biologists. Only the first five cards per player per board are used for the analysis. This reduces the chances that individual players who repeatedly play the same board, either through cheating or by repeatedly losing to Barney, can introduce bias based on overfitting that board. Each game should reflect only the player’s thoughts about the best genes for that board prior to seeing the results of the decision tree analysis.

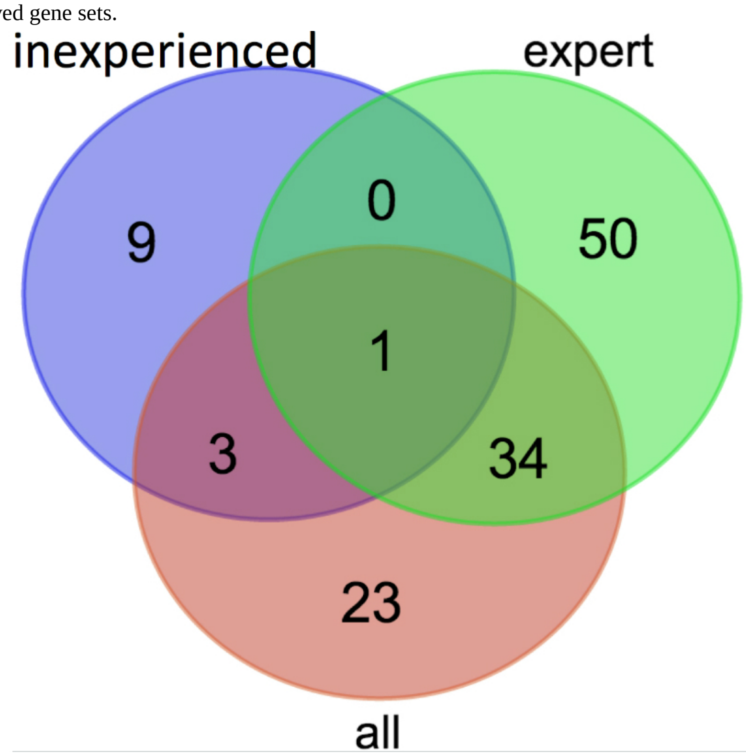
For all the results reported here, we select genes with $P \leq .001$ (see Aggregation Function in the Methods section). At that threshold, we observed 61 genes in the “all” group, 85 in the “expert” group, and 13 in the “inexperienced” group (Table 1). The complete set of game-derived gene rankings is available in Multimedia Appendix 3.

There was one gene, CASP1, which appeared in all three sets. The “all” gene set included 35 genes that also appeared in the “expert” set, as well as 4 genes from the “inexperienced” set (Figure 6 shows these sets). Aside from CASP1, there was no overlap between the “expert” and “inexperienced” gene sets.

Table 1. Predictor gene sets derived from The Cure.

Player group	n genes $P \leq .001$	Games considered	Contributing players
All	61	4314	477
Expert	85	1106	52
Inexperienced	13	1643	231

Figure 6. Overlap of game-derived gene sets.



Enrichment Analysis of Gene Sets

Given the gene sets identified above, the next question is whether or not they are relevant to breast cancer. Has knowledge successfully been transferred from the player population into the game? To address this question, we first used the WebGestalt enrichment analysis tool to identify which disease related terms were statistically overrepresented in the annotations of the genes [23]. We found both the “expert” gene set and the “all” gene sets to be significantly enriched for cancer-related diseases, while the “inexperienced” set was not significantly enriched for any diseases (Table 2). The background genes used for the enrichment analysis statistics corresponded to the 3731 genes that appeared in at least one game. The disease term with the most significant corrected *P* value in both the “all” and “expert” gene sets was “cancer or viral infections”. All of the top ten disease terms for both gene sets correspond to various kinds of cancer or cancer processes, such as “recurrence” and “disease progression”. Though they do not appear in the top ten results, “Breast neoplasms” and “Carcinoma, Ductal, Breast” are significantly represented in both gene sets (P < e-05).

Table 2. The top ten disease terms for the “expert” gene set based on WebGestalt analysis. All reported disease terms had adjusted *P* values using the Benjamini & Hochberg correction for multiple testing <.001. All of these terms were also significantly enriched in the “all” gene set with *P*<.001 except “Intestinal neoplasms“ which had a corrected *P* value of .01 in that set.

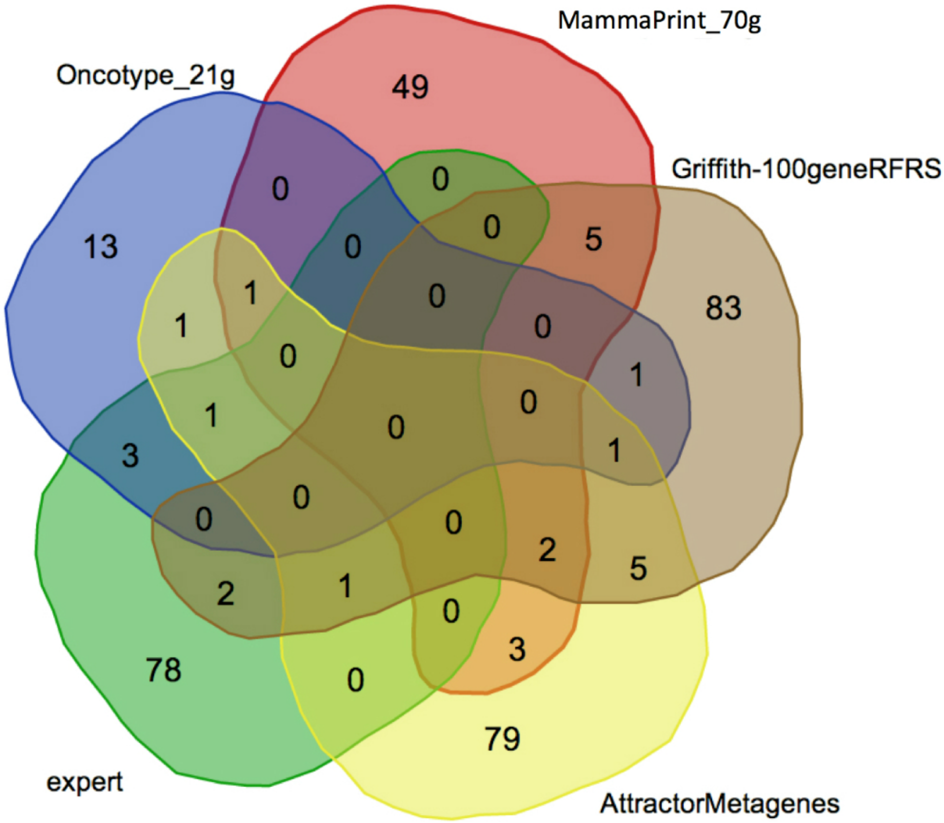
Disease term	Expert players (85 genes)		All (61 genes)	
	Genes in set	Adjusted *P* value (BH[a])	Genes in set	Adjusted *P* value (BH[a])
Cancer or viral infections	37	5.5e-16	25	8.1e-10
Neoplasms	32	4.7e-13	22	1.6e-08
Urogenital neoplasms	23	2.7e-11	12	9.0e-05
Cell transformation, neoplastic	16	4.7e-11	13	3.0e-09
Stomach neoplasms	14	2.6e-08	8	2.0e-04
Disease progression	16	3.7e-08	13	2.5e-07
Neoplastic processes	20	5.1e-08	18	1.3e-08
Recurrence	14	5.1e-08	11	1.1e-06
Intestinal neoplasms	15	6.1e-08	6	.01
Necrosis	15	1.1e-07	13	1.8e-07

[a]BH = Benjamini & Hochberg correction for multiple testing

Comparison to Established Predictor Gene Sets

In addition to the disease enrichment analysis, we measured the overlap between the game-derived gene sets and “gold standard” predictor gene sets used in commercial prognostic tests, and from recent publications. Figure 7 shows the overlaps between the expert game gene set, the 21 genes used in the OncoTypeDx test [24], the 70 genes in the MammaPrint test [2], the 100 genes recently identified via Random Forest analysis (RFRS) [4], and the 94 genes recently identified via the Attractor Metagenes approach [8]. Genes in the “gold standard” sets that never appeared in a played game were removed from the comparison (eg, only 58 of the 70 genes in the MammaPrint set were used.) The “expert” gene set contained four of the OncoType genes, zero of the MammaPrint genes, three of the RFRS genes, and two of the Attractor Metagenes. Based on a Fisher’s exact test, there was a statistically significant overlap with only the OncoType genes (*P*=2.026e-4).

Figure 7. Overlap of "expert" gene set derived from game data (in green) with prior published predictor gene sets. RFRS: Random Forest Relapse Score.



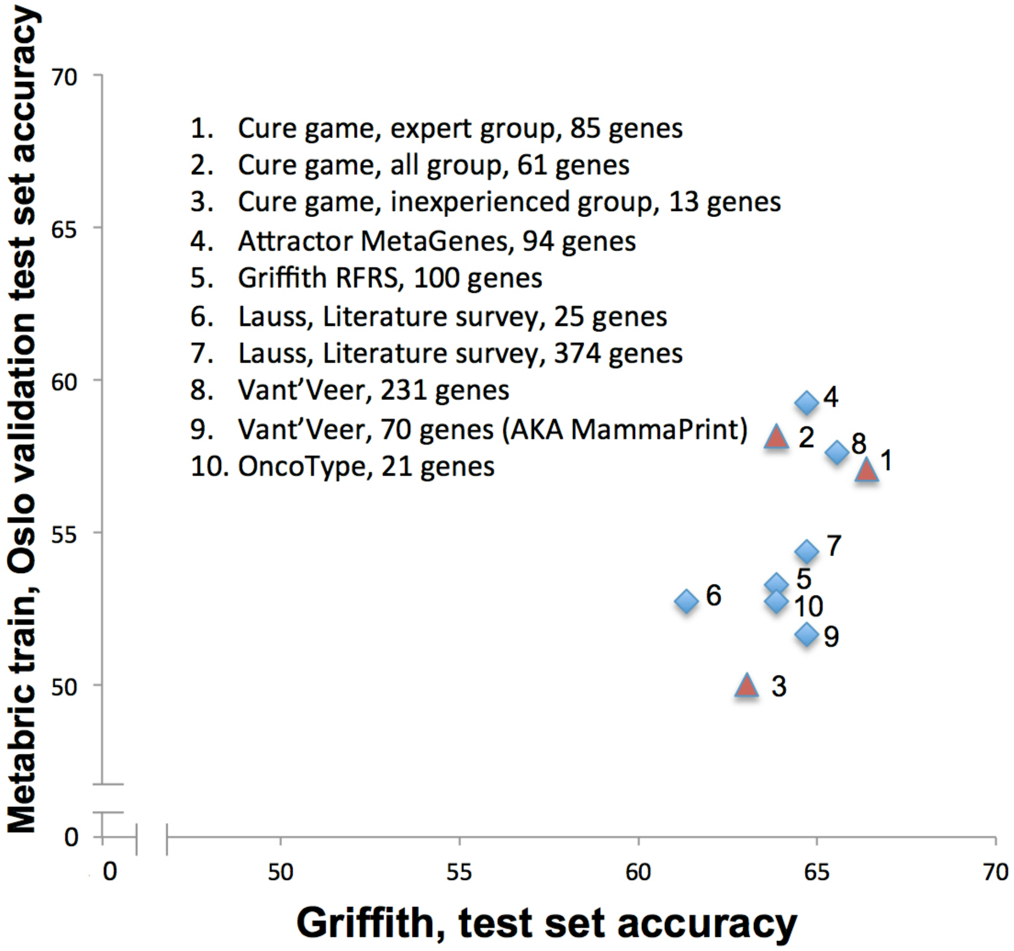
Classifier Evaluations

The gene set comparisons and enrichment analyses described above show clearly that the gene sets generated from the game data are nonrandom, with a significant representation of genes that are related to cancer. The final question addressed here is how well the game-derived gene sets do when used to create classifiers for predicting breast cancer survival.

We conducted two experiments, each involving the development of machine learning models for predicting 10 year survival based only on gene expression information. In the first, we trained an SVM classifier using gene expression data from the Metabric dataset [25], and tested it on the Oslo validation dataset generated for the Sage Dream7 breast cancer challenge [3]. In the second, we used the dataset from [4], using the same division of training/test data described in that publication. In both cases, we varied only the gene sets provided to the classifiers, and measured the performance of each gene set based on the accuracy of the SVM on the samples in the corresponding test set. Figure 8 shows that both the “expert” and “all” gene sets from the game performed comparably to the OncoType, MammaPrint, RFRS, Attractor MetaGenes, and to gene sets selected in a literature review [26]. In fact, the “expert” gene set from The Cure had the highest accuracy on the Griffith test set, and the third highest accuracy on the Oslo test set. In contrast, the 13 genes selected by the “inexperienced” players produced the worst classifier for the Oslo test set, and the second worst for the Griffith test set.

Based on these experiments, and others employing different machine learning methods (data not reported), we could not establish a statistically significant difference between the performance of models trained using the game-derived gene sets versus models trained with gene sets from more established methodologies. While we could not prove that the game-derived “expert” gene set was better than the other gene sets in a statistically significant manner, none of the other gene sets—including those used in commercial tests—were found to be consistently better either. The lack of a clear “winner” in this analysis reinforces the concept that there are actually many different gene sets whose expression signatures are nearly equally predictive of a breast cancer prognosis [27]. Identifying the optimal combination of genes, clinical features (eg, age, lymph node status), and machine learning approach remains a future challenge.

Figure 8. Evaluation of accuracy of models trained to predict ten year survival using gene sets derived from the game, and prior gene sets from the breast cancer literature. Lauss, Literature survey [27]. Vant'Veer datasets [3]. RFRS: Random Forest Relapse Score.



Player Survey

The Cure managed to attract and engage a surprisingly large number of people. To ascertain more about the player population, we conducted a survey of registered players as of November 2013. We sent an email to the 1162 players who had entered an email address when they registered, inviting them to answer questions about themselves, their motivations for playing, and their experience with the game. We received responses from 119 participants. While the respondents represent only about 10.24% (119/1162) of the total player population (and likely a more motivated segment), the responses do provide some interesting insights.

The first and perhaps most telling question in the survey was, “Why did you sign up for The Cure?”. Overall, 71.4% (85/119) indicated that they played to help breast cancer research, 52.9% (63/119) played to learn something, and just 43.7 (52/119) played in order to have fun. Respondents could select multiple answers. Given the design of The Cure website (“Play Games, Cure Cancer!”) [28], as well as the way it was promoted, it is surprising to see that the game aspect was actually the least motivational of the three. While we feel that developing this system as a game had a strong positive effect on recruitment and engagement, it is clear that there is a large pool of people that are highly motivated to contribute to breast cancer research in any way they can. The game was simply one more vehicle through which they could try to help. In some cases, this motivation is likely very personal, 63.6% (75/118) of respondents indicated that they know or have known someone that has or has had breast cancer.

Looking at the player demographics, we found that 59.0% (69/117) of the respondents were male, and 41.0% (48/117) female with 2 not responding. The largest age brackets were 21-29 years old (34.5%, 41/119) and 30-39 years old (28.6%, 34/119) (Figure 9 shows the ages).

Expanding on the expertise information collected when players registered, we asked the players to categorize their knowledge of breast cancer. The most popular answer by a wide margin was the middle expertise level, “I know some biology and have some understanding of what cancer is” at 57.1% (68/119) with numbers decreasing toward the high and low expertise levels (Figure 10 shows these answers).

Finally, we asked players whether the game was fun and whether or not they learned anything. Most (66.4%, 79/119) found the game to be “A little bit entertaining”, 14.3% (17/119) found it to be “very fun”, and 19.3% (23/119) found it “not at all” fun. The results for learning are similar, with 62.2% (74/119) feeling that they “learned a little bit”, 9.2% (11/119) that they “learned a lot”, and 28.6% (34/119) that they “did not learn thing”.

In summary, the survey showed that The Cure reached a demographically diverse audience containing both experts and novices, that most players found the game mildly entertaining and educational, and that the dominant motivation for playing was to help breast cancer research.

Figure 9. Ages of players.

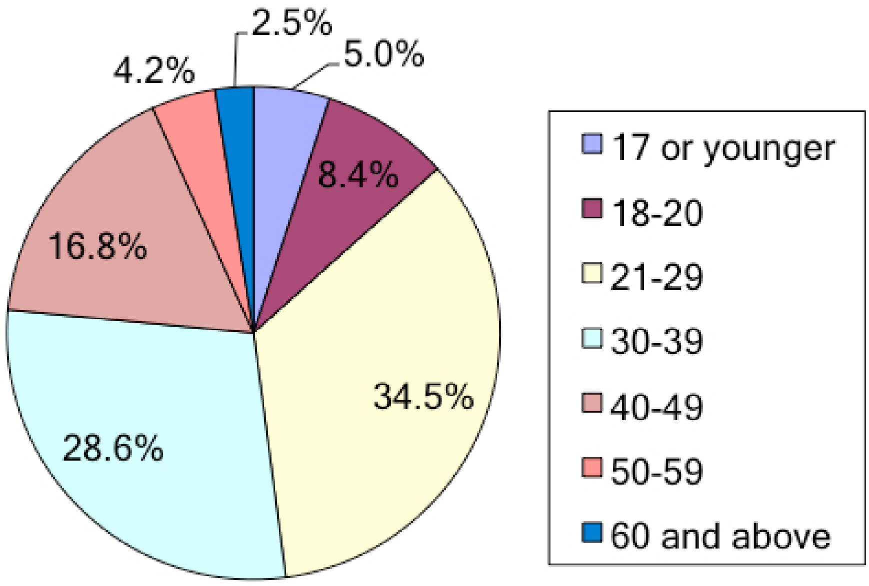
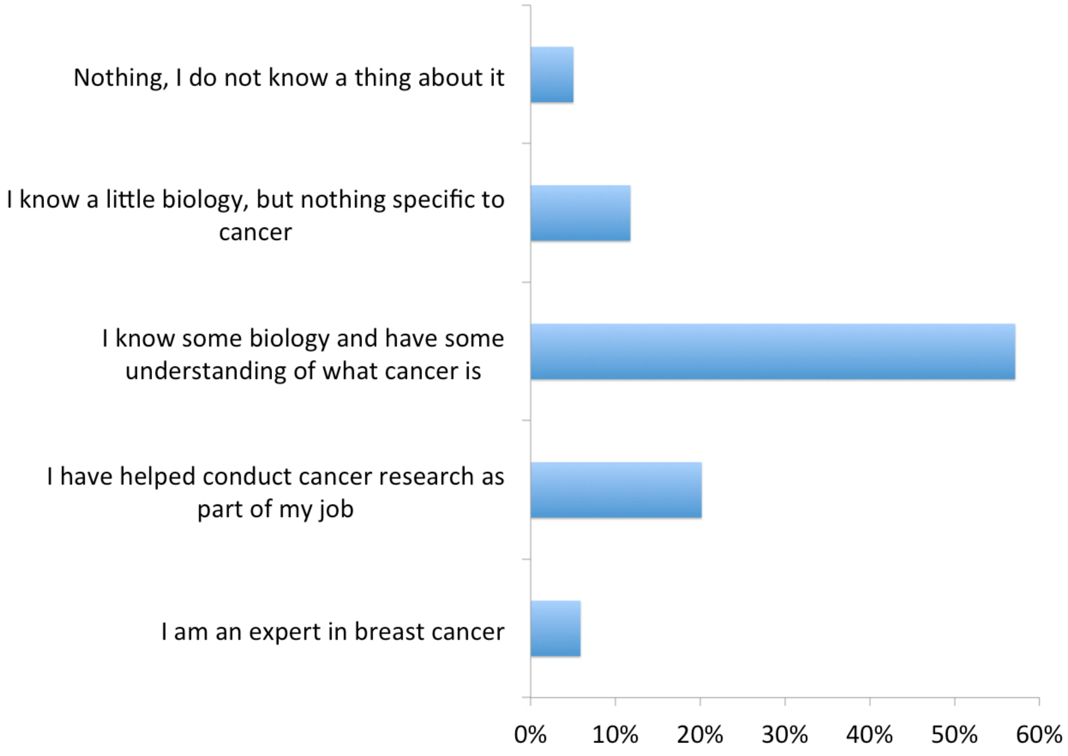


Figure 10. Levels of breast cancer knowledge among players.



Discussion

Principal Results

The principal contribution of this work is as an exemplar to show that crowdsourcing games can be developed as a means to address problems that require expert-level knowledge. To our knowledge, this is the first serious game of this kind. In the introduction, we laid out three foundational question areas pertaining to: (1) recruiting participants, (2) capturing knowledge, and (3) translating the captured knowledge to advance a research objective. We now briefly explore each of these in turn.

While previous work on scientific discovery games such as Foldit have focused on visual problems that do not require any knowledge on the part of the participants, the task presented in The Cure was knowledge intensive. In order to successfully participate, players either had to bring significant prior experience or be willing to invest a substantial amount of time learning. Given the challenging nature of the task, and the importance of prior knowledge, the results from the first year of the game were quite positive in terms of recruitment (1000+ players) and engagement (nearly 10,000 games). Based on the data collected when players registered, and through the survey, the game clearly succeeded in capturing the attention of a diverse audience including both novices and experts. While motivations were mixed, the dominant theme appeared to be a strong desire to help advance breast cancer research.

The second question was whether or not knowledge could be captured from players. The gene rankings produced from both the entire set of games played (the "all" set) and the games played by the "expert" players clearly demonstrate that advanced biomedical knowledge was transferred from the community through the game (Table 2). The game succeeded in capturing knowledge from players with prior experience, but it did not appear to successfully harness the reading and reasoning ability of the nonexperts. This was apparent in the poor performance of the genes extracted from the "inexperienced" players (Figure 8).

The final question was whether or not the collected knowledge could be used to advance the state of the art in breast cancer survival prediction. While we demonstrated that the gene sets selected by the aggregated actions of the player community were both relevant and competitive with gene sets produced using other means, we did not conclusively generate a better predictor of breast cancer prognosis (Figure 8). There is no doubt that the case for applying serious games in the context of knowledge-intensive challenges would have been strengthened by a better result here. However, it is important to keep in mind that this is an extremely difficult, well studied problem that may not even have an optimal solution [27]. The fact that the gene sets derived from the game are comparable in terms of predictive accuracy to gene sets identified using statistical approaches backed by literally decades of research provides strong evidence that this approach is worthy of additional study.

Limitations

The game described here was an early stage prototype with many limitations in terms of both its ability to achieve its purpose, and its ability to entertain players. Chief among the former was that the prebuilt boards severely constrained the number of different feature combinations that players could explore. The vast majority of possible gene sets simply could never be examined within this game framework. Further, because the aggregation function ranked individual genes rather than gene sets, it is unlikely that it would identify optimal feature combinations. In future iterations, it would be beneficial to adapt the game to allow advanced players more freedom to explore the feature space, while still maintaining the competitive dynamics that made the game entertaining.

Finally, the game could be made much more fun overall. The current formulation was highly repetitive, and had an extremely steep learning curve. The transition from the brief training stage to the real games was abrupt, and left many players confused. In the future, both the fun factor and the learning aspects of the game could be improved by implementing different levels of difficulty, providing more educational information in the early stages, and diversifying the tasks presented to players. Such changes should improve both player engagement and the quality of the information captured by the system. The code for The Cure game is open source, and we would warmly welcome any contributions or adaptations [29].

Conclusions

There is a large, heterogeneous population of people on the Internet that actively seek ways to use their minds to help solve important problems. Games such as The Cure provide one avenue to tap into this hidden resource for biomedical discovery.

Acknowledgments

We would like to thank all of the people who played The Cure. Research reported in this publication was supported by the National Institute of General Medical Sciences of the National Institutes of Health under award numbers R01GM089820 and R01GM083924, and by the National Center for Advancing Translational Sciences of the National Institute of Health under award number UL1TR001114. BMG and ASU conceived of the study. BMG and MN implemented the game. BMG drafted the manuscript. SL and CW contributed to the preprocessing of the microarray datasets. OLG provided advanced access to the microarray dataset used in the second two rounds of the game, and provided feedback on the game interface.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Additional detail on methods. A text document containing additional information about the methods used to process the microarray datasets, select genes for boards, and execute the machine learning experiments.

[PDF File (Adobe PDF File), 328KB - games_v2i2e7_app1.pdf]

Multimedia Appendix 2

Cure database export. The complete SQL database used to capture data for The Cure game. The database contains: (1) gene annotation information provided to the players in the game, (2) gene sets used to compose the boards in the game, (3) genes ("cards") selected by the players during their games including the order in which they were selected, (4) a log of games played, (5) logs of user actions including mouse click and hover events, and (6) player information (note that email and IP addresses have been removed). This is a compressed file that can be imported and opened using a MySQL database.

[GZ File, 31MB - games_v2i2e7_app2.gz]

Multimedia Appendix 3

Gene rankings from The Cure. An Excel workbook that shows the gene rankings generated from game play data. Rankings are shown for games from all players, from "experts" (those with a PhD or MD and knowledge of cancer), those with no expertise (no advanced degree, no knowledge of cancer, not a biologist), those with cancer knowledge, and those with a PhD or MD. Additional worksheets show the results from the WebGestalt analysis of the top ranked genes.

[XLSX File (Microsoft Excel File), 772KB - games_v2i2e7_app3.xlsx]

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Abbreviations

GWAP: games with a purpose
RFRS: Random Forest Relapse Score
SVM: support vector machine

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Review

Assessing Video Games to Improve Driving Skills: A Literature Review and Observational Study

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Abstract

Background: For individuals, especially older adults, playing video games is a promising tool for improving their driving skills. The ease of use, wide availability, and interactivity of gaming consoles make them an attractive simulation tool.

Objective: The objective of this study was to look at the feasibility and effects of installing video game consoles in the homes of individuals looking to improve their driving skills.

Methods: A systematic literature review was conducted to assess the effect of playing video games on improving driving skills. An observatory study was performed to evaluate the feasibility of using an Xbox 360 Kinect console for improving driving skills.

Results: Twenty–nine articles, which discuss the implementation of video games in improving driving skills were found in literature. On our study, it was found the Xbox 360 with Kinect is capable of improving physical and mental activities. Xbox Video games were introduced to engage players in physical, visual and cognitive activities including endurance, postural sway, reaction time, eyesight, eye movement, attention and concentration, difficulties with orientation, and semantic fluency. However, manual dexterity, visuo-spatial perception and binocular vision could not be addressed by these games. It was observed that Xbox Kinect (by incorporating Kinect sensor facilities) combines physical, visual and cognitive engagement of players. These results were consistent with those from the literature review.

Conclusions: From the research that has been carried out, we can conclude that video game consoles are a viable solution for improving user's physical and mental state. In future we propose to carry a thorough evaluation of the effects of video games on driving skills in elderly people.

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KEYWORDS

video games; driving; motor skills; health; coordination

Introduction

Aging and the lack of physical activity reduce cognitive abilities, as well as physical stamina, which in turn impacts a person's driving ability [1,2]. In many countries, especially in those with poor public transport, the ability to drive is essential. Without the ability to drive many activities such as visiting health care professionals, socializing, and purchasing groceries could be laborious. This reduces independence and the standard of living of people, thereby leading to increased health risks like reduced cognition and illness [3]. Studies have shown that the most rapidly growing segment of the driving population comprises of people over the age of 65 years [1]. With a larger number of those in the aging population still continuing to drive, it is vital to ensure that their driving skills are maintained. This is essential not only in improving their quality of life, but also to reduce the number of on-road accidents. Studies have shown that older drivers have a higher crash rate per distance travelled, with an increased risk of injury or death in the event of a car crash [4]. It has been shown that continued physical and mental training reduces the degradation of cognitive and physical functions, which are essential for driving [4-7]. Several activities to maintain physical and mental shape include regular physiotherapy, physical workout at the gym, and even playing puzzle games such as crossword. However these activities can be inconvenient to attend and could be boring for few individuals. This has been proven as studies show a 50% drop-out rate from exercise programs within the first 6 months [8]. Therefore, what is needed, is a more cost effective method of engaging individuals in exercise.

Vichitvanichphong et al [9,10] have observed that amongst various technologies adopted for aiding with the independent living of the elderly, games provide the most training to maintain their skills. This is attributed to the interactive nature of games, which thereby empowers them for better daily living. As explained above, one of the important skills for independent living is driving. The advantage that console games have is the ability to engage people in physical activity from the leisure of home while providing an interactive experience. It is also a cost effective method of providing interactivity with other individuals due to accessible, feasibility of set up in multiple homes, and provision of an intuitive feedback without the need to engage medical practitioners on a one-to-one basis. Not only do games improve physical states, but they also affect one’s cognition. With a vast selection of commercially available games, medical professionals could use a wide range of games as part of a daily training program to equip individuals with essential driving skills [11].

Earlier game consoles such as the Super Nintendo Entertainment System and the Nintendo GameCube required a wired controller for players to interact. There is evidence that even these games improved the cognition of players. Recently a newer wave of motion controlled consoles dominates the market. These not only improve the cognition of players, but also the affect their physical state by enabling the use of interactive gestures from the hand and body. Such technology has great potential for improving global health care. The Nintendo Wii released in 2006 has often been credited as the primary console initiating this revolution [11]. Since then several other commercial somatosensory gaming consoles have also entered the market. They include the PlayStation Eye and the Xbox 360 Kinect released in 2010. Xbox Kinect being physically, visually and cognitively engaging has been identified as an appropriate game console for the purpose of this study. To determine the potential and effectiveness of gaming on improving a person’s driving ability, a systematic review was conducted followed by an observatory study where the use of Xbox 360 Kinect games were evaluated.

Methods

Systematic Literature Review

To assess the effect of video games on driving skills, a systematic literature review was conducted to identify the most recent research related to the topic. The review was conducted over 4 months by searching various online databases including Google Scholar, PubMed, Scirus, Institute of Electrical and Electronics Engineers (IEEE) Xplore, Springerlink, ScienceDirect, and Wiley InterScience. The objective was to eliminate all papers that were not relevant to the topic: Video Gaming for Improving Driving Skills. All papers reviewed were written in English and published between the year 2000 and 2012.

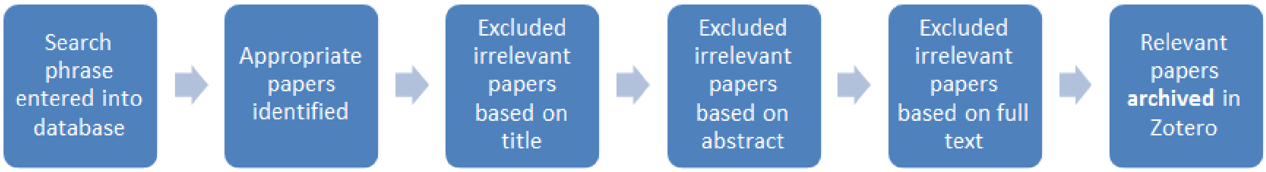
In terms of definitions, the topic Video Games included all forms of electronic games including console, computer, motion controlled, and the traditional gamepad/joystick controlled games. Driving skills included cognitive functions, physical ability, and reaction speed. Hence the first step was to identify synonyms for terms “video game” and “driving”. Once a list of synonyms had been compiled, the search phrase was created ("Video Game" OR "Computer Game" OR "exergame" OR "interactive game" OR "XBOX" OR "Wii" OR "PS2" OR "PS3" AND "car" AND "driving"). The word driving was then replaced with other words relating to motor skills which were speed control, lane change, lane observance, head check, shoulder check, lane deviations, touching lane, centerline, parallel parking, staring, pulling curb, signal, indication, turn, grasp wheel, turn wheel, wrong lane, gas, clutch, and seatbelt (ie, "Video Game" OR "Computer Game" OR "exergame" OR "interactive game" OR "XBOX" OR "Wii" OR "PS2" OR "PS3" AND "car " AND "speed control"). These phrases (21 in total) were then entered into each database and all relevant published papers found were screened first by title, then by abstract, and finally by full text. Any repeated articles in the search were excluded.

The methodology is illustrated in Figure 1. As the review was to look for the empirical evaluation of using gaming, to improve driving of the elderly, any published paper that did not have empirical results was excluded. Once the relevant papers were found they were archived using the reference management software Zotero 4.0, released in 2013 from Roy Rosenzweig Center for History and New Media. One limitation of this review was that the quality of papers, containing the relevant search terms was not assessed. This was due to the limited number of relevant papers. Therefore, all articles found were included.

On reviewing the shortlisted papers it was determined that video games could potentially improve driving skills both in terms of cognition and physical state. It was further determined that there were three major commercial motion controlled gaming consoles currently in the market that could potentially improve the skills of the drivers (Xbox 360 Kinect, Nintendo Wii, and Playstation Eye on the PlayStation 3 system). It was also determined that of the three consoles, Xbox 360 Kinect was the only console that did not require hand-held controllers and also had the ability to track lower body movement. Thus an evaluation of the Xbox

360 Kinect system was conducted to assess how effective it would be.

Figure 1. Article selection process for systematic literature review.



Self-Observatory Study: Evaluation of Xbox 360 Kinect Games

An Xbox Kinect System was purchased and tested for its benefits on improving driving skills by three researchers aged between 22 to 40 years. Several games including Kinect Sports, Just Dance 3, Kinect Adventures, Dr Kawashima's Body and Brain Exercises, and Forza Motorsports 4 were purchased for the study. These games were selected on consultation form a panel of experts in order to relate the physical, visual and cognitive functional skills from the game to actual driving skills. Also these games were fun, more enjoyable and served as a cheap alternative to exercise functional abilities. These games were then tested by the researchers between February to July 2012, during which presentations were carried out in small groups of five to ten researchers, where the capabilities of the console were demonstrated. Further discussions were held, wherein ideas and thoughts on the advantages and disadvantages of using the Xbox Kinect system to improve motor skills were discussed.

Results

Overview

The results of the literature review are illustrated in Table 1. In summary 150 papers were found to satisfy the criteria based on the abstracts' relevance to the topic with 78 papers being repeated. Of these, 29 papers were shortlisted based on the full text's relevance to the topic [12-40]. It was found that the Xbox 360 Kinect had several useful features including various levels of difficulty, improvements in memory, multiple games, reports on progress, entire body training, multiplayer, connecting peripherals including driving wheel and pedals, Internet connectivity, and a freely available software development kit (SDK). Though some of these features may be available in other consoles such as Nintendo Wii and PlayStation 3. The Xbox Kinect, unlike the other systems, need not have sensors attached to the player, thereby providing a more realistic experience.

Table 1. Results from systematic review.

Database	Number of results	Number of articles by titles	Number of articles by abstract	Number of repeated articles	Number of articles by full text
Google Scholar	2195	146	78	32	13
SpringerLink	684	74	38	23	7
Wiley InterScience	536	10	2	11	1
ScienceDirect	551	40	11	9	2
Scirus	226	19	6	3	2
IEEE Xplore	47	17	9	6	3
PubMed	46	13	6	4	1
Total	4285	319	150	78	29

Increasing Level of Difficulty

Several games have varying levels of difficulty, which provide an opportunity for less active players to gradually improve their abilities, rather than being disheartened when attempting a difficult level initially. Games such as Just Dance 3 have two modes, namely the 'Easy' and 'Normal' modes. The former mode trains only the upper body while the latter mode requires the use of the entire body including the legs and the hip. Another example is Kinect Sports which has 4 levels of difficulty; beginner, amateur, professional, and champion. On our evaluation, the beginner mode was found to be extremely easy and the amateur mode, in our opinion, was sufficiently adequate for keeping the players active.

Improved Memory

On several games, the player is trained on improving their memory. This could help improve the player's response time, thereby serving as a crucial skill in identifying signs such as traffic lights and speed limits while driving. The game, Just Dance 3 requires the player to memorize a certain pattern of poses before executing them on the gameplay. Brain and Body Exercises which tests various cognitive functions including math, logic, and memory.

Multiple Games

The Xbox 360 has a vast array of games, all of which train users at different skills. In our discussions, it was suggested that professionals such as physiotherapists could outline a training program on gaming to ensure the testing for all driving skills. For example Dr Kawashima's Body and Brain Exercises was evaluated for training the cognitive aspects required for driving with its mini games on logic, mathematics, and memory, combined with limited hand eye coordination training. Kinect Sports was found to be better for physical training, with an array of different sports such as soccer, boxing, table tennis, and bowling. Even within Kinect Sports, there were various mini-games, based on the various sports that trained specific muscle movements such as goalkeeping. The physiotherapists involved in our observational study, suggested 10 minutes on table tennis to improve hand eye coordination, followed by 5 minutes of soccer to train the legs, followed by 10 minutes of memory games for mental exercises.

Reports and Feedback

Most of the games provided a report at the completion of the game. This feature could motivate players and also be used by medical practitioners to monitor their progress. In Just Dance 3, players are rated on their timing and accuracy, with the gameplay choreography. This report could be compared with that of others worldwide. Another example would be Dr Kawashima's Body and Brain Exercises that measured the score over 3 games and provided a brain age score which again could be compared with the player's previous scores. Though mostly advantageous, this could be a disadvantage as poor scores in a few instances demoralize players.

Motivational Quotes

On completing certain games, motivational quotes that encourage players to improve on their scores or to train daily are provided. The issues with traditional self-training programs involving stretches and weights is the lack of human motivation on improvement or encouraging further participation. This lack leads to individuals failing to complete their exercises. Consequences like this, could lead to decreased training and eventually the deterioration of their driving skills [10]. Kinect Sports encourages players to exceed the average score recorded on the game and Dr Kawashima's Body and Brain Exercises plays congratulatory music and displays images, when players exceed their previous scores.

Training Entire Body

Kinect unlike traditional gamepad/joystick games, requires players to move the entire body and this could improve their coordination. In the game, Just Dance 3 the objective is to memorize choreographic moves and to repeat them accurately. This exercises the entire body, enabling better flexibility of the limbs along with improved coordination. Kinect sports has multiple games such as tennis, which requires active movements of the trunk and upper limbs and soccer, requiring mostly lower body movements.

Ability to Carry Weights

The issue was raised about the lack of resistance when playing games using the Kinect system. While testing the game, Kinect Sports, we noted that players could hold weights in their hands while playing games like bowling and tennis. This could drastically increase muscle weight and strength required for driving in the elderly. We tested this by asking the players to hold one kilogram weights while playing Kinect Sports and assessed their feedback. As expected, the feedback was positive and many stated that this seemed to make the gameplay more real. However, certain issues with controlling were found when holding items such as in the game, Forza Motorsport 3 where a wheel had to be handled while driving. These issues were mostly related to ergonomic concerns and are explained in the discussion section.

Multiplayer

Most of the games in more recent gaming consoles have a multiplayer mode, wherein the player could compete against other player in their living room or online. This feature that promotes competition, could serve as an impetus to use the Xbox for many individuals. Another advantage is that no additional equipment other than the Kinect sensor is required while playing the multiplayer mode as one Kinect sensor tracks up to 4 players simultaneously. Several games offer multiplayer modes such as tennis and boxing on Kinect Sports, which according our players were exhilarating and definitely a lot of fun. Just Dance 3, Dr Kawashima's Body and Brain Exercises, Forza Motorsports 4, and Kinect Adventures also have multiplayer modes and rank the scores of all players.

Peripherals: Driving Wheel and Pedals

Certain Xbox 360 games such as Forza Motorsports 3 allow the use of driving wheels and pedals in gameplay, which simulates a true driving experience. This could be very effective for improving driving skills in older adults. An issue however, is the additional cost of purchasing the driving wheel and pedals. Unlike more interactive games such as Kinect Sports, simulated driving games cannot be relied on for fitness training.

Internet Connectivity

All Xbox 360's can connect to a network router using a cable with a built-in 10/100 Ethernet network adapter. The upgraded console, Xbox 360 Slim also has built in wireless N 2.4 GHz networking which provides the option of Wi-Fi connectivity. With Internet connectivity, the Xbox 360 provides the option for constant monitoring of results from every game played. These results could be used to assess driving capability, amount of usage and areas for improvement. Several games such as Kinect Sports and Just dance 3 upload scores to the user's profile by default after obtaining an initial confirmation to do so.

Xbox Kinect SDK

The SDK is freely available and allows for the development of customized applications. This could be used to design simple, and cost-effective programs targeted specifically at improving specific skills required for driving. These programs can be run by connecting the Kinect System to a computer via a universal serial bus (USB) port. This eliminates the need for a Xbox 360 console, however to play the more interactive, cost effective and robust commercially games such as Kinect Sport, the Xbox 360 console is still required.

Ergonomic Issues

There were few ergonomic issues found while using the Xbox that could increase the risk of injury. The constant flashing of images during gameplay may trigger nausea and seizures, mostly in those with prior history. One researcher succumbed to this and was slightly ill, while playing Kinect Adventures. This is probably due to the result of quick color alterations that have been built into the games for players to pay more attention [41]. However, this could also cause some visual problems. One solution would be the use of sunglasses while playing [42]. Another concern when using the Xbox to exercise is the likelihood of injury while exercising.

Costs

The cost of the Xbox 360 250GB Kinect console buddle with three games at a major games retailer in January 2012 was $388 (Australian dollar). The cost of games, range from $20 to $150. The cost of purchasing such a console was relatively affordable and is a viable solution to improve driving ability.

Discussion

Principal Findings

According to our findings there are many benefits to using video games to improve driving ability. Aging and a lack of exercise lead to weakening of the mind and body. However, studies [43] have shown that the deterioration of the body and mind can be slowed down by exercising. Few methods of achieving this include physiotherapy sessions and swimming. Although for many people, these activities may be cumbersome to attend. Another option is to exercise at home, training both physically and completing mental challenges such as crossword puzzles from newspapers and magazines. The issue with this approach is that these exercises could get boring for few and they may neglect to complete them.

We also noticed few ergonomic issues in this study. In active games such as Just dance 3, the possibility of injury is high due to the balance required when twisting the body. However, while playing games such as Body and Brain exercises, the probability of getting injured is less. We find that the fitness of the players needed to be improved gradually either by beginning with less active games, or by beginning at a lower difficulty level and progressively increasing difficulty. It was also suggested that a system be designed to ensure emergency services, should someone be injured. As with physical exercise, players should be aware of their abilities and must avoid putting themselves into undue straining. Video game producers should consider physical limitations of aged players and specific ergonomic requirements could be implemented with more user-friendly factors.

Conclusions

Video Games, with the advantage of being designed for pleasure, also have the potential to increases physical activity. They are portable and can be easily setup at most homes providing a very convenient method of exercise, especially for those with reduced mobility. The results obtained from the evaluation of an Xbox 360 with Kinect suggest that it is a viable solution for improving the user's physical and mental state. Although there are a few issues with using the Xbox for exercise, such as risk of injury and nausea, steps could be implemented to overcome these barriers. Gaming consoles can be affordable, convenient, and motivational, thereby helping with the reduction of road accidents and increasing the average driving age. Eventually this improves the quality of life especially in older adults.

Future Work

Following our observatory study, we recommend that further investigations be conducted to find a correlation between gaming and improving driving skills. A promising approach would be to conduct long-term studies to compare the outcome of driving skills in seniors being trained with Xbox Kinect games.

Authors' Contributions

DS conducted the experiments explained in this paper and reported the results. PR supervised the aged care related issues in this study while ATK was involved with the technology related issues in this work. JJ worked on the gaming aspects and SV evaluated the results of the literature review.

Conflicts of Interest

None declared.

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Abbreviations

SDK: software development kit

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Original Paper

Diabetes Island: Preliminary Impact of a Virtual World Self-Care Educational Intervention for African Americans With Type 2 Diabetes

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Abstract

Background: Diabetes is a serious worldwide public health challenge. The burden of diabetes, including prevalence and risk of complications, is greater for minorities, particularly African Americans. Internet-based immersive virtual worlds offer a unique opportunity to reach large and diverse populations with diabetes for self-management education and support.

Objective: The objective of the study was to examine the acceptability, usage, and preliminary outcome of a virtual world intervention, Diabetes Island, in low-income African Americans with type 2 diabetes. The main hypotheses were that the intervention would: (1) be perceived as acceptable and useful; and (2) improve diabetes self-care (eg, behaviors and barriers) and self-care related outcomes, including glycemic control (A1C), body mass index (BMI), and psychosocial factors (ie, empowerment and distress) over six months.

Methods: The evaluation of the intervention impact used a single-group repeated measures design, including three assessment time points: (1) baseline, (2) 3 month (mid intervention), and (3) 6 month (immediate post intervention). Participants were recruited from a university primary care clinic. A total of 41 participants enrolled in the 6 month intervention study. The intervention components included: (1) a study website for communication, feedback, and tracking; and (2) access to an immersive virtual world (Diabetes Island) through Second Life, where a variety of diabetes self-care education activities and resources were available. Outcome measures included A1C, BMI, self-care behaviors, barriers to adherence, eating habits, empowerment, and distress. In addition, acceptability and usage were examined. A series of mixed-effects analyses, with time as a single repeated measures factor, were performed to examine preliminary outcomes.

Results: The intervention study sample (N=41) characteristics were: (1) mean age of 55 years, (2) 71% (29/41) female, (3) 100% (41/41) African American, and (4) 76% (31/41) reported annual incomes below US $20,000. Significant changes over time in the expected direction were observed for BMI (P<.02); diabetes-related distress (P<.02); global (P<.01) and dietary (P<.01) environmental barriers to self-care; one physical activity subscale (P<.04); and one dietary intake (P<.01) subscale. The participant feedback regarding the intervention (eg, ease of use, interest, and perceived impact) was consistently positive. The usage patterns showed that the majority of participants logged in regularly during the first two months, and around half logged in each week on average across the six month period.

Conclusions: This study demonstrated promising initial results of an immersive virtual world approach to reaching underserved individuals with diabetes to deliver diabetes self-management education. This intervention model and method show promise and could be tailored for other populations. A large scale controlled trial is needed to further examine efficacy.

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KEYWORDS

minority group; type 2 diabetes mellitus; self-management

Introduction

The Burden of Diabetes

Diabetes is a serious worldwide public health challenge that has been growing in prevalence, with an estimated 347 million people with diabetes worldwide [1]. There are two major forms of diabetes, type 1 and 2, affecting 10% and 90% of the population, respectively [1]. The burden of diabetes, including prevalence and risk of complications, is greater for minorities, particularly African Americans [2]. Diabetes affects approximately 4.9 million, or 18.7% of African Americans 20 years or older [3]. African Americans are 1.8 times more likely to have diabetes, 2.6 to 5.6 times as likely to suffer from kidney disease, and 2.7 times as likely to suffer from lower-limb amputations as non-Hispanic whites [3].

Harnessing the Virtual World

The Internet in general, and immersive virtual worlds, in particular, offer a unique opportunity to reach large and diverse populations with diabetes, while minimizing common barriers, such as lack of transportation or child care and scheduling conflicts. Immersive virtual worlds (eg, computer-based simulated 3-dimensional, 3-D, environments) are intended for users to inhabit and interact via an avatar, and communicate with others using voice and text chat tools. Second Life (SL) is one of the most frequently used virtual world environments, and offers a unique opportunity for reaching people with type 2 diabetes mellitus [4]. Several methodological and theoretical papers [5-7] have been published on the use of SL in supporting self-management in people with diabetes. To our knowledge, only one published study examined the outcomes of the use of a virtual environment for diabetes self-management education and support [8]. This pilot study demonstrated the feasibility and promising preliminary effects of this approach.

African Americans and the Internet

National trends demonstrate increased Internet use among African Americans. For example, in 2010 African Americans were estimated to be the fastest growing population for in-home broadband Internet adoption [9]. In addition, the percentage of African American adults with a home broadband connection grew by 22% from 2009 to 2010 (46% in 2009; 56% in 2010; and 64% in 2013) [9,10].

Study Purpose

The overall purpose of this study was to implement and evaluate the preliminary impact on self-care of a SL virtual world intervention ("Diabetes Island") designed to provide diabetes self-management education to facilitate optimal diabetes self-management in low-income African Americans with diabetes attending primary care clinics. A secondary goal of this study was to purposefully recruit underserved individuals who might not have the opportunity to participate due to lack of computer/Internet skills and/or access. If effective, this intervention could be tailored for other groups and scaled up to reach large populations with diabetes.

This paper addresses the acceptability, usage, and preliminary impact of the Diabetes Island intervention on self-care and related outcomes. The main hypotheses were that the intervention would: (1) be perceived as acceptable and useful; and (2) improve diabetes self-care (eg, behaviors, barriers, and dietary intake) and self-care related outcomes, including glycemic control (A1C), body mass index (BMI), and psychosocial factors (ie, empowerment and distress) over six months. In addition, average weekly Diabetes Island log-ins will be provided to examine usage.

Methods

Study Design

The evaluation of the impact of the intervention involved a single-group repeated measures design with three intervention assessment time points: (1) baseline, (2) 3 month (mid intervention), and (3) 6 month (immediate post intervention).

Setting, Eligibility Criteria, and Recruitment

The participants were recruited from a university-based primary care clinic. The eligible individuals were informed of the study details, invited to participate, and, those who were interested completed the consent process. Institutional Review Board (IRB) approval was obtained through the University of Illinois IRB.

The participants were enrolled in this study based on the following primary inclusion criteria: (1) African American; (2) age equal to or greater than 18 years; (3) fluent in English; (4) able to provide informed consent; (5) diagnosis of type 2 diabetes; (6) receiving medication therapy for diabetes (insulin or oral agents, or both); and (7) not pregnant, or planning a pregnancy during the study period.

Run-In Phase

An initial run-in phase was conducted to serve multiple purposes, including to confirm that potentially eligible participants had basic skills in using the computer and SL; to ensure that individuals were committed to participation; and to gather feedback to further refine the intervention and support usage. Over approximately two months, clinic staff identified and referred 112 potential participants to the research team during routine clinic visits. A total of 109 participants were enrolled in this run-in phase. The run-in phase activities were held at the research site, and included study orientation, assessments, and trainings. A goal of the study was to include individuals with a wide range of computer and Internet skills at enrollment, including individuals with limited or without any computer and/or Internet skill. Therefore, to support this goal, an intensive 2 hour in-person training was conducted as part of the run-in phase to provide: (1) basic skills in the use of a laptop (eg, power on; use mouse; and use keyboard), (2) Internet (eg, open and close browser; use desktop icons; and use address box), and (3) SL (eg, log in; walk; view and keep objects; and use voice and text chat). The participants were able to attend the training a second time where needed or desired. Feedback was obtained from the participants during this process on the intervention, and observations were made regarding any challenges during use.

Sample

A total of 69 participants were eligible for the intervention study (23/69 were lost to follow-up; 5 declined participation), and 41 consented and provided baseline assessments. There were four additional participants that withdrew prior to logging in at all; 37 participated in the intervention.

Data Collection Procedure and Measures

Data Collection and Procedure

Assessment was conducted during the run-in period to collect basic self-report information on demographic, sociodemographic, and technology use characteristics of the participants. Self-report measures, BMI, and A1C were collected at baseline, 3 months (mid program), and 6 months (end of intervention) by trained research staff. The participants came to the Institute for Health Research and Policy at the University of Illinois at Chicago for training and each assessment. The self-report measures were administered using an interactive (touch screen) computerized assessment method that included audio through headsets (where desired). The participants received US $25 for completion of each assessment at the research site.

Strategies to Overcome Access Barriers

All of the participants in the intervention were provided with the same type of laptop to minimize barriers to access, and to ensure that everyone had a computer that would support the 3-D multimedia aspects of the program. Support for Internet access was also provided where needed to eliminate lack of Internet access as a barrier. The computers were set up by research staff to include only the software necessary for the study, and participants were instructed to use the computer only for study purposes during the study period. The participants were informed after the run-in period, and during the intervention study consent process, that they could retain the laptop at the completion of the study.

Measures

Diabetes Control and Anthropometric Measures

Hemoglobin A1C level, a measure of long-term glycemic control, was obtained by a trained research staff member using the DCA2000+ Analyzer from Bayer (Mikashawa, IN). Height was measured using a portable stadiometer at baseline. Weight was measured using a Tanita Body Composition Analyzer at each assessment (Tanita Corporation of America, Inc).

Self-Care Measures

The self-care measures included: (1) the Summary of Diabetes Self-care Activities [11] (SDSCA) to assess diabetes self-care behavior; (2) the Environmental Barriers to Adherence Scale [12] (EBAS) to assess environmental barriers that interfere with self-care; and (3) the Fat-Related Diet Habits Questionnaire [13] (DHQ) to assess dietary intake.

The SDSCA was modified to include all of the original items, plus additional items to assess walking and specific nutritional content areas emphasized in the program (ie, reading food labels, choosing foods from the five food groups, and drinking water). The original SDSCA subscales were used for glucose self-testing, foot care, and medication use. The revised SDSCA subscales were examined in this study for general diet, specific diet, and physical activity. The medication use scale has been found to display a ceiling effect [11]; therefore, medication adherence was excluded as a self-care outcome in the current study. We additionally computed a composite score across these subscales, as done in previous studies [14].

The EBAS [12] examines 60 environmental barriers across four areas of self-care (ie, diet, exercise, blood glucose testing, and medication). A global barriers score is calculated by summing the responses to all of the items, and subscales are calculated for each of the self-care behavior areas. The DHQ [13] is a 22 item scale that assesses eating habits, and provides five factor scores measuring low-fat/nonfat substitution, modification of meat intake, avoidance of frying, fruit and vegetable replacement, and avoidance of fat. Lower scores over time, on the DHQ, reflect an increase in healthy eating.

Psychosocial Measures

The psychosocial measures included: (1) the Diabetes Empowerment Scale-Short Form [15] used to assess psychosocial self-efficacy and empowerment; and (2) the Diabetes Distress Scale [16,17] to assess diabetes related problems and distress.

Acceptability and Usage

Questions were included in the 6 month assessment to examine acceptability of the intervention. Acceptability questions covered topics related to ease of use, interest and comfort level, and perceived personal impact. Log-in data for Diabetes Island were collected to examine usage.

Intervention Components

Overview and Development

The participants in the intervention study (n=37) were given access to the intervention components during a 6 month period.

The intervention components included a study website for communication and tracking, as well as access to a SL dedicated study space, Diabetes Island, where a variety of educational activities were available as described below. The intervention was designed and developed by a multidisciplinary (physician, nurse educator, psychologist, and dietitian) research team, including experts in content, SL, and behavior change; and a technology development team, including designers and programmers. Input was also obtained from two advisory committees: (1) one included African American individuals with diabetes, and (2) the other included health educators who implement community-based diabetes education programs within similar populations. Advisory committee meetings were conducted to obtain input regarding the overall design of the virtual world intervention, and the specific content areas of the educational components. The development of the educational component was informed through input from the multidisciplinary research team, and feedback from advisory committees regarding patient needs. In addition, behavior change theory, particularly social cognitive theory [18], was used to guide the development of the intervention. The emphasis was on increasing knowledge (eg, formal and informal presentations; educational resources available); building self-efficacy through in-world contextual activities (eg, successfully making healthier food choices in a programmed fast food activity with feedback); observational learning or learning from other participants (eg, in-world interactive discussions on healthier eating); reinforcement (eg, receiving points for participation in educational activities); and goal setting (eg, setting personal activity goals using website). In addition, observations and feedback from the participants during the run-in phase were used to modify the intervention and its implementation. For example, the participants had challenges with using chat features, navigation, and working with objects. Therefore, in-world technical support sessions were added and modifications (eg, instructional signage) were made to the island to help the participants with various aspects of using SL (eg, navigation, keeping/using objects, and chatting).

Study Website

A study website was developed to: (1) communicate with the participants about project activities, events, and announcements; (2) track individual goals, activities, and accomplishments; (3) provide individualized feedback on activity completion; and (4) provide study and technical support information.

Second Life Intervention, Diabetes Island

SL is a virtual world or computer-based simulated 3-D environment intended for users to inhabit and interact via an avatar (a virtual world representation of the user). Users are identified by their avatar name, and can communicate with other users through voice and text chat tools. Real life anonymity is guaranteed unless the user chooses to share his or her real-world identity. Our study island was password protected, and only the study participants and the project team were provided with access to Diabetes Island.

Using their avatars, the participants could access a variety of educational resources available 24/7 (ie, on-demand) at different locations on Diabetes Island. In particular, these included several programmed scenarios (described below); nutrition labels and educational signage around the island; and a learning center with a variety of written materials (eg, National Diabetes Education Program materials) and videos (eg, American Diabetes Association videos). There were four programmed scenarios that provided interactive contextual learning opportunities particularly related to healthy eating and physical activity. For example, “choosing a healthy lunch on the go” focused on making healthier choices through reading food labels at a fast food restaurant.

Health professionals (as avatars) provided real time formal and informal educational sessions. A series of 10 formal presentation sessions (30-60 minutes in length) were offered, including: (1) six healthy eating topics led by a registered dietitian; (2) one on medication adherence led by a pharmacist; (3) one on physical activity led by an exercise researcher; and (4) two led by a nurse Certified Diabetes Educator on the “ABC’s” of diabetes and proper foot care. Several dietitian-facilitated real time discussions on healthier eating were offered in the grocery store, fast food restaurant, and home. An example of a dietitian-facilitated discussion opportunity involved meeting at the grocery store to discuss making healthier choices while shopping and reading food labels (Figure 1 shows this image). The participants received points for engaging in various Diabetes Island educational activities, and these points could be traded for clothing for their avatars.

Social activities, such as dance parties and sporting/leisure activities, were regularly offered on Diabetes Island to encourage the participants to visit frequently, and, thereby, facilitate engagement in the intervention. In-world technical support sessions and walking tours of the island were offered periodically to help the participants learn about the island and its use. When participants needed or requested guidance or information regarding their medical care, the project staff and presenters referred them to their primary care providers.

Figure 1. Dietitian-led discussion of reading food labels in the grocery store.

Intervention Procedure

The participants were given access to Diabetes Island for a 6 month period. There were regular (generally weekly) professional-led virtual world educational events, and periodic virtual world leisure/social events as described earlier. In addition, the participants had access to Diabetes Island 24 hours per day, seven days a week, and could access educational resources and participate in programmed activities on their own schedule. Since the participants' computer, Internet, and SL skills were diverse, the research team also provided periodic in-world technical support sessions to answer questions and assist with common technical challenges (eg, chatting, keeping/interacting with SL objects, navigation, and downloading updates). Instructional/technical support was also available through written manuals on the study website, and on an individual basis by telephone when in-world support sessions were not sufficient.

Analyses

In order to take into consideration the correlated nature of longitudinal data, and the fact that observations over time are nested within individuals, we performed a series of mixed-effects analyses with time as a single repeated measures factor. This approach is also quite compatible with an intent-to-treat approach to data analysis, as it does not require that respondents have complete data at all waves to be included in the analysis. The present analyses employed a Toeplitz covariance structure for the repeated observations, which assumes that the correlation between observations decreases the further out observations are in time. If a significant time effect was observed, subsequent pairwise post-hoc analyses were performed using the Sidak test. All analyses were performed using SPSS version 21.0 (IBM Corporation).

Results

Overview

The results section will describe characteristics of the study sample and the comparisons across time for the clinical, self-care, and psychosocial variables.

Baseline Sociodemographic Characteristics of Sample

The characteristics of the intervention sample (N=41) can be seen in Table 1. This group included individuals with the following characteristics: (1) mean age of 55 years; (2) 71% (29/41) female; (3) 76% (31/41) had a high school education or higher; (4) 22% (9/41) reported annual incomes above US $20,000; (5) 12% (5/41) reported current employment; (6) 98% (40/41) had insurance coverage, including Medicare/Medicaid; and (7) 12% (5/41) were married.

Table 1. Characteristics of the study participants (N=41).

Variables		Mean (SD) or n (%)[a]
Age		55.2 (9.6)
Female		29 (71)
Education		
	< High school	10 (24)
	High school graduate	12 (29)
	> High school	19 (47)
Annual household income		
	Less than US $20,000	31 (76)
	More than US $20,000	9 (22)
	Don’t know/refused	1 (2)
Employment status [b]		
	Currently employed	5 (12)
	Unemployed	1 (3)
	Other	35 (85)
Health insurance [c]		
	Yes	40 (98)
	No	1 (2)
Marital status		
	Married	5 (12)
	Never married	17 (42)
	Other[d]	19 (46)

[a]A subgroup of 41 individuals enrolled in the intervention study, 4 withdrew prior to initiating the intervention.

[b]The employment status category of “other” includes homemakers, students, and those retired and/or unable to work.

[c]The health insurance status category of “yes” includes Medicare and Medicaid.

[d]The marital status category of “other” includes separated, divorced, and widowed persons.

Baseline Technology-Related Characteristics

Table 2 shows the baseline technology characteristics of the study participants. Prior to participation, only 46% (19/41) of the participants had Internet access at home; 76% (31/41) had ever used video or computer games; 29% (12/41) reported experience with virtual or 3-D worlds previously (only one with SL); and 54% (22/41) reported that household members play video or computer games. There was diversity in the range of self-rated computer skills with 37% (15/41) poor-very poor, 34% (14/41) fair, and 29% (12/41) good-very good. The participants’ reported baseline computer/Internet skills and access indicates achievement of our recruitment goal of reaching diverse individuals, including a subgroup that might not otherwise have the opportunity to participate due to lack of resources and/or basic computer/Internet skills.

Table 2. Technology characteristics of the study participants (N=41).

Variables		n (%)
Home Internet		19 (46)
Use of video or computer games		
	Never	10 (24)
	Used to, but do not anymore	9 (22)
	Currently do, sometimes	15 (37)
	Currently do, frequently	7 (17)
Experience with virtual or 3-D world		12 (29)
Self-rated computer skills		
	Very poor-poor	15 (37)
	Fair	14 (34)
	Good-very good	12 (29)
Household member actively plays video or computer games		22 (54)

Acceptability Results

Table 3 is a summary of the feedback on Diabetes Island provided immediately post intervention (ie, 6 months). The feedback regarding acceptability, ease of use of Diabetes Island, and perceived impact was consistently positive.

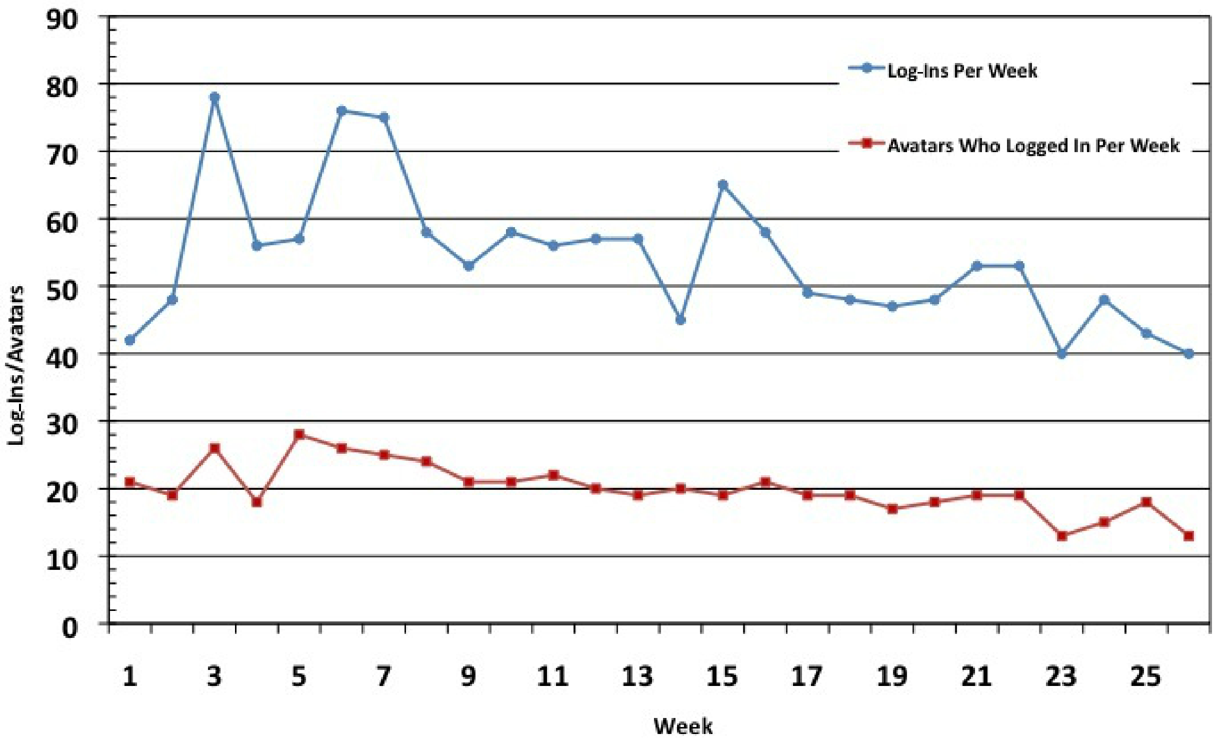
Table 3. Results of acceptability survey (n=33).

Acceptability item	Strongly agree, n (%)	Agree, n (%)	Disagree/ strongly disagree, n (%)
Diabetes Island is interesting.	23 (70)	9 (27)	1 (3)
Diabetes Island was easy to get around.	12 (36)	14 (43)	7 (21)
Diabetes Island is a comfortable place to spend time.	17 (52)	14 (42)	2 (6)
Diabetes Island motivated me to take better care of my diabetes.	15 (45)	16 (49)	2 (6)
Diabetes Island would be helpful to other people like me.	23 (70)	9 (27)	1 (3)
I learned things through Diabetes Island that I can apply to my own life.	22 (67)	11 (33)	0 (0)
I would recommend Diabetes Island to a friend or family member with diabetes.	22 (67)	10 (30)	1 (3)
I have used the things I learned through Diabetes Island to take better care of my diabetes.	16 (49)	17 (51)	0 (0)

Diabetes Island Usage

Although there was a sharp spike in log-ins for the first seven weeks, and a sharp decrease in the last four weeks, the rates were relatively consistent for much of the intervention period (Figure 2 shows this information). The total number of log-ins for the first half of the program was 771 compared to 637 for the second half. The total log-ins per week ranged from 40 to 78, with an average weekly log-in rate of 55. The average number of avatars that logged in per week was 20, with a range of 13 to 28. Consistent with the log-in rates, the usage patterns per avatar were greater in the first half of the time period, with ranges of 49% (18/37) to 76% (28/37) of avatars logging in each week compared with 35% (13/37) to 57% (21/37) in the second half.

Figure 2. Total weekly log-ins and total avatars that logged in each week.



Comparisons Across Time for Glycemic Control, Body Mass Index, Self-care, and Psychosocial Variables

Table 4 summarizes the results for A1C, BMI, self-reported self-care patterns, and self-care psychosocial variables across time. Significant changes over time were observed for BMI, self-care behaviors, environmental barriers to self-care, and diabetes related distress. In addition, a trend (*P*=.053) was observed for A1C, with decreases occurring from 3 to 6 months. The BMI level demonstrated a significant, but modest decrease across time. For the self-care behavior measure, significant improvements across time were found on the summary score and revised physical activity scale. There was one subscale on the DHQ (modify meat) that showed significant improvement, and a trend was identified on another subscale (substitution). The environmental barriers global score and diet specific subscale significantly improved across time. Scores on the diabetes distress scale also improved significantly across time. No difference was found on the empowerment scores across time. Among significant outcomes, post-hoc analyses revealed that significant changes occurred from baseline to 3 months. However, significant changes from 3 to 6 months were observed on diabetes related distress, and baseline to 6 months for BMI, diabetes distress, and the “modify meat” subscale of the DHQ.

The revised scores for the diabetes self-care measure include items added to reflect specific content of the program, such as reading food labels and walking.

Table 4. A1C, BMI, self-care, and psychosocial measures across time, baseline through 6 months.

Variables	Baseline (N=41), mean (SE)	3 months (n=36), mean (SE)	6 months (n=36), mean (SE)	*P*
A1C	7.4 (0.21)	7.4 (0.22)	7.1 (0.22)	.05
BMI	39.3 (1.60)	38.8 (1.66)	38.6 (1.66)	.02[c]
Diabetes self-care behavior				
Summary score	5.1 (0.15)	5.5 (0.16)	5.4 (0.16)	.03[c]
General diet	5.6 (0.26)	6.0 (0.27)	6.0 (0.27)	.22
General diet-rev	5.4 (0.25)	5.9 (0.26)	5.9 (0.26)	.09
Specific diet	4.8 (0.17)	5.0 (0.18)	4.8 (0.18)	.42
Specific diet-rev	5.6 (0.15)	5.7 (0.16)	5.6 (0.16)	.91
Exercise	4.0 (0.32)	4.7 (0.33)	4.5 (0.34)	.12
Physical activity-rev	3.9 (0.31)	4.7 (0.33)[a]	4.5 (0.33)	.04[c]
Self-testing	6.6 (0.28)	6.9 (0.29)	6.6 (0.29)	.46
Foot care	6.0 (0.33)	6.0 (0.35)	6.4 (0.35)	.29
Diabetes health questionnaire				
Substitution	2.7 (0.13)	2.8 (0.13)	2.5 (0.13)	.05
Avoid frying	1.9 (0.08)	1.8 (0.08)	1.8 (0.09)	.18
Replacement	2.8 (0.11)	2.7 (0.12)	2.7 (0.12)	.43
Modify meat	2.6 (0.13)	2.4 (0.13)	2.2 (0.14)[b]	.01[c]
Avoid fat	3.0 (0.07)	2.9 (0.08)	3.0 (0.08)	.70
Environmental barriers to adherence				
Global score	2.2 (0.11)	1.9 (0.11)[a]	2.0 (0.11)	.01[d]
Diet subscale	2.6 (0.12)	2.2 (0.13)[a]	2.3 (0.13)	.01[d]
Exercise subscale	2.5 (0.12)	2.3 (0.13)	2.3 (0.13)	.17
Glucose testing	1.9 (0.14)	1.6 (0.14)	1.7 (0.14)	.14
Medication subscale	1.8 (0.14)	1.7 (0.14)	1.5 (0.14)	.19
Diabetes empowerment	4.1 (0.12)	4.2 (0.13)	4.2 (0.13)	.89
Diabetes distress scale	2.4 (0.15)	2.3 (0.15)	1.9 (1.60)[a,b]	.02[c]

[a]significant, $P<.05$, post-hoc pairwise difference between the current and previous time point
[b]significant, $P<.05$, post-hoc pairwise difference between 6 months and baseline
[c]$P<.05$ for mixed-effects model analyses including baseline, 3 month, and 6 month time points
[d]$P<.01$ for mixed-effects model analyses including baseline, 3 month, and 6 month time points

Discussion

Diabetes Island Intervention

This paper described the acceptability, usage, and preliminary impact of Diabetes Island with low-income African Americans with type 2 diabetes attending a primary care clinic. The results of this study support our main hypotheses. The Diabetes Island intervention demonstrated participant acceptability, regular usage, and promising outcomes, including improvements in BMI, diabetes related distress, physical activity, dietary intake, and environmental barriers to self-care in a group of low-income African American adults attending a primary care clinic.

As planned, the group represented a diverse group regarding Internet/computer skills and Internet access prior to study participation. At baseline, less than half had Internet at home, and greater than two-thirds rated their computer skills as very poor to fair. The characteristics of the sample are generally consistent with those of individuals who are less likely to access Internet-based health information, especially those who are older and with lower education levels and lower income [19]. It is encouraging that once the participants were provided with the basic skills and resources to access the virtual world intervention, the majority logged in regularly during the first two months, and around half logged in each week on average across the six months.

The responses from the participants regarding the acceptability and usefulness of Diabetes Island were consistently positive. The participants appeared to be engaged in Diabetes Island, and reported that they found it useful to them and felt it would be useful to others like them. Therefore, once the access barriers are removed (eg, Internet/computer skills and access), Internet-based approaches might provide an additional strategy to reach underserved populations. In particular, African Americans represent a group that is adopting broadband Internet use at rates greater than other ethnic groups [9,10]. Second, the majority of our sample was not working outside the home due to retirement, lack of a job, being a homemaker, and/or disability. Being able to access interventions from home through the Internet would be a useful way to reach this population and overcome common barriers, such as scheduling, lack of time, and transportation. In addition, this approach offers an opportunity to interact with others with diabetes in a way that is anonymous and convenient.

The intervention outcome findings demonstrate positive changes in motivation and self-care. Self-care patterns were consistent with the literature, with the lowest levels found for lifestyle activities (ie, eating and physical activity habits), and higher levels for discrete behaviors (eg, medication use and foot care) [20]. In addition, the level of self-care increased across time in general, and was significantly improved for one physical activity and one healthy eating subscale. The intervention also showed promise in impacting A1C and BMI. The participants also indicated a reduction in their overall environmental barriers to self-care adherence, specifically related to eating behaviors. It is notable that changes related to healthy eating were the most consistent positive changes found in this study. This is an expected finding since there was a greater focus on topics related to healthy eating in virtual world professional-led educational events and programmed activities.

The examination of psychosocial variables showed significant reductions in diabetes related distress, but no significant changes in empowerment. The changes in diabetes distress are consistent with those found in our work with a similar population [21], and support the positive impact of the Diabetes Island intervention. Lack of change in empowerment was unexpected, and should be further examined in future research.

It is important to note that removing barriers to accessing the intervention was a goal of the study. To address this goal, basic computer/Internet skills and technology resources/support were provided to facilitate participation in the intervention. Therefore, for sustainability, this intervention would need to be delivered within a context where individuals currently have or can be provided with the necessary skills and resources to utilize this intervention. Innovative models need to be examined to disseminate this intervention outside of a research study. A potential translation model that may help overcome this resource challenge is to offer this intervention through community organizations and/or health centers that have available technology centers and that also ideally offer basic training in computer and Internet use.

Limitations and Directions for Future Research

Although this study provides promising preliminary findings regarding acceptability, usage, and outcomes of this intervention approach, there are several limitations to consider. In particular, the small sample size, quasi-experimental design, and sample selection are limitations. The small sample size may have limited the power to detect differences on some variables, and the lack of a comparison group necessitates cautious interpretation of the findings pending further research. Although a goal of the study was to focus on low-income individuals with a range of Internet and computer skills in order to bridge the digital divide, this goal served as a limitation to the generalizability of the findings. Future research is needed that includes a large diverse sample and comparison group, ideally using a randomized design. Since extensive training was provided in the run-in phase, and ongoing technical support was provided throughout the study to facilitate participation, the feasibility of this intervention outside of a research study needs further investigation. In addition, the intervention included a variety of components, and the participants may have engaged in some components and not others. Therefore, it is not possible to determine the most important components of the intervention from this study. Further research is needed to more carefully examine what components of this intervention impact different outcome measures, and how effective components can be delivered most efficiently with least cost.

Conclusions

This study demonstrated promising initial results of an immersive virtual world approach to reaching underserved individuals with diabetes to deliver diabetes self-management education. The study implementation bridged the digital divide to allow those traditionally lacking the necessary resources and skills to participate. This intervention model and method shows promise, and could be tailored for other groups. The findings address the primary questions of this paper, but raise new questions about this intervention approach and ways it might be tailored for different groups, and implemented using different models to reach those without technology/Internet access and skills. A large scale controlled trial is needed to further examine efficacy.

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Conflicts of Interest

None declared.

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Abbreviations

3-D: 3-dimensional
A1C: glycemic control
BMI: body mass index
DHQ: Diet Habits Questionnaire
EBAS: Environmental Barriers to Adherence Scale
IRB: Institutional Review Board
SDSCA: Summary of Diabetes Self-care Activities
SL: Second Life

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Original Paper

Virtual Rehabilitation for Multiple Sclerosis Using a Kinect-Based System: Randomized Controlled Trial

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Abstract

Background: The methods used for the motor rehabilitation of patients with neurological disorders include a number of different rehabilitation exercises. For patients who have been diagnosed with multiple sclerosis (MS), the performance of motor rehabilitation exercises is essential. Nevertheless, this rehabilitation may be tedious, negatively influencing patients' motivation and adherence to treatment.

Objective: We present RemoviEM, a system based on Kinect that uses virtual reality (VR) and natural user interfaces (NUI) to offer patients with MS an intuitive and motivating way to perform several motor rehabilitation exercises. It offers therapists a new motor rehabilitation tool for the rehabilitation process, providing feedback on the patient's progress. Moreover, it is a low-cost system, a feature that can facilitate its integration in clinical rehabilitation centers.

Methods: A randomized and controlled single blinded study was carried out to assess the influence of a Kinect-based virtual rehabilitation system on the balance rehabilitation of patients with MS. This study describes RemoviEM and evaluates its effectiveness compared to standard rehabilitation. To achieve this objective, a clinical trial was carried out. Eleven patients from a MS association participated in the clinical trial. The mean age was 44.82 (SD 10.44) and the mean time from diagnosis (years) was 9.77 (SD 10.40). Clinical effectiveness was evaluated using clinical balance scales.

Results: Significant group-by-time interaction was detected in the scores of the Berg Balance Scale (P=.011) and the Anterior Reach Test in standing position (P=.011). Post-hoc analysis showed greater improvement in the experimental group for these variables than in the control group for these variables. The Suitability Evaluation Questionnaire (SEQ) showed good results in usability, acceptance, security, and safety for the evaluated system.

Conclusions: The results obtained suggest that RemoviEM represents a motivational and effective alternative to traditional motor rehabilitation for MS patients. These results have encouraged us to improve the system with new exercises, which are currently being developed.

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KEYWORDS

multiple sclerosis; motor rehabilitation; virtual reality; natural interfaces; augmented reality

Introduction

Multiple sclerosis (MS) is an inflammatory disease in which the insulating cover of nerve cells in the brain and spinal cord are damaged. At present, there are approximately 3 million people who are affected with MS in the world, with rates varying widely in different regions and among different populations. Normally, the disease begins between the ages of 20 and 50, and it is twice as common in women as in men. There is no known cure for MS, but there are several therapies focused to improve function after an attack, preventing new attacks, and preventing disability. Therapies including medication and neurorehabilitation improve some symptoms, but do not change the course of the disease.

The methods used for the motor rehabilitation of patients with neurological problems require the performance of several rehabilitation exercises. These methods have two fundamental problems. First, they propose exercising motor skills by performing the exercises in an insistent and repetitive way. This is not very motivating and decreases the interest of patients to perform them, affecting their adherence to the treatment. Second, these methods require the patients to be in specific centers with the supervision of qualified personnel to ensure correct performance.

The use of new technologies, like virtual reality (VR) and natural user interfaces (NUI), in motor rehabilitation of patients with neurological disorders is well documented [1]. The advantages of VR compared to the traditional methods used for this purpose are: (1) it can recreate different rehabilitation exercises to be performed by the patient in a virtual way (virtual rehabilitation exercises); (2) it can configure the features of rehabilitation exercises, control their performance, and obtain relevant data from the patient performing the exercises; and (3) it can facilitate the interaction between the patient and the system by means of a wide variety of devices.

Furthermore, several studies have demonstrated that by offering virtual rehabilitation exercises as games, greater efficiency is obtained in the rehabilitation process, and the patients are motivated to perform the rehabilitation exercises and their adherence to the treatment is also greater [2-4]. The advantages of using NUI for game consoles with virtual rehabilitation systems are also well documented [5-10].

Some studies focus on the use of technical solutions for the rehabilitation of patients with MS. For instance, the use of VR and augmented reality (AR) for the rehabilitation of the gait [11], or the use of NUI for the rehabilitation of patients with reduced motor skills [12,13]. Nevertheless, this approach of using VR and NUI for motor rehabilitation of MS patients must be more thoroughly explored.

In the case of patients with MS, the performance of motor rehabilitation exercises in the rehabilitation process is even more important, particularly if patients still have good motor skills. MS patients could begin a rehabilitation process by performing virtual rehabilitation exercises using games and interacting with them in an easy and intuitive way, (ie, using NUI that are similar to the ones in game consoles). In this article, we present a Kinect-based virtual rehabilitation system (RemoviEM) that includes all of these features in one motor rehabilitation process. The specific features of the RemoviEM system were previously introduced by the authors in [14]. In this contribution, the authors present a randomized controlled single blinded trial to evaluate the influence of RemoviEM on motor rehabilitation of MS patients. Therefore, the aim of our study is to compare virtual rehabilitation with traditional rehabilitation exercises.

Methods

Trial Registration

Clinical collaborators determined that a public trial registry was not necessary because the features of the system do not create a potential risk for patients. Instead, before patient enrollment, an authorization was given by the clinical center staff. The patients were then informed about the study and all of the participants provided informed consent.

Participants

There were 56 patients with MS who were potential candidates for this study. The inclusion criteria were: (1) men and women between 18 and 65 years old, (2) patients have relapsing-remitting and secondary-progressive MS, (3) patients have a minimum score of 6 on all items of the domain of the Functional Independence Measure (FIM), (4) patients do not need assistive devices for ambulation or at most a cane, and (5) patients do not have cognitive impairments. The exclusion criteria were: (1) patients with flare-up symptoms, or (2) patients that cannot physically complete all rehabilitation sessions. With these criteria, a final sample of 12 patients was selected and randomly assigned to either the control group (traditional physiotherapy) or the trial group (RemoviEM therapy). All patients were on a similar baseline, with a level and type of impairment constant within groups. The randomization schedule was computer-generated using a basic random number generator. One patient in the control group dropped out of the clinical trial and that data is not included our analysis. Thus, the final sample consisted of 11 patients (7 men and 4 women ranging from 28 to 60 years old). The time since diagnosis for the sample ranged from 2 to 32 years. Age, gender, and chronicity did not affect the performance of each group. The participants had no previous experience with virtual rehabilitation systems. Table 1 shows a summary of the characteristics of the subjects.

Table 1. Patient demographics and time since diagnosis.

Issue	Control group, n=5 n (%) or mean (SD)	Trial group, n=6 n (%) or mean (SD)
Gender, n (%)		
Male	4 (80%)	3 (50%)
Female	1 (20%)	3 (50%)
Age (years)	40.60 (9.24)	48.33 (10.82)
Time since diagnosis (years)	4.70 (3.11)	14.00 (12.69)

Instrumentation

Overview

The software and hardware of RemoviEM will be discussed in detail below. In brief, the program consists of several virtual environments that are designed and developed to allow the patient to perform several motor rehabilitation exercises. The well-developed software allows the therapist to select and configure the exercises to be performed by the patient. The therapist can also follow the patient’s progress in the system. The hardware is composed of low-cost devices that allow virtual environments to be displayed. Interaction with these devices is very intuitive. The low cost of the system facilitates its integration in clinical rehabilitation centers.

Software

RemoviEM has three motor rehabilitation exercises: TouchBall, TakeBall, and StepBall.

TouchBall

The objective is to work on the balance and weight transfer of the patient, and to perform lateral movements of the trunk. Both issues are essential in order to achieve an improvement in gait and, consequently, to walk correctly.

In this virtual environment, the patient can interact in a standing or sitting position. Virtual objects appear at different heights on both sides of the patient. The aim of the exercise is to touch virtual objects with your hands, before they disappear, keeping your feet in the predefined zone (Figure 1). The patient has a time limit that is previously established by the therapist to accomplish this. The system also counts the number of hits/misses. If the patient touches the virtual object before it disappears using the hand indicated by the system, and not moving his/her feet outside of the predefined area, the MS patient obtains a hit.

Figure 1. This figure is the TouchBall virtual environment.

TakeBall

The objective is to work the Diagonals of Kabat MMSS. This is very important in neurological rehabilitation because MS patients work on complete movements of the upper limbs, requiring good coordination for their implementation.

In this virtual environment, the patient (in standing or sitting position) must move virtual objects from an initial position to a final position using both hands (Figure 2). The patient has a time limit that is previously established by the therapist to complete the movement. The system also counts the hits and misses. If the patient moves the virtual object from the initial position to the final position before it disappears, the patient obtains a hit.

Figure 2. This figure is the TakeBall virtual environment.

StepBall

The objective is to work balance and weight transfer and to perform lateral movements with monopodal load.

In this virtual environment, virtual objects appear at ground level on both sides of the patient. The patient must step on the virtual objects before they disappear (Figure 3). To make this movement more difficult, virtual obstacles appear between the original position of the feet and the virtual object. The patient must not touch these obstacles in order to achieve the objective. The patient has a time limit that is previously established by the therapist to step on the virtual object. The virtual environment also counts the number of hits/misses. If the patient steps on the virtual object before it disappears and does not touch the virtual obstacle, the patient obtains a hit.

Figure 3. This figure is the StepBall virtual environment.

Hardware

RemoviEM uses a LCD/LED TV (42"-47") to show the visual and auditory cues of the virtual environments. In order to interact with the virtual environments, the patient uses Microsoft Kinect. The system runs on a conventional PC.

Use

An AR setup is used for the system. The system shows the real image provided by the kinect, where the patient is included. Virtual objects are displayed over this image, allowing the patient to play with the system. The system identifies the different parts of the patient using the depth camera of the kinect. This type of AR allows increases the sense of immersion of the patient to perform exercises.

Workflow

The workflow is the same for all virtual environments. Initially, there is a screen that allows the therapist to setup the rehabilitation exercise taking into account the needs and features of the patient. The patient then watches a sequence of explanatory images about interaction with the virtual environment. The goal of these images is for the patient to learn how to interact with the system to be able to perform the rehabilitation exercise. Next, there is a new screen in which the patient can see how the system detects the skeleton of the patient's body, and also whether or not the patient is correctly positioned to perform the rehabilitation exercise. When the system detects that the body is properly positioned, a countdown allows the patient to prepare for the start of the exercise. Finally, at the end of the rehabilitation exercise, the system shows the patient and the therapist a final screen with a summary of the results obtained.

Intervention

The clinical trial was carried out in the neurorehabilitation service of the Multiple Sclerosis Association of Castellon (Asociación de Esclerosis Múltiple de Castellón, AEMC). Each patient participated in 10 one-hour sessions of rehabilitation and completed one session per week.

In each session, the patients in the control group (n=5) performed standard balance and gait rehabilitation exercises. The patients belonging to the experimental group (n=6) spent forty-five minutes performing the same exercises, and during the last fifteen minutes of the session, they performed the virtual rehabilitation exercises.

Before and after the rehabilitation program, all the patients were assessed by a specialist. This clinical assessment used several scales. Balance in static condition was assessed by the Berg Balance Scale (BBS) [15], the Tinetti Balance Scale [16], and the Single Leg Balance test (SLB). Balance in dynamic conditions was assessed by the 10-meter Walking Test (10MT) [17], and the Time "Up and Go" Test (TUG) [18,19]. In order to obtain subjective information about the treatment, a feedback questionnaire (the Suitability Evaluation Questionnaire, SEQ; [20]) was given to th patients.

Data Analysis

Repeated measure analyses of variance (ANOVAs) with time (before and after rehabilitation), the within-subjects factor and treatment option (control versus trial), and the between-subjects factor were performed for each one of the balance measures. The main effects of time, treatment option, and the time-treatment option interaction effects were evaluated. Simple contrasts were conducted for each significant time main effect to determine the source of the significant difference. A P value less than .05 was considered to be significant in each case.

Results

No significant differences in demographical (age and gender) or clinical (chronicity) variables at inclusion were detected between groups (P=.240, P=.353 and P=.147 for age, gender, and chronicity, respectively).

A repeated measure ANOVA at the beginning and at the end of the clinical trial revealed a significant time effect for the BBS (P=.014), Tinetti (P=.003), SLB test right foot (P=.041), and 10MW (P<.001). Nevertheless, there were no significant time effects for SLB left foot (P=.052) or TUG (P=.346). No group effect was detected for any outcome, except for TUG (P=0.027). Finally, significant group-by-time interaction was detected in the scores for BBS (P=.030) and SLB test right foot (P=.033) (Table 2). In addition, all the patients said they had fun during the treatment, and they did not suffer any discomfort (disorientation, cyber-sickness or adverse symptoms) when performing the virtual rehabilitation exercises.

The score of the SEQ for Virtual Rehabilitation systems [20] was 55.560/65 (SD 5.940). In addition, all the patients remarked that they had fun during the treatment. There was only one reported case of a patient not being in control of the exercises. None of the patients suffered from spatial disorientation or cyber-sickness, and no adverse symptoms were described by the therapists.

Table 2. Numerical data of the scores of scales and tests in the assessments carried out before and after the treatment. G: group effect; T: time effect; GxT: group/time effect.

Test	Before treatment		After treatment		Difference	Significance		
	Mean	SD	Mean	SD	Mean	GxT	G	T
BBS						0.030	0.546	0.014
Control	51.400	6.309	51.600	5.899	0.200			
Trial	48.000	6.325	50.333	5.630	2.333			
Tinetti						0.716	0.412	0.003
Control	25.000	2.236	26.000	2.449	1.000			
Trial	23.830	2.563	24.670	2.422	0.840			
SLB left foot						0.463	0.685	0.052
Control	15.378	14.172	18.672	15.540	3.294			
Trial	10.721	8.105	17.440	10.680	6.719			
SLB right foot						0.033	0.650	0.041
Control	18.692	15.509	18.517	15.743	-0.175			
Trial	11.730	9.179	18.339	10.604	6.609			
TUG						0.652	0.027	0.346
Control	8.590	4.608	6.930	1.812	-1.660			
Trial	10.692	3.468	8.318	2.063	-2.374			
10MW						0.472	0.531	0.000
Control	16.625	6.064	14.490	4.597	-2.135			
Trial	19.161	6.299	16.469	5.770	-2.693			

Discussion

Principal Findings

The study presented in this paper assessed the influence of a KINECT-based virtual rehabilitation system (RemoviEM) on the rehabilitation of patients with MS.

In relation with the static and dynamic balance abilities of the patients, measured with the Berg Balance Scale, there was a significant improvement over time on this scale. While the control group remained virtually stagnant over time, the experimental group showed a clear improvement. The results provide evidence of significant improvement in the experimental group compared to the control group over time.

Regarding the Tinetti Balance Scale, other common clinical test used to assess the static and dynamic balance abilities of the patients, both groups showed a similar trend. There was a significant improvement over time, although there were no significant differences over time between the two groups. The Tinetti Balance Scale measures balance as well as gait, but our system is focused only in balance; this partially explains why there were no significant differences between the groups overtime.

The Single Leg Balance test shows that the improvement in the experimental group was greater than the control group for both the right and left feet. This was statistically significant in the right foot (*P*=.033).

In the Time "Up and Go" test, used to assess a person's mobility, the improvement in the experimental group was higher than in the control group; however this improvement was not statistically significant. RemoviEM does not include specific training exercises "Sit-To-Stand", and the inclusion of such exercises would allow Time "Up and Go" test results to be better since they would train one of the basic parts evaluated by this test.

In relation to the 10-meter Walking Test, used to assess walking ability of patients, the results showed improvement over time, but no improvement was detected in significant group-by-time, which suggests that both groups improved similarly. This was likely due to the fact that the RemoviEM system does not specifically train gait.

The specialist also said that the patients were interested in performing virtual exercises with RemoviEM, and that the patients were entertained to a greater extent than when doing traditional exercises. All of this was found without detecting any cyber side effect in the MS patients. Thus, the RemoviEM system obtained additional motivation and adhesion to the treatment by the patients.

Limitations

The results obtained in most of the scales used show a significant improvement in the experimental group compared to the control group. From this perspective, we can confirm that virtual rehabilitation with RemoviEM is capable of improving the rehabilitation of MS patients. Nevertheless, we know that the small size of the sample should be taken into account, when analyzing these results. The deviation of several test is too high, thus the qualitative information of the associated means is reduced. A new study enrolling more patients could solve this problem.

Basically, RemoviEM includes rehabilitation exercises to work movements of the upper limbs, to acquire good coordination, to improve the balance and weight transfer of the patient, and to perform lateral movements of the trunk, with or without monopodal load. The improvements obtained in the present study are specifically in BBS, weight transfer, and TUG (ie, in the scales measuring the aspects mentioned above).

Nevertheless, more rehabilitation exercises to train specific movements like Sit-To-Stand, and other generic movements like gait and running should be incorporated in RemoviEM. Thus, it would be possible to study whether these improvements would also be significant on Tinetti and 10MW.

Conclusions

RemoviEM has helped patients with MS become more motivated and involved in the rehabilitation process. In addition, the exercises included in the system have allowed patients to obtain significant improvements in the rehabilitation of those movements for which they were designed. We think that the inclusion of new exercises that are designed for the treatment of other movements but that are not currently addressed can also give satisfactory results. Currently, a second stage of the RemoviEM system is being designed to include these new rehabilitation exercises, taking into account the suggestions of clinical specialists and MS patients.

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Authors' Contributions

JA Lozano-Quilis, H Gil-Gómez, JA Gil-Gómez and S Albiol-Pérez contributed to the design of the software and the study, the software development, the interpretation of data, and the draft of the article.
G Palacios, Habib M Fardoun, and Abdulfattah S Mashat contributed in the formulation of the overall research questions and assisted in revising the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

None declared.

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Abbreviations

AR: augmented reality
BBS: Berg Balance Scale
MS: multiple sclerosis
NUI: natural user interfaces
SEQ: suitability evaluation questionnaire
TUG: Time "Up and Go" test
VR: virtual reality

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Original Paper

Just a Fad? Gamification in Health and Fitness Apps

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Abstract

Background: Gamification has been a predominant focus of the health app industry in recent years. However, to our knowledge, there has yet to be a review of gamification elements in relation to health behavior constructs, or insight into the true proliferation of gamification in health apps.

Objective: The objective of this study was to identify the extent to which gamification is used in health apps, and analyze gamification of health and fitness apps as a potential component of influence on a consumer's health behavior.

Methods: An analysis of health and fitness apps related to physical activity and diet was conducted among apps in the Apple App Store in the winter of 2014. This analysis reviewed a sample of 132 apps for the 10 effective game elements, the 6 core components of health gamification, and 13 core health behavior constructs. A regression analysis was conducted in order to measure the correlation between health behavior constructs, gamification components, and effective game elements.

Results: This review of the most popular apps showed widespread use of gamification principles, but low adherence to any professional guidelines or industry standard. Regression analysis showed that game elements were associated with gamification ($P<.001$). Behavioral theory was associated with gamification ($P<.05$), but not game elements, and upon further analysis gamification was only associated with composite motivational behavior scores ($P<.001$), and not capacity or opportunity/trigger.

Conclusions: This research, to our knowledge, represents the first comprehensive review of gamification use in health and fitness apps, and the potential to impact health behavior. The results show that use of gamification in health and fitness apps has become immensely popular, as evidenced by the number of apps found in the Apple App Store containing at least some components of gamification. This shows a lack of integrating important elements of behavioral theory from the app industry, which can potentially impact the efficacy of gamification apps to change behavior. Apps represent a very promising, burgeoning market and landscape in which to disseminate health behavior change interventions. Initial results show an abundant use of gamification in health and fitness apps, which necessitates the in-depth study and evaluation of the potential of gamification to change health behaviors.

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KEYWORDS

gamification; mobile phone; behavioral health; health and fitness apps

Introduction

Mobile Phone Technology and Health Behavior Change

Mobile phone technology has recently become an area of focus for disseminating health behavior change interventions [1-3]. This technology has the capacity to provide for easy collection of personal health-related data and providing timely behavioral cues [4,5]. Additionally, research has focused on the benefits of mobile and Internet technologies for reaching diverse populations to reduce health disparities [6,7], and rural communities for health interventions [8]. Some of the most recognizable research has focused on text messaging interventions, or short message service (SMS) [9]. This technology has been used to study several health topics like physical activity [10], diabetes self-management [11], and smoking cessation [12].

Since 2007 when Apple introduced the iPhone, followed by Google's Android, mobile phone sales have outpaced those for conventional cell phones; 56% of Americans now own a mobile phone [13]. Third party apps are software programs that serve to expand the utility of mobile devices. Within just 6 years, Apple celebrated its 50 billionth app download, with Google only trailing slightly behind with 48 billion as of May 2013 [14]. This new market of software apps for Apple alone has resulted in over US $9 billion being paid to developers [14]. Health apps have also become a part of this market, with over 31,000 health and medical apps available for download [2]. With mobile phone ownership and the number and complexity of health apps likely to increase, the potential for technology-based health interventions to impact populations is expanding in ways previously not possible.

Gamification

The term "gamification" originally coined in 2008, and later broadly used by technology and health professionals through the first half of 2010, encompasses a broad spectrum of technology and game-like elements into the commercial world [15]. For functional purposes, the definition formalized by Deterding et al, will be used throughout the remainder of this paper. This definition states "gamification is the use of game design elements in nongame contexts" [15]. Companies have widely accepted and adopted gamification as a means to increase initiation and retention of desired behaviors [16], additionally it has been estimated that 60% of health initiatives in workplaces now include gamification elements [17,18]. Furthermore, gamification is on track to becoming a 2.8 billion dollar industry by the year 2016, with little to no evidence in the scientific literature as to its efficacy in improving desired outcomes in regards to health and health behaviors [19].

Gamification in mobile app technology has emerged as a popular strategy, both in commercial culture and the field of academia as a means of influencing behaviors [15,16,20,21]. Gamification is the use of game-like rewards and incentives, paired with desired behaviors, to increase motivations and sustain habits of individuals over time [15,20]. The use of this tactic in health and fitness mobile apps has increased despite little to no in-depth inquiry into its effectiveness and appropriate functionality [17,18]. The purposes of this study were to review health and fitness apps for elements of gamification, to determine the relationship between health app use of gamification and core elements of effective games, and to determine the extent to which apps with gamification elements contain critical health behavior constructs.

Methods

Study Design and Background

This study design involved an analysis of gamification and health behavior constructs of Apple iPhone health and fitness apps beginning in the winter of 2014. Each app was measured for elements of gamification and health behavior, as explained below in the subsection Measures. Research assistants were recruited from undergraduate and graduate health science students at a midwestern university. The research assistants were trained in the rubrics for gamification and health behavior constructs as seen in Tables 2 and 3.

Sample Identification

The sample was collected from the Apple App Store in the winter of 2014. This sample contained apps that are under the health and fitness section of the App Store and related to the particular health behaviors of diet and physical activity. There were 40 key search terms that were established prior to the sample collection using key phrases for both physical activity and diet apps that may contain gamification; keywords included, "running", "walking", "health games", "gamification", "diet", "calorie counting", and others related to these behaviors (see Table 1). The study's authors selected the search terms and have formal training in public health and health behavior. Search terms were entered into the Apple App Store on the most recent version of the iPad, due to the fact that iPads allow the user to filter search results. Search results were narrowed by: (1) iPhone Only, (2) Free Apps, (3) Health and Fitness, and (4) Popularity. According to most recent estimates, 90% of apps available in the Apple App Store are free, representing a growing trend toward a *freemium* platform, or in-app purchases for upgrades; for this reason only free apps were included in the sample generation, as they are most representative of the majority of available apps [22]. Additionally, previous studies reviewing the content of apps also ordered search results by popularity to ensure that the apps that were reviewed were highly used [23].

Table 1. Apple App Store search terms.

Physical activity search terms	Diet search terms	Gamification search terms
1) running	1) burn calories	1) games for health
2) jogging	2) diet	2) healthy games
3) walking	3) calories	3) health games
4) cross training	4) calorie counter	4) games
5) exercise	5) healthy diet	5) gamification
6) workout	6) diet tracker	6) gamified health
7) work out	7) healthy food	7) health challenge
8) aerobics	8) healthy eating	
9) trainer	9) carbs	
10) weight lifting	10) carb tracker	
11) cycling	11) carb counter	
12) fitness	12) lose weight	
13) health coach	13) BMI[a]	
14) cardio	14) healthy weight	
15) weight training		
16) fitness class		
17) health class		
18) aerobics class		
19) sports		

[a]BMI=body mass index

Coding Procedure

The detailed written descriptions for the first 20 apps that appeared in the search results under each topic were read and coded into an initial sampling rubric using Qualtrics online survey software. This was done in order to ensure that the apps that were downloaded and reviewed for the final analysis contained at least one component of gamification. The initial rubric contained basic descriptive information (name of the app, number of reviews, price, year of development, and whether the app pertained to health or a health behavior) and the six core components of gamification outlined by the public health literature, and explained below in the subsection Measures. Since the Apple App Store does not sort search results by page numbers, a set number was established for each search term; additionally, other sampling criteria in search engines has established that looking through a set number of primary results (ie, 1 to 2 pages) is enough to establish the quality of sampling, as users are unlikely to go beyond the first page of results [24,25].

A total of 800 apps were returned for preliminary coding. Some search terms yielded no relevant results as to the purposes of the study, so the results were not coded for that entire search term; for example, if none of the app descriptions contained any components of gamification, or if no search results were brought up. After eliminating duplicates, a total of 261 app descriptions were coded for inclusion in the final sample. In order to ensure sample quality, the sample was refined by using apps that were initially coded as having at least one of the six core components of gamification. After applying this criteria for inclusion, 129 apps were excluded from the sample for having no components of gamification, leaving a total of N=132 apps for a final analysis of apps using gamification.

Interrater Reliability

A hard-copy version of the survey with explanations of each individual game component and behavioral construct was supplied to each of the coders in order to provide a common reference for defining each individual term (see Tables 2 and 3). Each assistant independently coded an identical 10 percent of the sample in order to establish interrater reliability. A kappa coefficient was used to measure reliability between the three coders, a well established method that has been used in similar studies [23,26]. After coding an identical 10.6% of the initial sample (14/132), a kappa coefficient of 0.66 was measured between the coders. This is rated as a substantial level of agreement between coders, and is an acceptability measure of reliability for this study [27].

Table 2. Construct definitions and app functionality.

Behavioral constructs	Construct definition	Example function on app	Behavioral model/theory
Capacity			
Psychological			
General information	Information designed to increase basic knowledge about the behavior.	Information about Centers for Disease Control and Prevention guidelines for exercising. (Ex. 2 hours and 30 minutes of moderate aerobics per week)	HBM[a], TTM[b], TPB[c], SCT[d]
Self-monitoring	Behavioral tracking to increase the ability of the individual to make informed decisions.	Info-graphs, summaries of charts, and trends over time.	TTM[b], SCT[d], Fogg[e]
Stress management	Improving the emotional and mental ability to cope with change and make strategic changes in an individual’s life.	Information on how to cope with stress of changing your diet.	SCT[d]
Physical			
Skills training	Providing training to increase the physical ability of an individual to perform a behavior.	Instructional video/tutorial on a new lifting technique or a connection to a trainer.	TTM[b], SCT[d]
Simplicity or enabling factors	Things that serve to make the behavior easier to accomplish by eliminating barriers or making a task simple. (time, money, physical effort, etc)	Time management tools or money saving tools to help engage in the behavior more frequently.	SCT[d], PPM[f], Fogg[e]
Motivation			
Automatic			
Incentivization (rewards)	Based in operant conditioning, pairing the behavior with rewards or incentives to train an individual to value the behavior.	Gaining points that can be cashed in for a monetary prize, or creating a self-reward.	TTM[b], SCT[d]
Social support (positive reinforcement)	Pairing the behavior with support from new or old social spheres that provide validation and positive reinforcement with new behavioral changes.	Sharing information on social media for comments, discussion boards, and adding friends on an app interface.	TTM[b], SCT[d], PPM[f], Fogg[e]
Reflective			
Goal-setting	Creating small attainable goals to help individuals begin new behaviors and keep commitments.	Setting goals to run 3 times a week for 30 minutes.	SCT[d], Fogg[e]
Cognitive strategies	Perceived benefits, barriers, risks, severity, and social norms. Information about performing the behavior, and questions and discussions to help individuals evaluate beliefs.	A discussion board that prompts key questions related to the behavior.	HBM[a], TTM[b], TPB[c], SCT[d], PPM[f]
Self-efficacy	Creating a self-mastery experience or using modeling/ vicarious learning to help improve an individual’s confidence in doing the behavior.	Breaking the behavior into small attainable steps, notification of peers doing the correct behavior.	TTM[b], TPB[c], SCT[d], Fogg[e]
Opportunity/trigger			
Social			
Peer pressure	Using peers to enforce new rules about behaviors or changing social settings/context to eliminate negative influences on behavior.	Competitions or functions to encourage friends to achieve their goals. Shared accountability.	TTM[b], SCT[d], Fogg[e]
Physical			
Cues to action	Cues from the physical environment that help eliminate the need to depend on memory, and prompt needed action. (ecological momentary assessment).	Reminders through push notifications to go running.	HBM[a], Fogg[e], PPM[f]

Behavioral constructs	Construct definition	Example function on app	Behavioral model/theory
Stimulus control	Restructuring your environment to eliminate bad triggers and increase positive influences.	Setting constraints on unhealthy food in the house, limiting screen-time.	TTM[b], SCT[d], Fogg[e]

[a]HBM=health belief model
[b]TTM=transtheoretical model
[c]TPB=theory of planned behavior
[d]SCT=social cognitive theory
[e]Fogg=BJ Fogg model of behavior
[f]PPM=precede-proceed model

Measures

Each app was coded for general information, the 10 effective elements of games, 6 core components of gamification for health, and 13 core health behavior constructs. Given the above definition of gamification being “the use of game design elements in nongame contexts”, the rubric for components of gamification was similar to the rubric for game elements. This is due to gamification being adopted from the field of videogames; however, as shown below in Table 3, the rubric for game elements is more extensive and includes the “game context”. For the purposes of this paper, the 10 effective elements of games were taken from the current literature in the field of gaming, or rather the model of set standards for games set by professionals in the video gaming industry [28]. The six core components of gamification were taken from the behavioral and public health literature as defined by health professionals. General information included number of app reviews, use of external resources as citations (content validity), method of data collection (passive or active), target health behavior, app integration with other technologies, and perceived purpose of gamification. It should be noted that the number of app reviews was used as a crude measure of the popularity of the app, as the apps with the most reviews generally were reviewed more favorably, and likely received more downloads than other apps. Additionally, the search results were ordered according to the popularity in the app store (as detailed above), with the top results always having the largest number of reviews.

Coding of the 10 effective game elements was taken from the work of Reeves and Read, which outlined the ten effective elements of games, and quoted in the work of Deterding et al [15,28]. These elements included the following: (1) self-representation with avatars; (2) three dimensional environments; (3) narrative context (or story); (4) feedback; (5) reputations, ranks, and levels; (6) marketplaces and economies; (7) competition under rules that are explicit and enforced; (8) teams; (9) parallel communication systems that can be easily configured; and (10) time pressure (see Table 3). These components were coded as either 1=present and used in the app, or 0=not present.

The six gamification components were determined by reviewing the current body of literature and finding common themes and components of gamification used or discussed in the literature for impacting health behavior [15,17,18]. The same coding procedure as outlined above was used to code the gamification components, which included: (1) leaderboards, (2) levels, (3) digital rewards (points, badges), (4) real-world prizes, (5) competitions, and (6) social or peer pressure (see Table 3).

The 13 health behavior constructs were identified from the combined work of Doshi et al, Cowan et al, and Michie et al [23,29,30]. Doshi et al established a rubric for evaluating physical activity websites for health behavior constructs that included 20 constructs from the most common behavior models in use in public health practice, health belief model (HBM), transtheoretical model, theory of planned behavior, and social cognitive theory (SCT) [29]. Cowan et al, built on this work by applying the same rubric to physical activity apps [23]. However, not all of the constructs are applicable to mobile apps, and many of the constructs have similar overlapping definitions and components. Due to these limitations, a new rubric was compiled and consolidated for clarity. Additionally, work by Michie et al outlined the “Behavior Change Wheel” for conceptualizing behavior change interventions. This framework establishes health behavior as having 3 main components: (1) capability (psychological and physical), (2) motivation (automatic and reflective), and (3) opportunity/trigger (social and physical) (COM-B) [30]. Similar conceptualizations and iterations of this same model exist in precede-proceed model and the BJ Fogg model of behavior [31,32]. The 20 constructs from Doshi et al and Cowan et al were categorized based on these components from the COM-B system and consolidated.

The final rubric contained the following indicators for measurement for a total of 13 constructs (see Table 2); capability (Psychological, general information, self-monitoring, stress management; Physical, skills training, simplicity or enabling factors), motivation (Automatic, incentivization, social support; Reflective, goal-setting, cognitive strategies from HBM, self-efficacy), and opportunity/trigger (Social, peer pressure; Physical, cues to action, stimulus control). Constructs were included if they had clear distinguishable definitions, and if they had direct application to functions of an app on a mobile phone (Table 2). In order to eliminate subjective bias, the behavioral constructs were coded and scored the same as the game and gamification rubrics (Yes=1, No=0).

Data Analysis

Descriptive statistics were used to report on the integration of gamification components into health and fitness apps. After coding each individual app for effective game elements, gamification components, and health behavior constructs, a final score was totaled for each category. Linear regression analysis was used to test the remaining two hypotheses. The first regression assessed the association between game elements and total gamification components; integrating the total opportunity/trigger score, app reviews, target health behavior, and app integration with other technologies into the model. The second regression assessed the total gamification components with the three individual subbehavioral scores, capacity, motivation, and opportunity/trigger; using the purpose of gamification and app integration with other technologies integrated into the model. The final regression compared the total behavioral construct score to total game elements and total gamification components; integrating the number of app reviews, target health behavior, content validity, method of data collection, and app integration with other technologies into the model.

Results

Descriptive Statistics

Of the originally coded sample of 261 app descriptions, 52.5% (137/261) contained at least one element of gamification, with around 23.8% (62/261) containing at least half (3 or more) of the 6 most commonly used elements of gamification in health. Social or peer pressure was the most common element of gamification used, with just over 45.2% (118/261) of apps containing this component, followed by digital rewards, competitions, leaderboards, level of achievement or rank, and real world prizes (24.1%, 63/261; 18.4%, 48/261; 14.2%, 37/261; 13.4%, 35/261; and 10.0%, 26/261 respectively). Of the apps coded, a total of 88.5% (231/261) of the sample pertained to a health behavior, while the remaining 11.5% (30/261) were either primarily educational, or not focused on health behavior change.

Of the 132 apps that were downloaded and coded in the final comprehensive analysis, 68.2% (90/132) were exclusively for physical activity, 9.1% (12/132) were for dietary tracking and behavior, 19.7% (26/132) were comprehensive or both physical activity and diet, with 3.0% (4/132) targeting other health behaviors. There were 91.7% (121/132) of the apps that contained no citations or links to sources to verify the information provided in the app, and 29.5% (39/132) of the apps were found to integrate with other technologies or media. Around 97.7% (129/132) of the apps tracked some sort of data from the user, with 27.9% (36/129) tracking in passively (not requiring manual input of data), 55.0% (71/129) having active tracking (requiring the user to manually input data), and 17.1% (22/129) using both methods. Finally, coders rated the perceived purpose of gamification use in the apps. There were 14.4% (19/132) of the perceived apps' purpose that were coded as "to get people to interact with the app more", 32.6% (43/132) were coded as "to get people to do more completions of the desired behavior", 43.2% (57/132) were coded as both, and 9.8% (13/132) were coded as neither or "purpose unclear".

The 132 apps included in the sample had a mean behavioral score of 4.99 out of 13 possible (38.4%; Cronbach alpha=.65), a mean game score of 3.80 out of 13 possible (29.25%; Cronbach alpha=.72), and a mean gamification score of 2.28 out of 6 possible (38.13%; Cronbach alpha=.64). The behavioral score was further broken down into three components (as explained above): (1) capability (mean 2.11 of 5; 42.12%), (2) motivation (mean 2.30 of 5; 46.06%), and (3) opportunity/trigger (mean 0.58 of 3; 19.4%). Table 3 shows detailed descriptive statistics for each of the components of the 3 measuring rubrics designed for this study.

Table 3. Descriptive statistics for evaluation rubrics (N=132).

Measuring rubrics			N=132 (number of apps)	%	Mean	Median	SD
Behavioral			-	-	4.99	5.0	2.44
	Capacity		-	-	2.11	2.0	1.1
		General information	51	38.64	-	-	-
		Self-monitoring	129	97.73	-	-	-
		Stress management	19	14.39	-	-	-
		Skills training	42	31.82	-	-	-
		Simplicity or enabling factors	37	28.03	-	-	-
	Motivation		-	-	2.30	2.0	1.58
		Incentivization	32	24.24	-	-	-
		Social support (positive reinforcement)	54	40.91	-	-	-
		Goal-setting	75	56.82	-	-	-
		Cognitive strategies	68	51.52	-	-	-
		Self-efficacy	75	56.82	-	-	-
	Opportunity/trigger		-	-	0.58	0.0	0.68
		Peer pressure	48	36.36	-	-	-
		Cues to action	25	18.94	-	-	-
		Stimulus control	4	3.03	-	-	-
Game elements			-	-	3.80	3.5	2.68
	Self-representation with avatars		68	51.52	-	-	-
	3-D environments		8	6.06	-	-	-
	Narrative context		8	6.06	-	-	-
	Feedback from game (before or during)		45	34.09	-	-	-
	Feedback, reinforcement (after)		76	57.58	-	-	-
	Leaderboards		43	32.58	-	-	-
	Ranks of achievements		39	29.55	-	-	-
	Different levels of play		28	21.21	-	-	-
	Marketplaces and economies		19	14.39	-	-	-
	Competition under rules explicit and enforced		42	31.82	-	-	-
	Teams (multi-player modes)		19	14.39	-	-	-
	Parallel communication systems		64	48.48	-	-	-
	Time pressure		43	32.58	-	-	-
Gamification			-	-	2.29	2.0	1.66
	Leaderboards		43	32.58	-	-	-
	Levels of achievement or rank		34	25.76	-	-	-
	Digital rewards		73	55.30	-	-	-
	Real world prizes		24	18.18	-	-	-
	Competitions/challenges		51	38.64	-	-	-
	Social or peer pressure		78	59.09	-	-	-

Linear Regression Analysis

Results from the regression analysis (Tables 4-6) showed that greater inclusion of game elements was significantly associated with gamification components (*P*<.001), and was associated with the total opportunity/trigger score (*P*<.05). Second, inclusion of gamification components in app design was found to be significantly associated with total motivation score (*P*<.001), while showing no correlation to total capacity score or total opportunity score. Finally, the regression showed that inclusion of behavioral theory in apps was associated with inclusion of gamification components (*P*<.05), but was not associated with inclusion of game elements. Additionally, behavioral theory was positively associated with number of app reviews (*P*<.05), the targeted health behavior (*P*<.05), and was associated with method of data collection (*P*<.05).

Table 4. Regression analysis, for total game elements (N=132).[a]

Variable	DF	Type III sum of squares	Mean square	*F* value	*P*> *F*
Total behavioral score	1	0.2226962	0.2226962	0.09	.7661
Total gamification score	1	316.6222861	316.6222861	126.33	<.001[b]
Total opportunity score	1	13.1144394	13.1144394	5.23	.0239[c]
Number of app reviews	1	15.5375399	15.5375399	6.20	.0141[c]
Target health behavior	3	3.2131914	1.0710638	0.43	.7337
App integration with other technologies	1	6.9311679	6.9311679	2.77	.0989

[a]Number of observations used=132. r^2=.6717

[b]*P* value<.001

[c]*P* value<.05

Table 5. Regression analysis, for total gamification components (N=132).[a]

Variable	DF	Type III sum of squares	Mean square	*F* value	*P*> *F*
Total motivation score	1	24.17913828	24.17913828	28.94	<.001[b]
Total capacity score	1	0.02400399	0.02400399	0.03	.8657
Total opportunity score	1	1.73260282	1.73260282	2.07	.1524
Total game score	1	91.61451097	91.61451097	109.66	<.001[b]
Purpose of gamification	3	6.58606083	2.19535361	2.63	.0533
App integration with other technologies	1	0.00144093	0.00144093	0.00	.9669

[a]Number of observations used =132. r^2=.7169

[b]*P* value<.001

Table 6. Regression analysis, for total behavioral constructs (N=132).[a]

Variable	DF	Type III sum of squares	Mean square	*F* value	*P* > *F*
Total game score	1	9.46638187	9.46638187	3.07	.0825
Total gamification score	1	26.78349544	26.78349544	8.68	.0039[b]
Number of app reviews	1	35.73079259	35.73079259	11.57	.0009[b]
Target health behavior	3	49.69643792	16.56547931	5.37	.0017[b]
Content validity (citations)	1	5.73648830	5.73648830	1.86	.1754
Method of data collection on app	2	27.95652683	13.97826341	4.53	.0127[b]
App integration with other technologies	1	0.08936760	0.08936760	0.03	.8652

[a]Number of observations used =129. r^2=.4946

[b]*P* value<.05

Discussion

Gamification Use

This research represents, to our knowledge, the first comprehensive review of gamification use in health and fitness apps. The results show that use of gamification in health and fitness apps has become common, as evidenced by the number of apps found in the app store containing at least some components of gamification. The use of game elements was correlated with the use of gamification, which was expected as gamification borrows its constructs from the gaming space. Gamification scores correlated with the use of health behavior theory, although further analysis showed that only motivation accounted for the association. This was expected as gamification in the industry is generally used to increase the motivation of its users; however, this potentially highlights a missed opportunity with gamification apps focusing primarily on motivational components of behavior without adequately addressing capability or behavioral triggers.

Despite the inclusion of at least some components of gamification, the mean scores of integration of gamification components were still below 50 percent. This was also true for the inclusion of game elements and the use of health behavior theory constructs, thus showing a lack of following any clear industry standard of effective gaming, gamification, or behavioral theory in health and fitness apps. Moving toward an industry standard may be challenging, however, as it is difficult to measure the true impact of gamification without conducting experiments related to the impact of design features of apps. In large part there has been little effort for ensuring quality in commercial health and fitness apps or establishing effective and meaningful criteria for using gamification. In fact, the current success of health games is measured in revenue generation, not behavioral metrics [20,33,34]. Much research on gamification and health to date has focused on exergames, or games that require the individual to be physically active while playing the game [35]. Gaming consoles like the Nintendo Wii or Xbox Kinect have used interactive sensors to allow for more integrated types of game play that were not before possible [17,34]. Work by Adams et al has focused on developing evaluation frameworks for effective components and physical exertion in exergames [35]. The results of this study show the need for further examination of games in health through large sample studies in controlled settings in order to measure the true benefits of gamification for health.

As hypothesized, use of gamification was correlated with effective game elements established by the videogame industry. Additionally, game elements were correlated to app popularity, as represented by the number of app reviews. Considering the Apple App Store does not report data on popularity through downloads or consistent use of particular apps, reviews were the only quantifiable measure of popularity universally available for inclusion in analysis. In contrast, gamification was not correlated to app popularity when placed in the regression analysis (not reported in tables). This has significant implications for developers and health practitioners when designing games for health. If games are in fact more popular to the public, then the focus of developers should be to create in-depth, narrative gaming experiences and not apps that merely use convenient elements of games or gamification.

Much controversy has developed over the broadly used term, gamification. The widespread adoption of gamification in health apps has been criticized from the field of game developers, as it only adopts selective or “convenient” components of functional games into nongame settings [15,18,36]. This adaptation removes the fact that the traditional games are already naturally reinforcing and motivating, while complex behaviors such as diet and physical activity may not be [18,33,34]. Ferrara referred to the work of Gartner when describing this rapid expansion and widespread adoption of gamification as being a part of a naturally reoccurring “hype” cycle that occurs with new technologies, and later dies down after increasing amounts of failure and frustration from the field [18,37]. Additionally, the push towards gamification assumes that the use of rewards, levels, leaderboards, and external incentives are enough to sustain (health) behavior responses without using other components of games like problem solving, storytelling, and fantasy [15,18,36]. This mirrors the findings of this study, with results showing very little use of 3-D environments and narrative context.

Finally, the results of this analysis showed that the use of health behavior theory was correlated with the use of gamification and not the use of game elements. Further analyses showed that gamification correlated with the composite motivation score and not to capacity or opportunity/trigger. Perhaps apps that use gamification are trying to influence the motivation of users to engage in a desired behavior, while potentially ignoring the ability of an individual to perform the behavior and triggers to engage in a behavior. However, targeting ability of individuals to engage in a behavior is central to achieving long-term behavioral change [30]. A singular focus on motivation may temporarily support health behaviors, but without increased ability, motivation and self-efficacy may not be sustained [32,38].

While the new field of gamification is promising, it has overlooked other major components of health behavior theory in the development and implementation of gamified health. First, the concept of using incentives to increase adoption and retention of behaviors finds its origins in operant conditioning/reinforcement, or repetitive pairing of completion of the behavior with an external reward [35,38]. However, no attempt has been made to assess the use of gamification in mobile phone apps as it relates to operant conditioning. This review of gamification in health apps reveals that many apps rely on the digital rewards such as badges or points as being valued by the user, when in actuality, this may not be true. This perspective is not supported in traditional behavior change settings, with some professionals criticizing this use of gamification as being little more than a customer loyalty program not geared for comprehensive behavioral change [18]. Second, no assessment has been made as to whether or not external incentives in mobile phone apps adequately adhere to best practice in health behavior theory application. Indeed, many apps require too much effort in engagement for too little perceived worth or benefit, an imbalance that results in unreliable health behaviors [35,39,40].

Limitations

The findings of this study should be interpreted in the context of some key limitations. First, primarily free apps were reviewed in the sample of this study, which may have excluded relevant available paid apps that may use gamification. However, a growing trend over recent years has been toward making apps free to download, with 90% of apps currently being free [22]. As such, this sample should be considered sufficient representation of apps available considering this industry trend.

Second, apps were originally coded into the sample by reviewing the descriptions in the Apple App Store. Consequently, some of the apps initially reviewed (around 16.7%, 22/132) did not actually include elements of gamification as previously coded. However, this potential error came after complex review of apps after download, and was the result of inaccurate descriptions, not the researchers of this study. Further emphasis in the app industry should move toward quality control of descriptions and app content in order to provide better quality content to users. Finally, this study did not evaluate the role of design features of apps in effecting their behavioral efficacy. As such, the results should be interpreted with caution, and used to lay a foundational framework for developing future studies that can incorporate elements of app design in their evaluation; for instance, randomized controlled trials.

Conclusions

Apps represent a very promising, burgeoning market and landscape in which to disseminate health behavior change interventions. Initial results show an abundant use of gamification in health and fitness apps, which necessitates the in-depth study and evaluation of the potential of gamification to change health behaviors. Developers and health practitioners trying to influence behavior change and health outcomes should consider comprehensive integration of behavioral theory, independent of whether or not games or gamification is used. However, gamification may be an effective means of targeting motivational components, and games may be effective at triggering individuals and increasing popularity of apps. As it stands, the current industry use of gamification, game elements, and behavioral theory are subpar, illustrating a proliferation of apps available for download following no set industry standard that is currently available. This paper has the potential to not only impact the burgeoning industry of gamification in health and fitness apps, but to provide a framework for effective practice of integrating games and behavioral theory into mobile interventions to better impact the health of populations.

Acknowledgments

CL, JW, and BC conceptualized the study design and variables measured for this study. CL performed the initial search of the Apple App Store and coded the apps based on descriptions for inclusion in the sample. CL, TS, and DB coded the sample of apps. CL and JW performed the analysis of the results. CL, JW, and BC formatted and constructed the initial paper for publication.

Conflicts of Interest

None declared.

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Abbreviations

COM-B: capability motivation opportunity/trigger
HBM: health belief model
SCT: social cognitive theory
SMS: short message service

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Original Paper

Active Fantasy Sports: Rationale and Feasibility of Leveraging Online Fantasy Sports to Promote Physical Activity

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Abstract

Background: The popularity of active video games (AVGs) has skyrocketed over the last decade. However, research suggests that the most popular AVGs, which rely on synchronous integration between players' activity and game features, fail to promote physical activity outside of the game or for extended periods of engagement. This limitation has led researchers to consider AVGs that involve asynchronous integration of players' ongoing physical activity with game features. Rather than build an AVG de novo, we selected an established sedentary video game uniquely well suited for the incorporation of asynchronous activity: online fantasy sports.

Objective: The primary aim of this study was to explore the feasibility of a new asynchronous AVG—active fantasy sports—designed to promote physical activity.

Methods: We conducted two pilot studies of an active fantasy sports game designed to promote physical activity. Participants wore a low cost triaxial accelerometer and participated in an online fantasy baseball (Study 1, n=9, 13-weeks) or fantasy basketball (Study 2, n=10, 17-weeks) league. Privileges within the game were made contingent on meeting weekly physical activity goals (eg, averaging 10,000 steps/day).

Results: Across the two studies, the feasibility of integrating physical activity contingent features and privileges into online fantasy sports games was supported. Participants found the active fantasy sports game enjoyable, as or more enjoyable than traditional (sedentary) online fantasy sports (Study 1: t_8=4.43, P<.01; Study 2: t_9=2.09, P=.07). Participants in Study 1 increased their average steps/day, t_8=2.63, P<.05, while participants in Study 2 maintained (ie, did not change) their activity, t_9=1.57, P=.15). In postassessment interviews, social support within the game was cited as a key motivating factor for increasing physical activity.

Conclusions: Preliminary evidence supports potential for the active fantasy sports system as a sustainable and scalable intervention for promoting adult physical activity.

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KEYWORDS

physical activity; games for health; active video game; exergame; asynchronous; social support; multiplayer; enjoyment; intrinsic motivation; sports

Introduction

Background

Traditional video games have been sedentary in nature, requiring small hand or thumb movements and very little physical exertion. By contrast, active video games (AVGs) (also known as: exergames, exertainment, or active gaming), link participants' physical activity to various aspects of video game play, thereby promoting greater physical exertion. In 2011, the American Heart Association published a science panel proceedings report highlighting the promise of AVGs and encouraging further research on their efficacy [1].

Unfortunately, active video games have to this point proven relatively limited in their effectiveness. In particular, empirical tests of active video games that link players' physical activity with game features in real-time (ie, synchronously) have only minimally and temporarily increased physical activity [2]. Further, the intensity of the exercise achieved while playing many of the most popular synchronous active video games (eg, Wii, Kinect, Move) has fallen below the minimal threshold for moderate intensity physical activity [3]. An additional challenge is economic; thus far, "neither children nor parents . . . have purchased enough healthy videogames to make it profitable" [2].

Theoretical and evidence-based strategies for designing more effective AVGs have been proposed [1,4,5]. Self-determination theory (SDT) is a macro-theory of human motivation that has been applied to identifying factors that might sustain individuals' motivation in general (eg, in classrooms, the workplace, and in sports) [6], as well as within sedentary video games [5] and AVGs specifically [7,8]. SDT postulates that the more often basic psychological needs for autonomy, competence, and relatedness are satisfied within a game, the more enjoyable and satisfying the experience, and thereby more sustainable the motivation [9]. These three basic psychological needs can be supported in innumerable ways within games. Games can support the need for autonomy by providing participants with opportunities to explore or make choices. When challenges within a game are calibrated to stretch a participant's ability (ie, by optimal challenge), the need for competence is satisfied. Finally, the need for relatedness is supported when people feel connected to others, which can occur with fictional characters depicted in games, or with real people, as in some multiplayer video games. Research supporting the integration of social support into AVGs has been particularly compelling [10], even with a virtual other or cyber buddy [11].

Baranowski and colleagues [2] also identified evidence-based factors that might improve the efficacy of AVGs. Inclusion of a meaningful and engaging narrative seems to help sustain engagement with AVGs [12]. Additionally, asynchronous (versus synchronous) integration of participant activity with game features may elicit more generalizable and sustainable changes in physical activity. Asynchronous AVGs integrate video game features with activity that takes place when participants are not engaging directly with the gaming interface (eg, through use of an accelerometer that monitors steps over the course of an entire day or week). Participants playing an asynchronous AVG may be sedentary while engaging directly with the gaming interface; the activity occurs asynchronously, (ie, at a different time). While asynchronous AVGs are promising for motivating sustained increases in physical activity, relatively few have been developed (versus synchronous AVGs). Several exceptions include the now defunct Ubifit garden [13], Pokewalker, and Gemini [14] games, as well as smartphone integrated game applications like Nike+'s NikeFuel Missions, and Six to Start's Zombies Run! series; but to the best of our knowledge, no rigorous empirical tests of these asynchronous AVGs have been published.

Although new AVGs could be developed using these theoretical and empirical strategies, a more economical alternative approach is to integrate physical activity into sedentary video (or online) games that have proven appeal. Currently, one of the most popular and enduring online games among adults in North America are variations of a game platform collectively referred to as *fantasy sports*.

Online Fantasy Sports as a Platform for Building an Asynchronous Active Video Game

Fantasy sport (also known as rotisserie, roto, or owner simulation) is a game that involves participants selecting professional athletes, and earning points based on the real world performance of those professional athletes. The most common variants of this game involve a group (or league) of participants acting as fantasy team "owners." Each fantasy team owner drafts and manages a roster of uniquely claimed players over the course of a professional sport season (see Figure 1 in Multimedia Appendix 1); a typical fantasy "league" might include 8 to 12 teams, each managed by an individual team owner (see Figure 2 in Multimedia Appendix 1). Fantasy team owners have the ability to trade, cut, and sign players in a manner analogous to the real owners of professional sport teams (see Figure 3 in Multimedia Appendix 1). Online hosts of fantasy sport games provide automated scoring and opportunities for electronically mediated discussion between league owners, including message boards and direct messaging (see Figure 4 in Multimedia Appendix 1).

For a number of reasons, we hypothesized that online fantasy sports, a traditionally sedentary online game, might represent a gaming platform uniquely well suited to supporting a scalable, sustainable AVG for increasing physical activity. First, traditional (sedentary) fantasy sports are extremely popular (>41 million players in the US and Canada, alone), supporting high potential reach [15]. Second, fantasy sports have established enduring appeal, supporting prolonged engagement; participants play in leagues that last for several months, and often play season-after-season for multiple years within the same league. Popularity and sustained motivation may be related to the ample opportunities for experiencing psychological need satisfaction afforded while playing traditional fantasy sports games. Specifically, this platform provides game players with many options for customizing their teams in ways that can reflect their identities (e.g., selecting athletes for reasons that include their personalities, shared cultural, or regional affiliations), thereby supporting *autonomy need satisfaction*; this platform facilitates finding leagues that include similarly skilled opponents, thereby optimizing challenge, and *competence need satisfaction*; and fantasy sports leagues are social, providing opportunities for interpersonal interaction and *relatedness need satisfaction*.

Third, traditional fantasy sports already involve a form of asynchronous integration between physical activity (that of professional athletes) and game features; as such, fantasy sports games may be especially well suited to asynchronous integration of participants' physical activity (as recommended by Baranowski et al [2]. Fourth, the basic features of traditional fantasy sports are in the public domain and thus economically and practically amenable to augmentation.

Fifth, although traditional fantasy sports are sedentary, thematically these games involve attending to physical activity data generated by professional athletes. Thus, asking individuals to attend to their own physical activity data is copasetic with traditional fantasy sports in terms of attending to data, and specifically data related to physical activity. Further, we hypothesized that the game's defining theme of professional sports would have several potential advantages. For example, activating thoughts related to physical activity (regarding professional sports) might prime greater activation of participants' goals to increase physical activity by virtue of shared semantic and associative networks. Nonconscious priming of goals has previously been shown to increase intensions to pursue those goals [16]. Further, fans of professional sports often identify very strongly with professional sports teams, often fanatically/intensely so, a motivational dynamic that has previously been effectively leveraged for promoting physical activity among overweight and obese male soccer fans in Europe in the context of an intervention delivered in-person [17]. Relatedly, the strong appeal of professional sports, and as such online fantasy sports, to men (approximately 80% of fantasy sports participants are male; Fantasy Sports Trade Association FSTA, 2013), may be especially advantageous in light of evidence that men have traditionally been underrepresented in behavioral health interventions [18], and relatively less willing to engage in health-related online support communities [19].

The primary purpose of this pilot research was to test the feasibility of an active fantasy sports intervention. We tested this in the context of two studies, using two versions that were focused on different sports (baseball and basketball). Feasibility was assessed in terms of participants' self-reported satisfaction with the game overall and with specific features. An exploratory aim of this research tested whether participants increased their physical activity while playing the game, as objectively assessed by accelerometers.

Methods

Study 1: Active Fantasy Baseball

Overview

To test the feasibility of the proposed active fantasy sports system, we conducted a 13-week proof-of-concept field study from April to June 2013. The focal sport selected was Major League Baseball, a sport that was integral to the early development of traditional (sedentary) fantasy sports.

Recruitment

Participants were recruited using a convenience sampling procedure that involved reaching out to the principle investigator's online social network. This included inviting individuals with whom the principal investigator had participated in prior traditional fantasy sports leagues. The investigative team considered a number of potential issues related to using this form of convenience sampling (e.g., social desirability bias and experimenter demand characteristics), but opted in favor, given the early formative phase of research and low fidelity execution that could be offered at this stage. No financial incentives or other compensation were offered in exchange for 13-weeks of participation.

Inclusion criteria were highly inclusive; participants had to be over 18 years of age and able to engage in physical activity without significant risk of injury. We intentionally did not exclude individuals who were meeting the recommended amount of physical activity at baseline in order to mirror real-life fantasy sports leagues where players have varying levels of fitness; these inclusion criteria help maximize ecological validity and the potential reach of our intervention.

Protocol

After the nature of the study was explained and participants provided their written informed consent, all participants completed a set of preintervention questionnaires. A screening tool (Physical Activity Readiness Questionnaire, PAR-Q) was administered to confirm that the participants were physically prepared to increase their physical activity without significantly risking injury; this measure was designed for adults aged 15-69, and asks about 7 physical activity risk factors (eg, chest pain, dizziness, and joint problems) [20]. All participants passing screening then received an accelerometer to wear for at least 1-week of baseline recording. During the baseline activity recording phase, participants were asked to maintain their activity level. Each participant's baseline activity was subsequently used to set individually calibrated weekly physical activity goals during the 12-week intervention phase.

Those participants who exceeded the recommended 10,000-steps/day average during the baseline activity recording phase (n=3) were asked to maintain their baseline average each week during the 12-week intervention phase. This policy was instituted as a conservative precautionary measure to ensure the safety of our participants, as well as to purposely deemphasize the value of excessive activity. Those participants who fell short of the recommended 10,000-steps/day average during the baseline activity recording phase were asked to increase their activity by 10% each week, up until their weekly goal became 10,000 steps/day and was capped at that level.

During the 12-week intervention phase, participants competed in a fantasy baseball league hosted by Yahoo. The principle investigator, serving as league commissioner, managed game-related consequences using the league commissioner tools provided by Yahoo (and standard to other major online fantasy sport hosts, including ESPN and CNNSI) once a week. Cumulatively, these managerial tasks performed by the principal investigator required less than 30 minutes each week; these managerial tasks are described in more detail below. Figure 5 in Multimedia Appendix 1 includes screenshots with accompanying explanations of the league commission tools provided by Yahoo. Game-related consequences tied to physical activity during the 12-week intervention phase were two-fold. First, failure to meet a weekly activity goal resulted in the loss of one player (professional athlete) from that participant's team roster. The player dropped was selected at random, but could not include one of the best (high value) players from a list maintained and updated weekly by Yahoo (ie, the can't cut list). This made the consequences for failing to meet a weekly goal meaningful, but not extreme. Second, at the end of each week, the league's waiver wire priority was reset by the principal investigator based on the rank order of participants' percent of activity goal completed. If and when two or more team owners request to claim the same player who has recently been dropped from another team, the waiver wire priority is used to determine which team owner will be awarded that player. Participants were updated on their physical activity goal progress (and that of others in the league) twice a week via messages posted to the league message board. Participants were able to access their own physical activity data at any time via Fitbit's website or smartphone application; similarly, the fantasy league itself was available to participants via both Yahoo's website and smartphone application.

Finally, at the end of the 12-week intervention phase, all participants completed a structured interview with a study staff member by phone or in-person. Participants provided feedback on their experiences using activity-contingent features of the game, and were also given an opportunity to propose new features. Procedures were approved by the Institutional Review Board at the Illinois Institute of Technology IIT.

Materials

Preintervention Measures

Self-reported demographic information provided at baseline included: age, sex, race, education, height, and weight. Participants also reported their prior experience playing traditional versions of online fantasy sports and self-reported their physical activity over the month prior to enrolling in the study using the Godin Leisure Activity Measure [21]. Intrinsic motivation, specifically enjoyment for exercise in general, was assessed using a 3-item version of the Intrinsic Motivation Index, Cronbach alpha=0.93 [22].

Objective Physical Activity

During the 1-week baseline activity recording phase and 12-week intervention phase, physical activity was objectively assessed using a low-cost triaxial accelerometer (a Fitbit Zip). Fitbit's proprietary algorithms convert raw accelerometer data into estimates of steps taken, calories burned, and distance traveled. For the sake of parsimony, we focused exclusively on steps taken and set weekly goals based on average steps/day. Lee, Kim, and Welk [23] found that the FitBit Zip achieved energy expenditure estimates within 10.1% of criterion values concurrently obtained from a portable metabolic system (ie, Oxycon Mobile).

Postintervention Measures

Participants provided quantitative feedback on their experience related to intrinsic motivation for physical activity and for the active fantasy sports game, their attitudes toward different activity-contingent features of the game and new proposed features, and their willingness to play active fantasy sports in the future. Intrinsic motivation (for exercise in general and for the active fantasy sports game in particular) was assessed using separate 3-item versions of the Intrinsic Motivation Index; Cronbach alpha=0.88, and 0.71, respectively [22]. Attitudes toward specific features and willingness to play were assessed using single item Likert-scale questions created for this study.

Study 2: Active Fantasy Basketball

Overview

A second pilot study was run for 17 weeks from November 2013 to February 2014 using a fantasy basketball league (specifically, the National Basketball Association).

Recruitment

Study 2 participants were recruited using poster advertisements on a medium size, urban university campus in the Midwestern-region of the United States. Although participants in Study 1 reported a strong preference for knowing everyone in their league cohort in advance, we felt it was important to test the feasibility of the system within a league comprised of strangers-at-baseline. Interested individuals emailed the study's principle investigator, received a brief overview of the study, and were screened for eligibility.

Protocol

After recruitment, the protocol for Study 2 essentially mirrored that for Study 1. Only a few aspects of the protocol were changed. First, the intervention period lasted for 16 weeks (rather than 12). Second, during the intervention period, participants who recorded fewer than 4000 steps in a day were given credit for 4000 steps. This change was made in order to avoid having participants severely punished in the event that they left their accelerometer at home on one or more days and because it was more logistically feasible to execute. Third, participants were offered the opportunity to win small competition-contingent financial incentives based on league performance (1st place was awarded US $150; 2nd place was awarded US $100; 3rd place was awarded US $50, with each subsequent place lowering in increments until the 8th and final place).

Results

Study 1: Active Fantasy Baseball

Sample Demographics

Summary

There were 9 adult males who participated with 100% retention over the 13-week study. Mean age was 34.89 years (SD 2.26, range 32-40). Of the male participants, 8 were White and 1 was Asian. The sample was highly educated, all participants had "some college" or higher. Mean body mass index was 25.20

(SD 1.80, range: 22.38-27.70), which falls slightly above the normal range. The average number of online fantasy sports leagues played prior to the study was 15.70 (SD 19.57, range 0-64). There were 2 participants who had never played traditional fantasy sports before.

Enjoyment

Self-reported enjoyment of the active fantasy baseball game was significantly higher than neutral (3) on the 7-point scale, mean 5.59 (SD 1.22), one-sample t_8=6.36, *P*<.001. Further, participants rated active fantasy sports as significantly more enjoyable compared to traditional fantasy sports, one-sample t_8=4.43, *P*<.01. Participants self-reported intrinsic motivation for exercising in general did not change significantly from preintervention (mean 4.59, SD 1.52) compared to postintervention (mean 5.15, SD 1.57); paired t_8=1.72, *P*=.13. Findings are summarized in Table 1.

Table 1. Comparison of demographics and outcomes in studies 1 and 2.

Variable	Study 1 (n=9) Active Fantasy Baseball n (%) or mean (SD)	Study 2 (n=10) Active Fantasy Basketball n (%) or mean (SD)
Age in years	34.89 (2.26)	25.50 (3.89)
% male	10 (100%)	9 (90%)
Leagues played in previously / experience	15.70 (19.57)	3.36 (3.96)
BMI	25.20 (1.80)	23.61 (3.18)
Godin activity score at baseline	52.88 (30.36)	40.09 (14.69)
Steps/day at baseline	8678.44 (1784.50)	6961.70 (2137.85)
Steps/day across the intervention phase	11,364.22 (3426.11)	6267.34 (1877.58)
Enjoyment of active fantasy game	5.59 (1.22)	5.23 (1.36)
Number of posts to message board	9.22 (8.57)	1.50 (2.42)
Number of co-participants known well at baseline	4.22 (2.68)	0.60 (0.52)
Preference for knowing co-participants at baseline	2.33 (0.71)	2.10 (1.10)
Preference for everyone being equally active at baseline	0.67 (1.94)	1.00 (2.00)
Ideal impact of physical activity on the game	5.00 (1.23)	5.70 (1.16)
Actual impact of physical activity on the game	3.11 (1.05)	3.70 (1.57)

Social Factors

During postintervention interviews, participants frequently cited social aspects of the game as especially motivating and enjoyable. The mean number of posts to the league message board per participant was 9.22 (SD 8.57, range 0-25). On average, they reported knowing 4.22 (SD 2.68) other participants in the league before the start of the season (ie, just over half the other participants in the league). When asked, “How much better or worse would this game have been if you knew everyone in the league very well before starting the season?” (-3=much worse; +3=much better), the mean response was +2.33 (SD 0.71), a strong preference for knowing everyone in the league before the start of the season. Participant mean responses on the social aspects of the game are listed in Table 1.

Relative Impact of Fitness

Finally, we asked participants about their preferences with regard to the relative influence of their physical activity versus sedentary strategy on game outcomes. We asked, “If you could choose the degree or amount that team owners’ physical activity impacted the outcomes of an active fantasy sports league, how impactful would you make it?” (1=a very small impact / the least active owner could still win; 7=a very large impact / the least active owners could not win). The mean response was 5.00 (SD 1.23). Next, we asked, “In this pilot study, how much do you think team owners’ physical activity impacted the league outcomes?” (using the identical 7-point scale). The mean response was 3.11 (SD 1.05). The mean difference between these two ratings (mean 1.89) was statistically significant, paired t_8=3.69, *P*=.006.

Physical Activity

Participants’ self-reported and accelerometer-measured physical activity varied at baseline (the mean Godin activity score was 52.88, SD 30.36, range 14-119, and mean steps/day 8678.44, SD 1784.50, range 5913-11,053). Across the 12-week intervention phase, participants averaged over 30% more activity, paired t_8= 2.63, *P*≤.05 (12-week mean 11,364.22, SD 3426.11, range 4064-15,949).

Given that the 3 participants who were already exceeding the goal of 10,000 steps/day at baseline were asked to maintain their baseline level of activity, we also calculated the mean change in activity for two subgroups, (ie, those given goals to maintain) (n=3, mean change = +2962.67, SD 3136.51) and those given goals to increase activity (n=6, mean change = +2547.33, SD 1357.78); both groups increased their activity.

Study 2: Active Fantasy Basketball

Sample Demographics

Summary

A total of 15 applicants responded to recruitment materials expressing interest in the study; 3 did not wish to enroll due to lack of interest. Of the 12 adult participants enrolled in the study, 2 participants dropped out of the study after the first week of the intervention, leaving us with a sample size of 10 (9 males, 1 female). The two participants who dropped out had not played online fantasy sports previously, quickly decided that the game was more complicated than anticipated, and were unwilling or unable to invest time in learning the rules. Mean age was 22.50 (SD 3.89, range 18-30). Of the participants, 4 were White, 4 were Asian, 1 was Black, and 1 was Multiracial. The sample was highly educated; all participants had "some college" or higher. Mean body mass index was 23.61 (SD 3.18, range 19.31-29.18), which is within the normal weight range. The average number of online fantasy sports leagues played in prior to the study was 3.36 (SD 3.96, range 0-9); 6 participants had never played traditional fantasy sports before.

Enjoyment

As in Study 1, self-reported enjoyment of the active fantasy sports game itself was significantly higher than neutral (3) on the 7-point scale, mean 5.23 (SD 1.36), one-sample t_9=5.19, *P*≤001. Furthermore, when asked to compare active fantasy sports relative to traditional (sedentary) fantasy sports in terms of enjoyment, participants rated active fantasy sports as marginally more enjoyable, one-sample t_9=2.09, *P*=.07. Participants' self-reported intrinsic motivation for exercising in general did not change significantly from preintervention (mean 4.63, SD 1.64) compared to during the intervention (mean 4.639, SD 2.18).

Social Factors

The mean number of posts to the league message board was significantly smaller than in Study 1, mean 1.50 (SD 2.42, range 0-6). On average, they reported knowing 0.60 (SD 0.52) other participants in the league before the start of the season. When asked, "How much better or worse would this game have been if you knew everyone in the league very well before starting the season?" (-3=much worse, +3=much better), the mean response was +2.10 (SD 1.10), a strong preference for knowing other league members. However, when asked: "How much better or worse would this game have been if everyone in the league was roughly as active as you were at baseline?" (-3=much worse; +3=much better), the mean response was 1.00 (SD 2.00), indicating no clear preference.

Relative Impact of Fitness

Finally, we asked participants about their preferences with regard to the relative influence of their physical activity versus sedentary strategy on game outcomes. We asked, "If you could choose the degree or amount that team owners' physical activity impacted the outcomes of an active fantasy sports league, how impactful would you make it?" (1=a very small impact / the least active owner could still win; 7 a very large impact / the lease active owners could not win). The mean response was 5.70 (SD 1.16). Next, we asked, "In this pilot study, how much do you think team owners' physical activity impacted the league outcomes?" (using the identical 7-point scale). The mean response was 3.70 (SD 1.57). The mean difference between these two ratings (mean 1.89) was statistically significant, paired t_9=3.00, *P*=.015, indicating that participants wanted physical activity to be more impactful on league outcomes.

Physical Activity

Participants' self-reported and accelerometer-measured physical activity varied at baseline (the mean Godin activity score was 40.09 (SD 14.69) range 14.00-65.50 and mean steps/day 6961.70, SD 2137.85, range 3346-10,473), and during the 16-week intervention phase (mean 6267.34, SD 1877.58, range 4427.97-9607.24). Physical activity did not significantly increase during the intervention phase, paired t_9=1.57, *P*≤.15.

There was one participant who was already exceeding the goal of 10,000 steps/day at baseline and was asked to maintain his or her baseline level of activity. Change in activity for that participant (n=1, mean change = +865.76) was higher than for those given goals to increase activity (n=9; mean change =-75.31, SD 1481.79).

Discussion

Principal Findings

The present investigation demonstrates the feasibility of linking physical activity goals to features and privileges within an extremely popular sedentary video game, online fantasy sports. There were high rates of retention in both studies (zero attrition in Study 1, two dropouts very early in Study 2), and regular posting to the league message board in Study 1. Especially encouraging findings from this study related to participants' ratings of the degree to which they enjoyed playing active fantasy sports. Across both studies, participants reported enjoying active fantasy sports, and rated it significantly higher than neutral. In Study 1, participants rated active fantasy sports as even more enjoyable than traditional fantasy sports; Study 2 participants rated it as neither more nor less enjoyable than traditional. Study 2 participants had less previous experience with fantasy sports and knew fewer participants in the league, which likely influenced their enjoyment of the league.

Participants in both Studies 1 and 2 reported that knowing other participants in the league at baseline would be highly desirable. As such, we believe interventions of this kind have the best probability of success if groups of friends can be recruited for participation together. These circumstances also more faithfully reflect the typical way that traditional (sedentary) online fantasy sports leagues form.

Although the two pilot studies were not designed or powered to test the system's potential for increasing physical activity, encouraging findings were observed. The use of accelerometers provides an objective indicator of changes in physical activity, and can be considered a major strength. In Study 1, participants increased their physical activity by over 30% during the active fantasy baseball season compared to baseline. We note that in both studies, participants who were already meeting the activity goal of 10,000 steps/day at baseline were instructed only to maintain their level of activity (3 participants in Study 1, 1 participant in Study 2).

Limitations

Design limitations include the lack of a control or active comparison condition, and the low fidelity (manual, as opposed to automated) execution of the integration between physical activity data and fantasy sports game features. Consequences were administered manually by the principle investigator using standard tools provided by Yahoo to league commissioners. A more elegant execution of the system could be achieved by leveraging open APIs made available by both accelerometer providers (eg, Fitbit) and fantasy sports league hosts (eg, Yahoo, Espn, or CNNSI). Despite these limitations, the important contribution of swifter, proof-of-concept trials of this kind is being championed in the emerging field of technology-support and mobile health research [24].

The samples in both studies were small (n=9, and n=10), and were not representative of the general population, especially with regard to gender. This limits the generalizability of the findings. However, we note that the sample demographics were relatively consistent with the population of adults who play traditional online fantasy sports (ie, predominately male, Caucasian, and well-educated). We also note that participants' self-reported height and weight were potentially biased; future studies should include measurements of height and weight taken by research staff members with appropriately calibrated instruments.

Future Directions

The present research suggests a number of directions for future research. First, leveraging open APIs associated with accelerometer providers and fantasy sport hosting websites will reduce the burden on research staff, allowing researchers to collect data from much larger and more representative samples. Second, it will be important to test the efficacy of the active fantasy sports system for increasing physical activity relative to a usual care or active comparison group (eg, participants assigned to receive an accelerometer for self-monitoring purposes and a group message board only) using a randomized controlled trial. Group-randomization could be employed in order to recruit groups of participants who know each other before enrolling in the study. Third, aspects of the game can potentially be tailored according to the characteristics and preferences of the participants. For example, participants in both studies expressed a desire for their physical activity to have a greater impact on game outcomes. Optimization study designs may help us refine which activity contingent features are maximally effective, test different ways of measuring physical activity (eg, with wearable technology or specialized exercise equipment), and assess different rules for setting activity goals in order to maximize both optimal challenge and perceived fairness. Prior research also shows that levels of competitiveness may influence enjoyment of games and thus may have implications for intrinsic motivation [25,26]; future research may tailor game features or match players based on competitiveness. Fourth, given the preliminary evidence that social factors helped motivated participation and intervention success, future research should investigate this issue further (eg, qualitative and quantitative analysis of message board usage). Fifth, future research may expand the variety of target sports (eg, football, soccer, hockey, golf, rugby, cricket, etc), thereby potentially increasing reach.

Potential Public Health Impact

As noted in the introduction, Baranowski and others [2] have argued that the public health impact of previous AVGs has been limited by low uptake and high cost. As such, we think it is useful to highlight a number of unique strengths associated with active fantasy sports interventions that support potential reach and cost-effectiveness.

Importantly, we believe the established massive popularity of traditional (sedentary) fantasy sports provides a powerful dissemination channel. In 2014, over 41 million adults in the United States (US) and Canada alone played online fantasy sports [15]. For reference, in 2014, the entire population of Canada was roughly 34 million. If even a fraction of the traditional fantasy sports audience could be persuaded to try active fantasy sports, this would represent significantly greater reach than previous AVGs. Further, while most AVGs have not made social features integral or required, preliminary evidence suggested that social aspects of the active fantasy sports intervention were important. As such, active fantasy sport interventions may be especially well suited to implementation by organizations interested in promoting physical activity (eg, schools, or employer sponsored wellness programs). Active fantasy sports leagues sponsored by organizations could significantly magnify reach and, by leveraging existing social ties, may also improve efficacy.

Further supporting the potential reach of active fantasy sport type interventions are a number of factors limiting costs associated with software development, labor, and equipment. As noted earlier, the game platform that active fantasy sports interventions are built on (traditional fantasy sports) is in the public domain and supported by numerous companies ("host" websites, including Yahoo, ESPN, and CNNSI). By taking advantage of existing, sophisticated game platform infrastructure provided by numerous hosts, developers achieve significant cost reductions relative to building a comparable AVG de novo. The major hosts of traditional online fantasy sports offer open API access to external application developers specifically to encourage innovation of this kind. Furthermore, established hosts currently offer consumers access to traditional fantasy sports games without charging fees (major hosts typically use an advertising-based revenue model), minimizing an important barrier for low-income consumers. At present, the overhead and labor costs associated with administrating an active fantasy sports intervention are already very low; the intervention was administered remotely (as opposed to in-person) and involved minimal administrative effort (<1 hour per week). By leveraging device and host APIs, future iterations of this intervention may further automate oversight and reduce costs, especially relative to gold-standard interventions such as individual professional coaching delivered in-person. A third factor related to cost concerns the affordability of equipment used for objectively measuring physical activity. The present versions of the active fantasy sports intervention employed a low cost accelerometer (retail price US $60) that was provided to participants. However, the cost of dedicated wearable accelerometers is rapidly falling; similar models are currently available for as low as US $12 per unit [27]. Smartphones, which typically include sophisticated built-in accelerometers, are increasingly ubiquitous, reducing the cost of activity tracking equipment further still. The cost of more sophisticated activity tracking devices (eg, activity trackers that incorporate heart rate sensors, global positioning system, and accelerometry, including Apple's iWatch, Fitbit's Surge, and Microsoft's Band) should similarly fall if the proliferation of wearable activity tracking technology continues.

Conclusions

To summarize, this study provides strong support for the feasibility of integrating physical activity contingent features and privileges into an online fantasy sports game platform. Participants found this asynchronous active video game system enjoyable, as or more enjoyable than traditional (sedentary) online fantasy sports. Social support within the game was cited as an important factor for both enjoyment and increasing physical activity. Future research is needed to test the efficacy of this system using a randomized controlled trial and optimization-type designs, and with a larger, more diverse sample of participants. The scalability and reach of active fantasy sport interventions represents a significant strength.

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Conflicts of Interest

The lead author of this manuscript (Moller) is also the sole inventor of a US Patent Application currently under review at the US Patent and Trademark Office (filed on December 3rd, 2013), titled: "Incorporating objective assessments of fantasy-team-owners' physical activity into fantasy sport platforms" (Serial No. 14/088,632). Ownership of the referenced intellectual property is vested in Illinois Institute of Technology. For the other authors of this manuscript, no competing financial interests exist.

Multimedia Appendix 1

Screenshots of a fantasy sports team roster, a league comprised of multiple fantasy sports teams, a fantasy team owner tool for offering a player trade to another fantasy team owner, a fantasy sports league message board, and fantasy sports league commissioner tools.

[PDF File (Adobe PDF File), 3MB - games_v2i2e13_app1.pdf]

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Abbreviations

AVG: active video game
SDT: self-determination theory
FSTA: Fantasy Sports Trade Association
PAR-Q: Physical Activity Readiness Questionnaire
IIT: Illinois Institute of Technology

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Viewpoint

How to Systematically Assess Serious Games Applied to Health Care

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Abstract

The usefulness and effectiveness of specific serious games in the medical domain is often unclear. This is caused by a lack of supporting evidence on validity of individual games, as well as a lack of publicly available information. Moreover, insufficient understanding of design principles among the individuals and institutions that develop or apply a medical serious game compromises their use. This article provides the first consensus-based framework for the assessment of specific medical serious games. The framework provides 62 items in 5 main themes, aimed at assessing a serious game's rationale, functionality, validity, and data safety. This will allow caregivers and educators to make balanced choices when applying a serious game for healthcare purposes. Furthermore, the framework provides game manufacturers with standards for the development of new, valid serious games.

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KEYWORDS

consensus; serious game; applied game; telehealth; mobile health; video game

Background

Serious or *applied games* are digital games with the purpose to improve individual's knowledge, skills, or attitudes in the "real" world. Serious games applied to medical or health-related purposes are growing rapidly in numbers and in types of applications. Serious games have been shown to be at least as effective as conventional tests in improving cognitive abilities in the elderly [1] and even more effective than conventional neuropsychological interventions when it comes to improving neuropsychological abilities of alcoholic patients [2]. Serious game-based interventions have been used to support rehabilitation in disabled patients, showing equal effectiveness compared to conventional training programs [3]. Games have been applied to promote healthy behavior in children [4] and educate patients [5,6]. Serious game-based patient education has also been shown to increase the treatment adherence among adolescents with leukemia [7]. A third application for serious games is training medical personnel [8]. Serious games have been shown to add to Advanced Life Support training [9] and improve understanding of geriatrics principles among medical students compared to conventional training methods [10]. Patients [11], students, and professionals [12] generally view game-based interventions as fun and challenging.

Although results for serious games in terms of effectiveness for such purposes are promising, their implementation as "serious" modalities for prevention, treatment, or training in health care is hindered by lack of understanding of the underlying concepts among health care professionals, or even distrust. Before doctors and patients consider using serious games as a useful solution for a health care-related problem, it is important that they understand what problem is being addressed by the game and that a proposed claim on effectiveness is indeed trustworthy. Many clinicians are currently undereducated in judging a serious game's safety or effectiveness. Information on individual games is often hard to find in disorganized app stores and websites [13]. Studies on serious games' validity and effectiveness remain scarce [8,14]. The idea of applying a video game in health care may even be resentful to certain clinicians or patients. In addition, threats to data safety fuel distrust towards electronic applications in health care altogether [15]. Such issues menace the practical application of serious games throughout health care, subsequently limiting investments in smart solutions that may actually prove beneficial in the end.

This article discusses the first tool for the systematic assessment of serious games applied to medical use, for educators and clinicians. The information collected and organized accordingly, will aid health care practitioners to understand and appraise the risks and benefits of specific serious games in health care in a uniform manner.

Assessment Framework

To our knowledge, there is currently no systematic framework for the assessment of serious games in health care described in literature. Therefore, the Dutch Society for Simulation in Healthcare (DSSH) [16] has developed a consensus-based framework, categorizing important items that assess a serious game's safety and validity. Eight individuals (see Acknowledgements section for details) from six different institutions experienced in designing, applying, or researching serious games for health care-related purposes participated. The reporting standards for *non*-game mobile health apps for medical purposes (mHealth), published by Lewis [17] and Albrecht [18], was used as a basis. This system is applied by the peer-reviewed mHealth app assessment initiative of the *Journal of Medical Internet Research* [19]. Due to inherent differences in the functionality of *games* compared to purely informational *mHealth* applications, this framework required re-evaluation.

The panel reviewed the items from these reporting standards during two meetings. All items in the Albrecht framework [18] were systematically evaluated. For each of the 5 categories, items irrelevant to serious games were removed and if necessary, extra items were added. During the second panel meeting, the framework was re-evaluated and all members approved the final version.

The framework described provides 62 items in 5 main themes (Table 1), aimed at assessing a serious game's rationale, functionality, validity, and data safety. It specifically does *not* aim to assess its effectiveness in terms of success or user attractiveness. The panel defined serious games (other than a regular medical application) as digital applications instigating a specific behavioral change to its user, in the form of skills, knowledge, or attitudes useful to reality [20]. The framework does therefore *not* apply to (mobile or Web-based) digital health apps with a purely informational purpose, for which the *mHealth* app assessment framework is designed [18].

Table 1. Items relevant for the assessment of a serious game used for health care-related purposes.

	Category	Item	Question
Game description	Meta-data	Operating system	Operating systems of the game
		Version	Version
		Web-link	Web-link
		Project type	Commercial, non-commercial, other
		Access	Public / restricted / other
		Adjunct devices	Is an adjunct device needed?
	Development	Funding	How was development funded? Eg, funding agencies, investors
	Sponsoring / Advertising	Advertisement policy	Is the game free of commercial pop-ups?
			If not, what is advertised?
		Sources of income	Are there sources of income within the game?
		Sources of income outside game	What are the sources of income of the owner/distributor?
	Potential conflicts of interest	Affiliations	What affiliations do the publishers have that could influence content or user group?
		Conflicts of interest	What interests do the publishers have that could influence the game's content or user group?
		Disclosure	Are conflicts of interest disclosed?
Rationale	Purpose	Goal or purpose	What is (are) the purpose(s) of the game?
		Disclosure	Is (are) the purpose(s) disclosed to users?
	Medical device	Medical device	Is the serious game a medical device, or not?
		Class	If yes, which class?
		Approval by legal bodies	If yes, does it comply to the necessary requirements (FDA-approval, CE-mark?).
	User group	Specific user groups	For each user group: disease/condition, or health care profession.
		Description	Please specify gender, age (range), and other relevant descriptive items.
		Limits	Are there age limits, or other limits?
		Disclosure	Is the intended user group disclosed?
	Setting	Patient care	Is the game used in patient care?
		Training courses	Is the game used in training courses or -curricula?
		SCORM compliancy	If used in training courses or curricula, is the serious game SCORM-compliant?

	Category	Item	Question
Functionality	Purposes / didactic features	For every purpose of the game:	
		Learning or behavioral goals	What content will the player learn?
		Relation learning and game-play	How does the learning content relate to the gameplay?
		Instruction	What intervention leads to the learning transition (eg, tutorial, instructions (in-game))
		Assessment (progress) in game	Through which parameters is progress in the game measured?
		Assessment parameters	Which parameters are to designers' opinion indicative for measuring learning effects?
	Content Management	Content Management system	Is the Content Management System restricted to specified persons or institutions?
		User uploaded content	If no, are users allowed to upload their own content?
		Content monitoring	How is uploaded content checked?
		Restrictions and limits of the serious game	Please describe restrictions and limits of the serious game. What content on the learning goals is not covered?
	Potentially undesirable effects	Potentially undesirable effects	What potential undesirable effects could the game have?
		Disclosure	Are such potential undesirable effects disclosed to the user?
		Measures taken	What measures are taken to prevent potential undesirable effects?
Validity	Design process	Medical expert complicity	Were medical experts (content experts) involved in the design process from the start?
		User group complicity	Were representatives from the user group involved in the design process from the start?
		Educationalist complicity	Were educationalists involved in the design process from the start?
	User testing	User testing	Did user testing take place? What were the results, and how were these incorporated in the design?
	Stability	Platform stability	Does the game produce the same results on different platforms?
	Validity (effectiveness)	Face validity	Do educators and trainees view it as a valid way of instruction?
		Content validity	How is its content validated to be complete, correct, and nothing but the intended medical construct?
		Construct validity	Is the game able to measure differences in skills it intends to measure?
		Concurrent validity	How does learning outcome compare to other methods assessing the same medical construct?
		Predictive validity	Does playing the game predict skills improvement in real life?

	Category	Item	Question
Data protection	Data protection and privacy	Data processing	How is data collected in the serious game?
		Patient privacy	Are patient-specific data stored in the game?
			If yes, are patient informed consent criteria met according to relevant national standards?
		Data ownership	Who owns and stores the data resulting from play?
		Data storage period	During what period are data stored?
		Data removal	Can the user delete data temporarily and/or permanently?
		Data storage security	Is the data storage secured in conformity with laws of the countries stated above?
		Data transmission security	Is the data transmission secured in conformity with laws of the countries stated above?
		Disclosure	Are all items on "data protection" disclosed to the user?

Assessing Medical Serious Games

Game Description

When evaluating a specific serious game, it should be thoroughly described and registered (including information about the manufacturer or owner to whom the game should be attributed and the version). Equally to mobile applications, a special interest is taken into the owner's policy concerning revenues from sponsoring and advertisements, both during development as well as its use. Sources of revenue and affiliations (eg, pharmaceutical industry) may bias or threaten a serious game's validity for obvious reasons. These should be fully disclosed to the game's users. Sources of income within a game can be equally relevant to the costs required for the initial purchase.

Rationale

This clarifies the game's purpose outside the game. This external purpose (eg, improving eye-hand coordination in laparoscopic surgery) may differ from the actual goal *in* the game (eg, completing a quest in an underground world [21] or playing a tennis game [22]). This clearly differs from the Albrecht framework, because most mHealth apps have a single obvious purpose (internal goal = external goal). A game's purpose relates to the intended user group and the setting in which it is used, similar to mHealth apps.

Additionally, serious games might fall within the scope of the medical devices, requiring specific guidelines to be implemented, set by the US Food & Drug Administration (FDA), European Committee (Conformité Européenne, CE), or national equivalents. This specifically applies to games with a distinct diagnostic or therapeutic purpose. Moreover, integration of serious games into electronic learning environments may demand certain technical requirements. The industry has set standards to improve the interoperability of e-learning content (the Sharable Content Object Reference Model; SCORM)[23]. Its implementation will improve the integration of educative serious games in learning management software.

Functionality

Functionality of a serious game clearly differs from that of an mHealth app. These usually contain "dry" content (eg, medical information) or an obvious functionality (eg, communicating or registering information), whereas a game requires the user to operate or interact with the content, with the ultimate goal to change ones behavior in real life (ie, learning). To understanding this process, information is required on the game's content, how the instruction is delivered, how performance is assessed and how these aspects are integrated in the gameplay [24,25].

Consequently, it is important to register information on the game's content management. For instance, users may be able to add content themselves, making content validation an important issue. This directly influences the game's content's validity.

Finally, undesired results or negative transfer of learning could occur in the interaction with a serious game, which is not the same concept as "gaming the game" (ie, cheating), an effect that may very well enhance learning [24]. If validation research is not present, at least a logical connection between gameplay and behavioral or learning goals should be present and disclosed by the developer.

Validity

Validity determines whether an instructional instrument (such as a serious game) adequately resembles the construct it aims to educate or measure. More formally, "the degree to which evidence and theory supports the interpretations of [game] scores entailed by the proposed use of [the game]" [26]. The American Psychological Association has set a series of standards to measure validity [26]. Whereas many validity types have been described, validity research in medical education usually contains several consequential phases [27,28]. First, experts should scrutinize the game's content to determine its legitimacy (*content* validity). Second, experts and novices judge the instrument's apparent similarity to the construct it attempts to represent (*face* validity). *Construct* validity reflects the ability of the instrument to actually measure what it intends to measure (ie, the difference in performance between groups of users with different levels of experience in reality). *Concurrent* validity reflects the correlation between performance on the serious game and their performance on an instrument believed to measure the same construct (eg, a simulator or course). The ultimate goal is to prove a game's *predictive* validity: does performance in the game lead to better outcomes in reality? Most validation research currently published in the medical domain uses these concepts [29]. For individual cases, relevance of specific validity types may differ. When considering mHealth apps in general, content validity may be the sole source of validity.

Validity research is frequently a long and costly enterprise. Many newly developed serious games have therefore not yet undergone validity research [8]. The framework therefore determines a number of steps to pre-assess a serious game's potential as a valid instrument, with regard to its design and initial testing phases. This encompasses the involvement of user groups, content experts, or educationalists in the design (if relevant to the game's purpose). Next, if a game has undergone user testing and stability testing, the game is more likely to have higher face- and content validity.

Data Protection

Threats to user privacy are imminent in electronic and mobile health apps, especially when patient-specific data are measured or entered in the game [15]. This considers data "at rest" on devices or servers, as well as data "in transit". It must be clear whether data is collected by the game, who owns the data and whether users can request to remove their data. Storage and analysis of personal data should be disclosed to users and must be in conformity with the laws applied in countries the serious game is distributed in. Special care must be taken if patient information is collected. These items are in general conformity with the requirements for mHealth apps described in Albrecht's framework [18].

Discussion

When using serious games in health care, end users (clinicians, patients, or educators) must decide whether games are safe and effective enough to be used for their intended purposes. In order to do so, they need consistent, transparent, and reliable assessments. Are applied games really stating their claim in this field? In the framework described in this article, both developers and end users are supported in assessing relevance, validity, and data safety of an applied game. In order to become a "qualified game", developers should disclose comprehensive information on their products and claims. They must provide transparency to meet the standards. The *Journal of Medical Internet Research* and the Dutch Society for Simulation in Healthcare [16] have launched an international peer-reviewing initiative for serious games in health care.

The safe application of technology-enhanced solution remains the responsibility of the health care provider. Choosing if a serious game answers to the user's needs, can be based on information concerning 5 main areas described in this article. The majority of the items cannot be assessed using objective parameters. For instance, claiming a specific serious game's predictive validity should be supported by solid evidence. A comprehensive evaluation by a panel of experts in the form of a quality label could form a more practical solution.

Guidelines have been recently published reporting standards to support clinicians and patients in distinguishing high quality mhealth apps [17-19] and medical websites [30]. These standards form the basis for the framework described in this article. These standards have two important shortcomings when it comes to games. First, explicit information on a serious game's content and didactic features is required, as the external purpose of a serious game is frequently less obvious to the user than in the case of mHealth apps. Second, serious games require additional validation steps (eg, construct and predictive validity), compared to non-interactive information platforms. Gameplay is dynamic and learning goals in gameplay are often not disclosed to the user. In fact, the user learns by playing the game, whereas discovery in itself may be part of the gameplay. Disclosing learning goals would thus be counterproductive.

There are several limitations to the framework described in this study. It considers validity of the serious game's content and its didactic functionality. Validity does not predict a game's success nor its attractiveness to the user, which also depend on its entertainment capability and distribution method [31]. It does not wish to objectify which game is most fun, but merely which game is most valid. A second consideration is that in the scientific field of validity research in medicine, validity concepts other than the one used in this framework have been proposed [32]. The "classical" validity concepts (content-, face-, construct-, concurrent-, and predictive validity) have been most frequently used in validity research in medicine and therefore the most logical to encompass in the framework presented in this article [27,28].

In summary, this consensus-based tool provides the end users the support required when assessing the effectiveness and relevance of serious games in health care. An FDA-approval or CE-mark is simply insufficient for this purpose. In order to prevent wrongful application and data theft of unsuspecting patients or medical students, this information on medical serious games should become publically available to all end users. This will aid the prescription of safe and effective games to patients and the implementation of games into educational programs.

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Conflicts of Interest

None declared.

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