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Original Paper

Mommio's Recipe Box: Assessment of the Cooking Habits of Mothers of Preschoolers and Their Perceptions of Recipes for a Video Game

Maciel Ugalde¹, PhD; Leah Brand², MA; Alicia Beltran¹, MSc; Hafza Dadabhoy¹, RD, MSc; Tzu-An Chen³, PhD; Teresia M O'Connor¹, MPH, MD; Sheryl O Hughes¹, PhD; Tom Baranowski¹, PhD; Richard Buday⁴, FAIA; Theresa A Nicklas¹, DrPH; Janice Baranowski¹, RD, MPH

¹Childrens Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, TX, United States

²School of Information, Center for Health Communications Research, University of Michigan, Ann Arbor, MI, United States

³Health Research Institute, University of Houston, Houston, TX, United States

⁴Archimage, Inc, Houston, TX, United States

Corresponding Author:

Tom Baranowski, PhD

Childrens Nutrition Research Center

Department of Pediatrics

Baylor College of Medicine

1100 Bates St.

Houston, TX, 77584

United States

Phone: 1 7137986762

Email: tbaranow@bcm.edu

Abstract

Background: Vegetables are an important part of a healthy diet because they help prevent several chronic diseases. Mothers of preschoolers reported difficulty getting their young children to eat vegetables, and many did not know how to cook child-pleasing recipes.

Objective: The cooking habits of mothers of preschoolers, their perceptions of recipes designed for their children, and the involvement of their children in food preparation were assessed to inform a food parenting video game called *Mommio*.

Methods: A cross-sectional survey design was used. Eligibility criteria included mothers of 3- to 5-year-old children who reported difficulty getting their children to eat vegetables. Participants completed a demographic questionnaire with questions about their food preparation practices. They were asked to select up to 4 of the 10 provided recipes they wanted to try and to prepare and report back on their experiences.

Results: Most (46) of the 50 recipes included in *Mommio*'s in-game recipe box were evaluated at least once and some up to 5 times with a total of 85 evaluations. This well-educated, mostly employed, sample of 27 mothers of preschoolers preferred simple, quick recipes. They ate primarily at home, made dinners from scratch, and indicated that the 46 recipes were generally simple, quick, and easy to prepare. Involvement in preparation enhanced their child's acceptance of the food. Prior food and preparation preferences influenced the children's acceptance of the dish at the ensuing meal.

Conclusions: The high rate of home recipe preparation indicated that including a recipe selection and preparation component in a food parenting video game could be attractive and may enhance effectiveness. Mothers reported that the recipes provided were generally easy to prepare, tasted good, and the instructions were easy to understand, suggesting they could be helpful to the mothers when playing a vegetable parenting game. Some mothers reported that involving their children in recipe preparation influenced their children's willingness to eat the vegetables. The highest rated recipes are being included in the game, and mothers will be encouraged to involve their children in recipe preparation.

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KEYWORDS

parenting; video game; child; preschool; cooking; vegetables

Introduction

Vegetables are an important part of a healthy diet because they help prevent several chronic diseases [1,2]. As childhood eating habits are initiated early and tend to track into adulthood [3], young children should eat recommended amounts of vegetables to establish a lifelong pattern for optimal health. However, many mothers reported difficulty getting their young children to eat vegetables, and many did not know how to cook child-pleasing recipes [4]. Although research has found that levels of food preparation skills were related to a higher quality of dietary intake, the literature is inconsistent about how frequently adults prepare food at home. In one study, most young adults (males and females) performed food preparation tasks monthly or less often [5], whereas in another study, two-thirds reported cooking the main meal at least 5 times per week [6]. Other studies found that elementary school students with higher self-efficacy for cooking were more likely to consume a family dinner [7] compared with those with higher involvement in food preparation [8]. In Wales, some parents learned cooking skills at a university or in community cooking classes [9], but new technologies are now available that may distribute cooking education more widely [10]. How frequently any particular group of parents, who might use new technologies, is likely to cook and thereby be able to benefit from training in recipe preparation is not clearly known.

Mommio, a first-person role-playing mobile three-dimensional (3D) video game currently under development [11,12], is being designed to train players in parenting practices effective in getting children to enjoy and eat vegetables over the long term [13]. Intended for mothers of preschool-aged children, an alpha test of an early version of *Mommio* featured an in-game “recipe box” containing a limited number of vegetable recipes [11]. Participating mothers reported that they liked the feature, requested that more recipes be provided in the game, and said that they wanted to try the recipes in real life [11]. Although a recipe feature would appear desirable in *Mommio*, some studies have indicated a high frequency of eating meals away from home, thereby possibly negating the value of a recipe feature [14].

Interactive media, including video games, have been shown to advance parenting skills [15]. Although a recent review of cooking interventions had positive outcomes, the preferred design of cooking or food preparation interventions for inclusion in a video game could not be determined because of their substantial heterogeneity [16]. Although studies have indicated that involving children in preparation enhanced children’s acceptance of or preference for the foods [17,18], this has not been demonstrated with preschoolers. Involvement of children in setting goals to make recipes increased fruit and vegetable consumption [19] but was limited to older children. Previous studies have assessed cooking skills of individuals and tested recipes for a specific audience. One study assessed the self-reported confidence using eight cooking techniques, confidence in cooking ten foods, and ability to prepare four types of dishes in individuals aged 19 years or older [20]. Another study described the methods followed to create a Web-based cookbook, “@TheTable,” to provide pediatric cancer

patients and survivors resources to lead healthier lifestyles [6]. However, these studies did not necessarily generalize to mothers of healthy young children. Furthermore, the types of recipes that appeal to mothers of preschoolers are not clearly known; so, this study asked mothers about their preferences.

This study assessed the following: (1) the cooking habits of mothers of preschoolers who had difficulties getting their children to eat vegetables, (2) the acceptability and usefulness of potential recipes in a vegetable parenting game (ie, *Mommio*), and (3) whether mothers would report that involving their preschool children in food preparation would increase their children’s consumption of vegetables. Participants also evaluated recipes designed for possible inclusion in the game.

Methods

Research Design

A cross-sectional Web-based questionnaire of parents of 3- to 5-year-old children was followed by testing and evaluating recipes; the recipe evaluations were reported in an online questionnaire. Eligible participants included mothers who reported difficulty getting their children to eat vegetables. Mothers who reported no difficulty with vegetables or noted that their children did not live with them most of the time were excluded. Participants were recruited from a panel of mothers who had participated in prior formative research for the *Mommio* game, supplemented with additional participants recruited from the Children’s Nutrition Research Center’s research volunteer list, social media posts, and flyers posted throughout Houston’s Texas Medical Center and Rockford, Michigan. The sample was kept to a small number to facilitate the speed of data collection and analysis for game development. Saturation, the point at which no additional responses are reported, is the usual criterion for sample size in qualitative research [21]. In our experience of qualitative research with parents on children’s diet, a sample of 20 is ample to reach saturation. This study, including its methods and questionnaire items, was approved by the institutional review board of the Baylor College of Medicine. Digital informed consent was obtained.

Recipes

A list of 10 vegetables (potato, broccoli, pepper, corn, carrot, tomato, zucchini, spinach, green beans, and cucumber) most frequently consumed by 3- to 5-year-olds was generated from the National Health and Nutrition Examination Survey. Recipes that included these and many other nutritious vegetables were collected primarily from our prior projects and public websites [22-25]. Given the palates of small children and the assumption that mothers may have limited time and cooking experience, recipes were selected with simplicity in taste and preparation in mind. Modifications were made, such as removing salt and pepper amounts from the ingredient list and substituting “as per taste.” Ingredients not commonly found at grocery stores or deemed expensive were removed or modified with more commonly available pantry items or less expensive alternatives. The main nutritional consideration when selecting recipes was to provide 4 vegetable servings of half a cup each. No explicit restrictions were placed on the nutrient composition of the recipes but those high in fat and sugar were not included.

Recipes included side dishes made to accompany a larger caloric item and main dishes designed to be the meal's major energy source. Listings of ingredients and preparation instructions for the 50 recipes are available from the corresponding author. To facilitate selection for testing, recipes were combined into 5 groups such that each group of 10 recipes contained side dishes, main dishes, and a variety of vegetables.

Game Design

A 3D representation of a home and a grocery store allows a child character (nicknamed "Kiddio"), a dog, and a male adult character to roam the house. The nonplayer characters are controlled by artificial intelligence algorithms. The player assumes the role and point of view of the child's mother. Player exploration (walking around, opening cabinets, operating kitchen appliances, etc) is permitted and expected. The player primarily interacts with Kiddio, a preschool-aged character, who prompts the player to act by saying "I'm hungry." As shown in [Figure 1](#), the player must then select and prepare a vegetable recipe in the kitchen's recipe box on which the mother must click. The recipes were organized into three categories. When the player

selects a category, a series of recipe names appear ([Figure 2](#)). When a specific recipe is clicked, the recipe name, numbers of servings, and ingredients appear ([Figure 3](#)). Another click elicits the nutrient content of the recipe ([Figure 4](#)). Once all four cards are seen, the player is informed that the dish is now prepared and placed on the kitchen table. The player mother needs to have vegetables at home to prepare the recipes. If no vegetable is available at home, the mother must go to the store to purchase some. She gets points for bringing the child to the store and for involving the child in recipe preparation. Once the player and Kiddio are seated at the kitchen table, the player encourages Kiddio to eat the vegetable, but Kiddio refuses. The player can then try different food parenting strategies by choosing from four statements to tell Kiddio—two effective or two ineffective—or modifying the environment (eg, turning off the television). If she selects ineffective ways, she moves toward losing the game. Selecting effective parenting items moves the player toward winning. At the conclusion of each *Mommio* quest, Kiddio either tastes the vegetable to signify a victory or runs out of the room, indicating a loss.

Figure 1. Initiate food preparation.



Figure 2. Recipe box.



Figure 3. Recipes.



Figure 4. Nutrient content of recipes.

Data Collection

Each participant first completed a demographic and screening questionnaire that included the questions listed in Tables 1 and 2. Those who qualified were randomly assigned to one of 5 recipe groups. Every participant was emailed an invitation with a link to an online recipe selection questionnaire, unique to her assigned group. Then, participants selected up to 4 of the 10 recipes to prepare, serve to, and evaluate with their child. After recipe selection, participants received an individualized email with instructions and copies of their selected recipes. Upon recipe completion, participants were directed to an online evaluation questionnaire, which included open-ended questions about the prepared recipes and whether and how the child was involved in cooking. A sample of 20 parents participated in the evaluation of the recipes. Another 7 did not respond to email inquiries after completing the screener. A total of 7 parents volunteered to evaluate more than their original 4 recipes. Participants received gift cards for completing each component. Participants who tested and evaluated 4 or more recipes also received a kitchen apron containing a *Mommio* video game logo. To ensure most recipes were tested, the last 4 participants to join the study were asked to include recipes not selected by previous participants. Testers were obtained for 46 of the 50 recipes. An overall recipe rating scale was employed: "Considering your entire experience of preparing, serving, and tasting the recipe, how would you rate this recipe?" with the following 5 response options: "Hated it," "Disliked it," "Didn't hate or like it," "Liked it," or "Loved it."

Data Analysis

Quantitative data were analyzed using the statistical analysis system (SAS version 9.4, SAS Inc, Cary, NC). Descriptive statistics were used to calculate frequencies and percentages. Answers to open-ended questions were coded using thematic analysis [26] according to the following themes: affordability of ingredients, recipe instructions and preparation, healthy meals, children's involvement in cooking, sensory evaluation, and recipe modifications. Thematic analysis lists categories of similar comments obtained from the transcript within prespecified themes, which defined the purpose of the study. In contrast to more formative research, which clusters comments and redefines clusters across multiple iterations, thematic analysis is primarily a list of nonduplicated responses within prespecified categories.

Results

Sample Descriptors

A nonrepresentative sample of 27 mothers of 3- to 5-year-old children participated in the study. They included mothers who had contributed to prior formative research for the *Mommio* game (11 participants), were selected from the Children's Nutrition Research Center's research volunteer list (11 participants), or were recruited via online posts and flyers (5 participants). The sample was well educated (70% had graduated from college), married (78%), employed (78%), worked full-time outside the home (63%), and had a household income over US \$60,000/year (59%; Table 1).

Table 1. Sample demographic characteristics for selection survey (N=27).

Characteristics	n (%)
Child's gender	
Male	20 (74)
Female	7 (26)
Education	
High school graduate or general equivalency diploma	1 (4)
Technical school	1 (4)
Some college	6 (22)
College student	7 (26)
Postgraduate study	12 (44)
Marital status	
Married or living with someone else	21 (78)
Single, never married	4 (15)
Divorced, separated, or widowed	2 (7)
Employed	
Yes	21 (78)
No	6 (22)
How do you usually spend your day?	
I work full time outside the home	17 (63)
I work full time at home for pay	0 (0)
I work part time outside the home	3 (11)
I work part time at home for a pay	0 (0)
I am a student	0 (0)
I am a stay-at-home mom	7 (26)
Income	
Less than US \$30,000	5 (19)
US \$30,000 to US \$60,000	6 (22)
Over US \$60,000	16 (59)

Most of these mothers (52%) made lunches for their children on weekends only and reported diverse frequencies of preparing snacks for their children but provided dinner or supper at home most days of the week (59%; [Table 2](#)). Most mothers (63%)

reported the ability to cook, but preferred simple, quick recipes; finding quick, easy ways to make foods for lunches (78%); preparing finger foods (44 %) or fruit and vegetables (41%) for snacks; and cooking from scratch for dinner (63%; [Table 2](#)).

Table 2. Food preparation skills and practices from the screening survey (N=27).

Survey questions	n (%)
How would you rate your cooking ability?	
I am an excellent cook and love to cook from scratch	4 (15)
I can cook but prefer to use very simple, quick recipes	17 (63)
I can cook when I have to, but I don't like to cook	4 (15)
I can cook if I use mostly premade dishes or mixes	0 (0)
I can cook a little, but I'm not very confident in my kitchen skills	2 (7)
I can't cook	0 (0)
How often do you provide lunch at home for your 3- to 5-year-old child?	
Post 7 days/week	5 (19)
Most days of the week	6 (22)
Weekends only	14 (52)
None	2 (7)
Other	0 (0)
When you provide lunch at home for your 3- to 5-year-old child, what best describes what you do?	
Make a meal mostly from scratch using various recipes	5 (19)
Find quick, easy to make foods (eg, salads, leftovers, sandwiches, and simple recipes)	21 (78)
We eat a lot of fast food or deli take-out, something quick	1 (4)
How often do you provide a snack at home for your 3- to 5-year-old child?	
Several times a day, every day	8 (30)
Once a day, 7 days/week	8 (30)
Most days of the week	8 (30)
Weekends only	3 (11)
None	0 (0)
Other	0 (0)
When you provide a snack at home for your 3- to 5-year-old child, what best describes what you do?	
I serve finger foods, mostly food other than fruit and vegetables (eg, prepackaged snacks, lunchables, and heat and eat type of foods)	12 (44)
I serve mostly fruit and vegetables	11 (41)
I use recipes to make snacks from scratch	0 (0)
Other	4 (15)
How often do you provide dinner or supper at home for your 3- to 5-year-old child?	
7 days/week	10 (37)
Most days of the week	16 (59)
Weekends only	0 (0)
None	0 (0)
Other	1 (4)
When you provide dinner, supper, or the evening meal at home for your 3- to 5-year-old child, what best describes what you do?	
I make a meal mostly from scratch using various recipes	17 (63)
I find quick, easy to make foods (eg, meal mixes, preprepared foods from restaurants or grocery store, and heat and serve foods)	6 (22)
We eat a lot of fast food or restaurant take-out, something quick and easy	2 (7)
Other	2 (7)

Recipe Ratings

A subsample of 20 mothers evaluated a total of 46 recipes. Each recipe was evaluated at least once and up to 5 times with a total of 85 evaluations of the 46 recipes. The recipes were well received. A total of 13 recipes received a mean recipe rating of 5 (“Loved it”), with another 13 receiving a 4 or higher rating (“Liked It”). Of these top 26 recipes, 20 recipes were rated as “very easy to prepare” and another 8 recipes rated as “somewhat easy.” A diverse variety of vegetables were rated at the higher end of the mean recipe rating scale. The same diversity was true for the vegetables at the lower end of the scale, suggesting no one or two vegetables dominated the positive or negative ratings. Furthermore, 4 recipes were not selected for testing by at least one mother. No obvious pattern can be discerned as to why these were not selected, except possibly for “spiciness” in the title of one recipe. Neither the number of ingredients nor the reported ease of preparation appeared to be associated with the recipe ratings. As would be expected, the taste of the recipe was related to the mean overall recipe rating, and the instructions were generally easily understood.

Less than half of the parents (45%) had prepared a similar dish before. When asked how likely it was that they would make each dish, 46% of the parents reported that the dishes would definitely be made and 35% reported that they might be made. In addition, 61% of the parents indicated they had all of the ingredients at home needed to prepare the recipes. Moreover, 74% of the parents reported that the recipe instructions were “very easy to follow with few ingredients” and easy to prepare (87%):

My family loves chick peas and hummus; it is pricey to buy it already made. I always wanted to learn how to make it, but I thought it was difficult, but this recipe proved me wrong.

Many reported that the ingredients were inexpensive:

Peppers have great benefits and usually they are on sale.

Most parents (81%) liked the finished recipes. Parents mentioned that they enjoyed learning new ways to prepare vegetables:

A different way of preparing veggies is always nice.

Other parents appreciated the new take on old recipes:

It was easy and something similar to what I have made before, just without lemons.

Multiple parents evaluated the recipes according to the time needed for preparation or expressed a concern about long preparation time:

It was simple and did not take a lot of time to cook.

The recipe was very easy to follow. It just takes a lot of time.

The preparation took longer than I expected.

One of the mothers commented on the need for only basic equipment:

I really liked this recipe. It was different and very easy. Love that I only had to use one pot.

Alternatively, another mother commented on the food preparation skills needed to prepare one of the recipes:

It was extremely difficult to cut the squash. It was hard and difficult to control or hold still. The deseeding was like trying to clean out a pumpkin—very messy.

Some parents said they liked that the recipes were a healthier version of some foods they already consumed:

I liked it, it was easy to make. It's a healthier substitution for any dip...

It is a great recipe. I usually hate the salty pizzas from stores although we have to eat them once in a while. The recipe is simple and I can add salt as little as I want.

Child Involvement in Recipe Preparation

The 3- to 5-year-old children were involved in preparing 51% of the recipes. One of the participants stated:

It was easy to do with the kids, very few ingredients all in one baking dish. They enjoyed the experience.

Participants indicated that children helped by washing vegetables; adding ingredients to the blender, bowls, or pots; or measuring or mixing ingredients. Some participants commented on how children’s involvement in the preparation of the recipes influenced their willingness to try the foods:

She was very proud to serve what she made and she made her siblings excited about helping with meals as well.

...did not want to try them but since she helped making the recipe and the 3-year-old ate all of his, she went ahead and ate them once I gave her ranch yogurt dressing to dip them in.

Child Consumption of Recipe

Approximately 88% of the children tasted the finished recipes and 73% ate them. Prior food preferences were mentioned as an important factor when children decided to try their food:

He doesn't dislike broccoli so it wasn't hard to ask him to try.

They hate the taste of pepper, so I was not able to make them eat even a bite.

Some mothers mentioned how the method of preparation influenced their children’s consumption of the recipe:

Both of my children enjoyed the recipe more than I expected. The small cubes of potatoes really helped them eat it better.

My child had a hard time handling the corn and eating it off the cob.

The final presentation of the recipe was also relevant:

It was a very different pasta recipe for him, he loved that it had corn and beans and it is very colorful.

He didn't want to try it at all, maybe because it looked boring

Spicy flavors were not popular among 3- to 5-year-old children:

For my little people, cayenne pepper is not a spice they prefer, so I think it's an odd seasoning in this recipe. I even cut it in half and still had complaints about being too spicy...

Another mother mentioned:

Kids were afraid to try at first because they thought it would be spicy.

Recipe Modification

Only 40% of the participants modified the different recipes when evaluating them. These modifications were made because of the family food preferences. They commented:

We don't like the taste of parsley so I used a purple leaf...don't know the name of it but it is my 3-year-old's favorite vegetable growing in our backyard.

We added olives. We always add olives to the pizza. My kids insist.

When asked if they would modify the recipe before they make it again, 54% said they would:

I would add something to make it more flavorful. The red peppers were good and the lemon juice, but even after adding salt and pepper I would have added more spices or other veggies to make it have a more flavorful taste.

The small potatoes I bought for the recipe inspired me. I want to try to make them tastier.

Discussion

Principal Findings

This sample of 27 well-educated and mostly employed mothers of preschoolers regularly cooked at home, unlike most families in the United States [14]. Although they tended to make and serve quick, easy dishes for lunches and snacks, they made dinner from scratch and infrequently ate out of their home. The high frequency of home-prepared meals in this sample (22% and 59% of mothers who participated in this study said that they prepared lunch and dinner at home, respectively, most days of the week) was similar to that in a population-based study in the United Kingdom [6]. This may indicate that mothers interested in playing a video game to promote effective vegetable parenting practices prepare a lot of meals offered to their preschool child and, thereby, could benefit from a recipe preparation component in the game.

Of the 50 recipes offered, 46 were tested by at least one mother. A total of 41 recipes received scores above the median possible recipe score (2.5), with 13 receiving the highest rating (5) and 18 receiving the next highest rating (4-4.5). This suggests that an ample number of tasty, easy-to-understand and prepare recipes are available for incorporating into *Mommio*. According to open-ended questionnaire responses, mothers preferred recipes that included basic ingredients and little equipment, similar to a review about recipe development for limited-resources audiences [27]. Mothers also enjoyed recipes

from the app that showed different ways to prepare and present vegetables to their children.

Some participants (15%) reported that the recipes were healthier versions of foods they currently ate. However, mothers' primary perceived barrier to preparing the recipes was the time required. In 2015 in the United States, 59% of all women and 70% of mothers with children under the age of 18 years were employed outside their home [28], similar to the sample in this study. To overcome the struggle of making time-efficient and nutritious family meals, working women often incorporated precooked and convenience foods into their daily family meals [29] and preferred preparing an evening meal in less than 15 min [30]. Attempting to prepare meals quickly could lead to a decreased transfer of cooking skills from parents to youth, with the inability of children to prepare healthy meals as they transition to adulthood (as identified among young adults) [5].

Older children (aged 6-10 years) who participated in the food preparation process ate significantly more salad 42 g (76%) than the ones where only the parent prepared, likely because of enhanced feelings of autonomy and pride [31]. Mothers in this study perceived that their children enjoyed being involved in the preparation of the recipes and increased their willingness to try the foods similar to other findings [27]. As only half of the parents involved their children, future research should address factors influencing child involvement in home food preparation.

The mothers in this study mentioned that the way ingredients were presented was an important factor in a kid friendly recipe. The need to cut food into 0.5-inch chunks to avoid choking hazards [32] was well received by their children. Future versions of the recipe box app will include warnings to ensure child safety when tasting the recipes.

Research has indicated that preexisting child food preferences were a major determinant of intake [17]. In this study, participants were randomly assigned to one of the 5 different groups containing 10 recipes of a variety of dishes and vegetables to decrease selection bias. Although recipes met other needs of the parent and child, children tended to eat the foods they already preferred. This suggests that parents should know their children's preferences and make and serve vegetables generally congruent with those preferences, along with occasionally introducing new vegetables. Other strategies available for increasing children's acceptance of low preference foods include offering the child choices, modeling, involving the child in food purchases and preparation, among others [33,34].

Limitations

As the game's name suggests, *Mommio* was designed for mothers, and therefore, fathers were not included in this sample. No effort was made to deliberately include mothers with high school education or less, a demographic known to lack confidence in preparing healthy meals [35]. Future studies should be designed to address this harder-to-reach group of mothers. To increase participant diversity, recruitment should be attempted at community centers, food banks, and day care. Moreover, the study's design and recruitment procedures may have self-selected mothers who like to cook. All data were

obtained by self-report from the mothers, who could be biased, and the sample was small, which limits internal validity and generalizability. However, this was an efficient method for collecting and analyzing data rapidly enough to influence the game design.

Conclusions

We found that the high rate of home recipe preparation indicated that including a recipe selection and preparation component in a food parenting video game could be attractive and may

enhance effectiveness. Mothers reported that the recipes provided were generally easy to prepare, tasted good, and the instructions were easy to understand, suggesting they could be helpful to the mothers when playing a vegetable parenting game. Some mothers reported that involving their children in recipe preparation influenced their children's willingness to eat the vegetables. The highest rated recipes are being included in the game, and mothers will be encouraged to involve their children in recipe preparation.

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Conflicts of Interest

RB is the president of Archimage, Inc, the company making *Mommio*, and may profit from any sale of the game.

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Abbreviations

3D: three-dimensional

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

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Original Paper

Breaking Health Insurance Knowledge Barriers Through Games: Pilot Test of Health Care America

Sara Champlin¹, PhD; Juli James¹, MA

Mayborn School of Journalism, The University of North Texas, Denton, TX, United States

Corresponding Author:

Sara Champlin, PhD
Mayborn School of Journalism
The University of North Texas
1155 Union Cir
Denton, TX, 76203
United States
Phone: 1 9403697651
Email: sara.champlin@unt.edu

Abstract

Background: Having health insurance is associated with a number of beneficial health outcomes. However, previous research suggests that patients tend to avoid health insurance information and often misunderstand or lack knowledge about many health insurance terms. Health insurance knowledge is particularly low among young adults.

Objective: The purpose of this study was to design and test an interactive newsgame (newsgames are games that apply journalistic principles in their creation, for example, gathering stories to immerse the player in narratives) about health insurance. This game included entry-level information through scenarios and was designed through the collation of national news stories, local personal accounts, and health insurance company information.

Methods: A total of 72 (N=72) participants completed in-person, individual gaming sessions. Participants completed a survey before and after game play.

Results: Participants indicated a greater self-reported understanding of how to use health insurance from pre- (mean=3.38, SD=0.98) to postgame play (mean=3.76, SD=0.76); $t_{71}=-3.56, P=.001$. For all health insurance terms, participants self-reported a greater understanding following game play. Finally, participants provided a greater number of correct definitions for terms after playing the game, (mean=3.91, SD=2.15) than they did before game play (mean=2.59, SD=1.68); $t_{31}=-3.61, P=.001$. Significant differences from pre- to postgame play differed by health insurance term.

Conclusions: A game is a practical solution to a difficult health issue—the game can be played anywhere, including on a mobile device, is interactive and will thus engage an apathetic audience, and is cost-efficient in its execution.

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KEYWORDS

health insurance; games, experimental; young adult; information literacy

Introduction

Serious games are designed to cultivate skills for a specific topic and do so by activating existing schema in the mind of a player to ultimately produce “new knowledge” and experiences [1]. In contrast to reading a pamphlet or searching online, players engage with serious games, given their inherent fulfillment of a need to have fun or be satisfied, as suggested by self-determination theory [2]. As such, serious games are increasingly implemented to train or immerse players in novel experiences so that they may encounter and test structures and

concepts in an enjoyable way. In turn, players often exhibit increased conceptualization of specific challenges, even for stigmatized health issues such as sexual risk [3]. In addition to building skill sets, games can increase self-efficacy and result in behavior change [4]. Given these benefits, serious games are a growing, effective medium for current and future generations of young adult audiences [5].

There exists a variety of health-oriented serious games. In some cases, health-focused games allow players to explore risky or challenging situations without having to experience the direct effects they might encounter in the real world (eg, dying or

harming someone, experiencing a negative health outcome, mismanaging a decision) [6]. This includes training and allowing players to practice specific skills such as attention and reaction time while driving [7] or learning and experiencing how to prepare surgical instruments [8]. Other games emphasize education and promoting an increased understanding of action-oriented knowledge. For example, after playing a game titled Mommio, mothers indicated that they acquired knowledge by experiencing interactions between a mother and a child who does not enjoy eating vegetables [9]. Other games depict topic-specific knowledge increases, such as increased information about nutrition as a result of playing a diet- and exercise-oriented game titled SpaPlay [10].

A key benefit of serious games for health, specifically, is to stimulate or motivate patients for health efforts that may be perceived as unpleasant or uninteresting and thus avoided [6]. Games can also help players understand specific positions or roles in one's life, akin to imagining what it would be like to try on a specific identity [6]. Games of every kind allow players to take on roles outside of their everyday lives, which can have positive impact [11,12].

According to the Entertainment Software Association, 56% of Americans today play video games, and nearly half (48%) of frequent gamers are considered mobile and/or social gamers [5]. Moreover, 77% of college-aged men and 57% of college-aged women report playing video games [13]. As such, digital and Web-based games are a reasonable and strategic platform to engage with these audiences. Games present an additional opportunity to connect audiences with news and with health. The overlapping, growing trends in gaming and media speak to the opportunity for using a mobile-ready Web-based game to engage new demographics in meaningful health information in innovative ways, reach existing audiences with alternative, interactive journalism, and speak to a new generation of media users on the devices and in the media with which they are already interacting.

In this study, we developed a serious game that draws from principles of journalism, educational and video game design, and learning and literacy, in conceptualizing an online game experience [14,15]. Given that young adults may currently avoid or misunderstand health insurance information, a game is a practical solution to this difficult health issue. A Web-based health game may be particularly appropriate for young adults, almost all of whom use the Internet. The game can be played anywhere, including on a mobile device, is interactive and will thus engage an apathetic audience, and is cost-efficient in its execution.

Health Insurance Literacy

Having health insurance has been linked to a number of advantageous health outcomes, including increased access to health monitoring, screening, information, and beneficial health decisions [16]. As a result, those who do not have health insurance are at a greater risk for serious and exacerbated health consequences related to cancer, cardiovascular issues, hypertension, diabetes, kidney disease, human immunodeficiency virus infection, and injury [16].

Understanding, selecting, and using a health insurance plan, however, is a complex process and requires a plethora of diverse literacy and numeracy skill sets [17]. Politi and colleagues argue that health insurance plan comprehension and decision making are "essential" for the consumer [18]. Thus, determining ways to discuss and facilitate health insurance information with the public is an important avenue for health-based research. Simultaneously, patients are increasingly encouraged to take ownership of their own health information and participate in their own health care [19-21]. As a result, patients are given a growing amount of health insurance information and details to interpret and consider [22].

Although the initiation of the Affordable Care Act increased the number of Americans who hold health insurance policies [23], it is not yet known whether health insurance consumers indeed have knowledge and confidence in how to use their benefits [24]. Previous research suggests that insured adults lack an understanding of terminology and how to use this important entity. Many states have implemented the use of health insurance counselors to aid consumers in their understanding and selection of a health insurance plan. Interviews with counselors point to critical health insurance literacy concerns; patients tend to avoid reading information about specific plans and, as a result, misunderstand how much coverage they have or how much they owe as the result of a medical procedure (eg, if the patient pays a premium, the patient might think he or she does not owe any additional medical costs) [25]. Counselors also note that patients rely on word-of-mouth information about plans; often misunderstand terms such as "co-pay," "deductible," and "co-insurance"; and lack knowledge about provider restrictions such as being in network/out of network [25].

Historically, young adults have the lowest rates of health insurance plan enrollment among all nonelderly adult age groups [26,27]. Young adults remain the age demographic with the fewest insured individuals; 14.4% of young adults aged between 18 and 24 years did not have health insurance in 2015 and 17.9% of those aged between 25 and 34 years [28]. Limited research has specifically tackled strategies for best communicating health insurance information to this vulnerable population. It is worrisome that young adults may not be equipped with the knowledge or skills to appropriately select and enroll in a plan. Furthermore, young adults with plans may struggle when navigating the health care system and amass high health care bills.

Health insurance literacy is particularly low among young adults, including those who are highly educated. In one study, none of the participants felt "good" or "very good" about their understanding of a list of health insurance terms and at times transposed definitions or had questions about the information [29]. The need for increased understanding about health insurance among young people is a long-standing health challenge. Robertson and Middleman called for greater health insurance education for young people based on their findings that almost half of the adolescents in their study were unaware of "how their medical bills [were] paid" [30]. Young adults should be equipped with the information necessary for them to

make informed decisions when it comes to getting and using health insurance.

Newsgames

For this project, we created a Web-based newsgame, “Healthcare America,” to explore the possibilities for what games can offer the problem of engaging and informing young adults in concepts connected to health insurance literacy. Bogost and colleagues define “newsgames” as games that apply journalistic principles in their creation [14]. For example, a newsgame might implement stories from various first-person sources or illustrate the complexities of a real-world issue.

Specifically, newsgames infuse the concept of real-world *narrative* into game play. Narrative communication and storytelling are promising methods to increase engagement of an audience with content, yet are not frequently utilized in health-related research and interventions [31]. Thompson and Kreuter note that “vivid, engaging writing can help audiences identify with storytellers and understand health messages” [32]. A growing interest in research is the narrative work written by medical professionals, which can promote improved on-the-job skills when read and considered by other professionals working in this industry (ie, learning from someone else through their stories) [33]. It was the hope of this study that playing a game with client-based narratives generated from news and real-world encounters and interviews would contribute to increased understanding of health insurance information.

Newsgames are an emerging digital practice for today’s journalists, although games for journalism are not new. Historically, crossword puzzles and news quizzes have been found in newspapers and on broadcast radio as tools to engage audiences in interacting with news facts and information in engaging and fulfilling ways. As video games have evolved and the benefits of game design have grown out of commercial markets into serious and educational spaces, journalism has also begun taking the best practices of game design for nuanced storytelling, immersive learning and informing strategies, and engaging audiences in complex systems through play [34].

We selected a newsgame approach for Healthcare America to explore a mobile game execution for health journalism and to experiment with and contribute to the design models for engaging journalism. Games at the intersection of journalism and health provide new, strategic opportunities to create playful experiences around complex issues and offer real-world learning created from real data designed into hypothetical interactive narratives. These serious games provide a platform for audience engagement in ways that health communication and health journalism have only just begun to explore (conventional tools in health media communication include pamphlets and flyers, public service announcements, and radio ads) [11].

The purpose of this study was to develop an interactive-narrative newsgame that presents entry-level health insurance information and scenarios to young adults. To our knowledge, this study is the first to design and test an interactive game that encourages young adults’ interaction with health insurance concepts.

We hypothesized the following statements based on the notion that young adults often lack an understanding of many health

insurance terms [29] and exposure to an interactive game about health insurance will improve this knowledge; given this, after game play:

Hypothesis 1: Participants will exhibit a greater self-reported, general understanding of what health insurance is and how to use health insurance.

Hypothesis 2: Participants will exhibit increased self-reported understanding of critical health insurance terminology.

In addition to examining whether participants perceived themselves to have learned about health insurance terminology from the game, we sought to measure whether participants increased in their objective knowledge of health insurance terminology after game play.

Hypothesis 3: Participants will be able to correctly define a greater number of health insurance terms following game play.

Findings from this study will have important implications for many groups. Equipping young adults with a greater understanding and confidence in what health insurance is and how it works can lead to better overall health outcomes. Additionally, this study offers practical solutions for health practitioners, educators, and counselors who design programs to improve health literacy and access to health information. In the remainder of this paper, the development of a health insurance game created for young adults will be described and its effects tested. Implications for health practitioners, including health insurance counselors and other financial advisors, will be discussed.

Methods

Game Development Tool

We used the Playable Media Story Builder (Phoenix, Arizona) platform to develop the game, Healthcare America. The Story Builder is a visual engine that allows publishing of hosted, cross-platform responsive, interactive narrative games. The engine, designed to empower journalists to prototype narrative games, was funded by the Knight Foundation Knight Prototype Fund. The Playable Media team designed and developed the tool in collaboration with journalists and journalism students at Arizona State University through the News-Play Project, a partnership between Arizona State University’s New Media Entrepreneurship & Innovation Lab and Center for Games & Impact Innovation Lab.

Game Design and Development

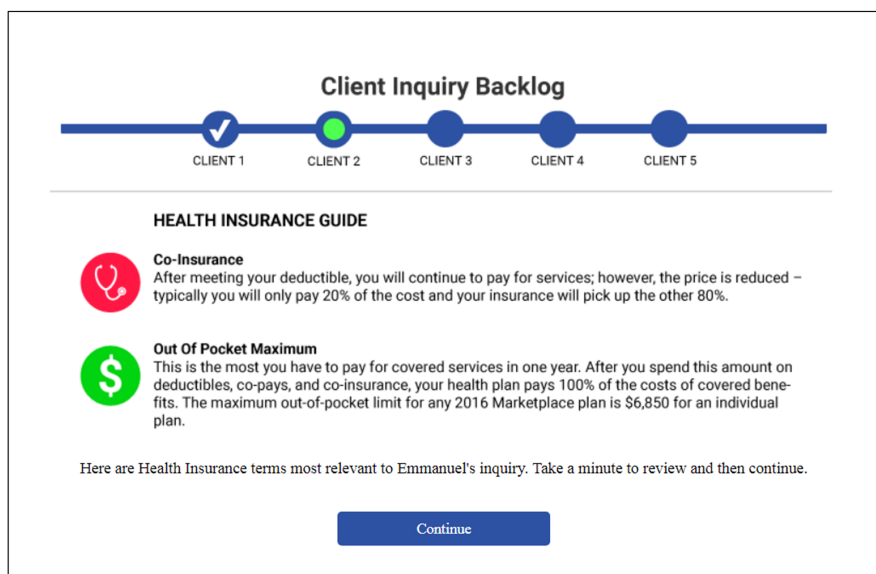
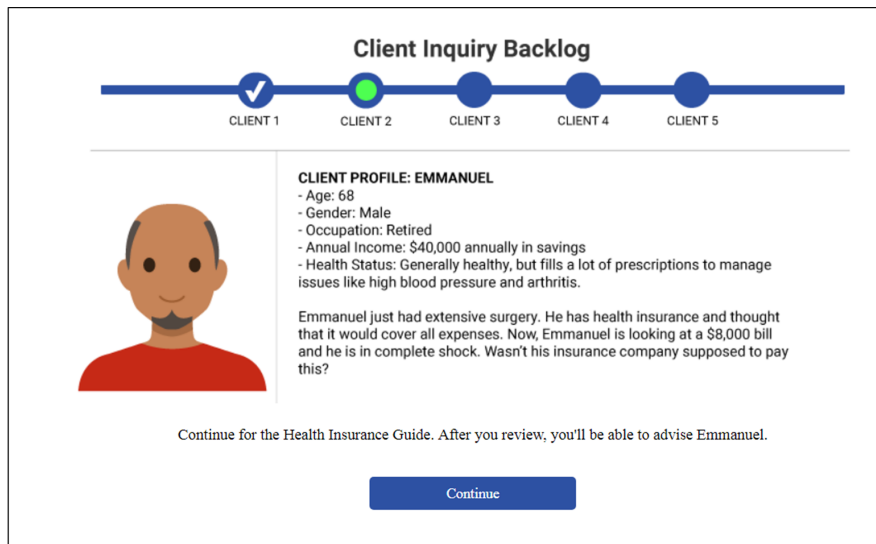
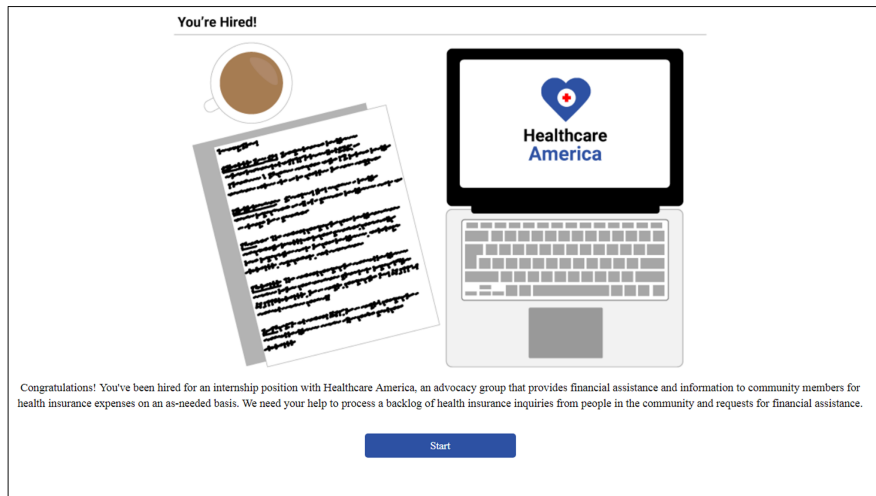
Healthcare America positions the player as working for a health information advocacy organization with a series of client cases. The game interface includes simple graphics, narrative text, player choices, and two meters measuring community wellness and health care assistance funds (see [Figure 1](#)).

Using a newsgame design approach to develop game content, we gathered stories about personal struggles with health insurance from people in our community, undergraduate students, and national news stories. We collaborated with a news writing and reporting class to further investigate through

personal narratives the ways in which people struggle with health insurance in the real world. Additionally, we pulled fact-based information from health insurance websites, the HealthCare.gov website, and our university's health insurance

Web page. We collaborated with stakeholders and knowledge experts at our university about how they typically administer information and guidance about health insurance to students.

Figure 1. Examples of the user interface and game play of the health insurance game.



As a result of this exploration, five scenarios or “client cases” were developed for the game based on real-world stories and information gathered from stakeholders and health insurance consumers. Characters included in the game were developed to consciously include a variety of different race/ethnicities, sex (white female, African American male, Hispanic female, white male, Asian female), age, and occupation.

Following these steps, we adapted the list of health insurance terms used by Wong and colleagues [29] to include the following: “the Affordable Care Act,” “deductible,” “monthly premium,” “referral,” “in-network provider,” “co-payment,” “out-of-pocket maximum,” “coinsurance,” and “health maintenance organization (HMO) and preferred provider organization (PPO).” Within the game, each term and a corresponding definition was provided to the participant for their review. See [Figure 1](#) for a screenshot of two definitions, which were both relevant for a case in which a consumer in the game had recently encountered unexpected health insurance charges.

The game opened with a brief introduction and explanation of the game on screen. Game instructions, including the meaning of the game meters (Community Wellness, that is, how healthy the participant or player made the community, and Healthcare Assistance Fund, that is, the amount of money spent to assist the client), were then provided. With these meters in mind, the central goal of the game was to be a “successful intern” by assisting clients with troubling health insurance cases—aiming to maximize Community Wellness without spending all of the organization’s Healthcare Assistance Fund.

Participants read and experienced each of the aforementioned cases; key details about what happened and what went wrong for the client were presented. Then, health insurance terms were provided. Participants then selected one of three options for how to advise each client, which took into account how much each option would contribute to the overall Community Wellness (Did the participant help improve the health of the community through his or her advising decision?) and how much money would be spent from their Healthcare Assistance Fund, which was capped at US \$5000.

To summarize and provide a specific example, the prototype narrative design of Healthcare America blends real-world

experiences of stories from using, or struggling to use, health insurance. In the game, these stories are translated to “client cases.” The player is given a role within the narrative and the goal of “solving” or assisting a series of client cases while working as an intern (with the promise of being promoted to a full-time position for a job done well).

The player reads a client case file (eg, Vanessa who is a 42-year-old female, a project manager and mother of 2, annual income US \$35,000, who regularly sees a therapist to manage her mental health and well-being. She fills a prescription for antidepressants on a monthly basis. “Vanessa sent us [Healthcare America] an email because she’s confused about what just happened at the pharmacy. After being diagnosed with depression, Vanessa has a regular prescription for antidepressants. Today the cost of her medication was much higher than usual.”) and is then provided with information about specific health insurance term (in the case of “Vanessa,” it is information about co-payments). The player is then able to advise the client using several options, each of which is linked to a corresponding increase or decrease in the Community Wellness meter, the Healthcare Assistance Fund, or both. The player advises the client presented and then learns the outcome of the corresponding meters.

There are obstacles to overcome (the main conflict is to balance solutions to clients’ health care and health insurance problems) and rewards for overall Community Wellness and the Healthcare America’s Healthcare Assistance Fund. The game ends if the player depletes the Community’s Wellness or Healthcare Assistance Funds as a result of his or her decision to assist a client (a loss) or if the player successfully assists all 5 clients (a win); see [Figures 2, 3](#) and [Multimedia Appendix 1](#).

We kept in mind the *body of information* as is needed both for a narrative driven game and for narrative-driven journalism, and *situated* the information a player would need to use [35,36]. As game designers, we designed each level of Healthcare America based on a health insurance problem and distributed the essential information the player would need across the game to overcome obstacles and work toward the goal at the start of each level to gauge how much health insurance term information the player would need and could use—just enough information and just in time [36].

Figure 2. Design of game meters: (1) Healthcare assistance fund and (2) community wellness.

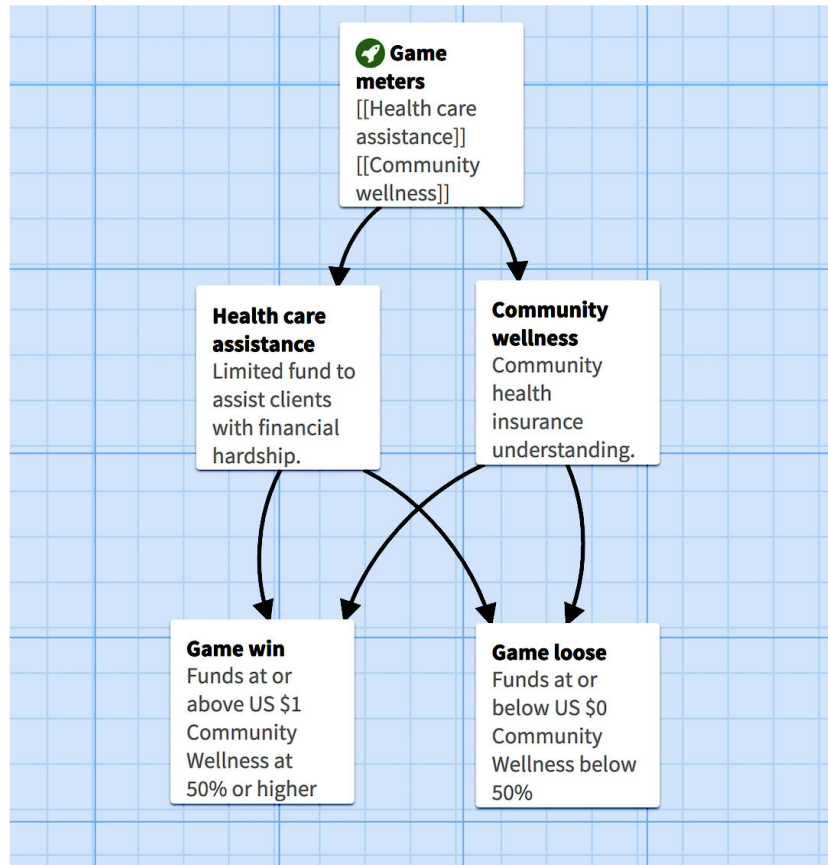


Figure 3. An example of the community wellness meter options.

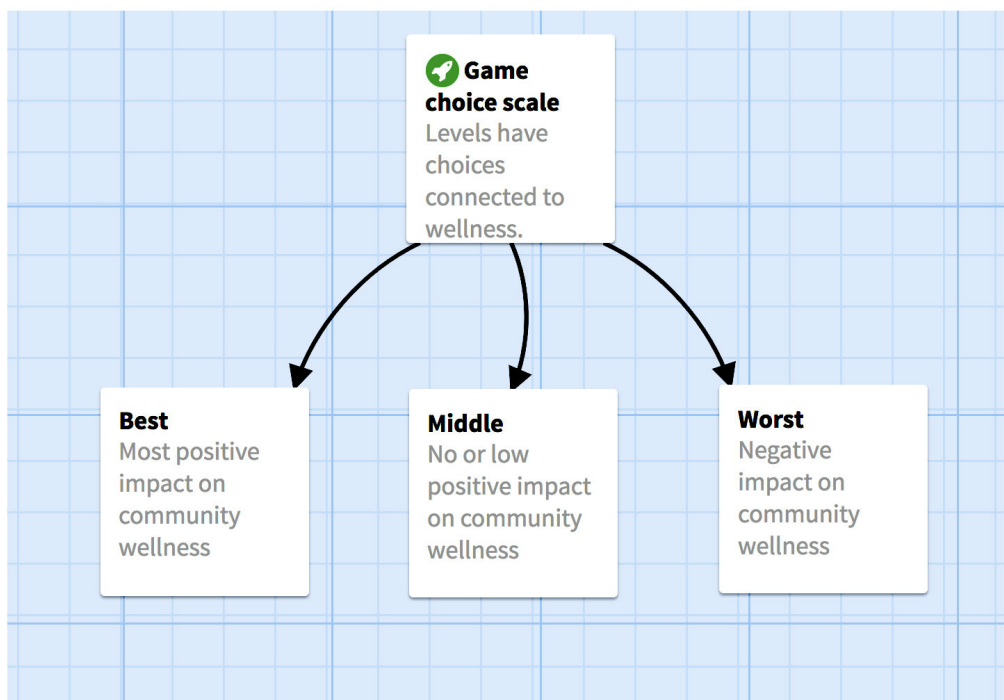


Table 1. Demographic information of sample (N=72).

Characteristic	Sample
Sex, n (%)	
Male	29 (40)
Female	43 (60)
Race/Ethnicity, n (%)	
White	27 (38)
Black, African American	18 (25)
Hispanic, Latino/a	17 (24)
Asian	5 (7)
Mixed	4 (6)
Other	1 (1)
First-generation college, n (%)	
Yes	19 (26)
General health, n (%)	
Excellent	8 (11)
Very good	30 (42)
Good	27 (38)
Fair	5 (7)
Poor	1 (1)
Don't know	0 (0)
Academic year, n (%)	
Freshman	19 (26)
Sophomore	12 (17)
Junior	26 (36)
Senior	10 (14)
Super senior (+4 years)	3 (4)
Other	1 (1)
Non-English household, n (%)	
Yes	17 (24)
Without health insurance, n (%)	17 (24)
Age in years, mean (SD)	21.15 (3.49)

Participants

A 2-tailed power analysis calculated for paired data was performed with G-Power to calculate an estimated sample size of 67 participants (effect size=0.35, with 80% power, and $\alpha=.05$) [37]. In total, 75 (N=75) students were included in this study. Due to a computer error, three of these participants were unable to play the game and were thus removed from the dataset, resulting in 72 (N=72) valid participants. The demographic information of the sample is included in Table 1.

Procedures

A call for participants was administered via email to classrooms, or a Web-based classroom boards through journalism and communications courses on campus. Participants indicated their

interest by contacting the research team via email and scheduling an appointment. Each participant completed an individual, in-person data collection session. All study procedures were approved by the relevant institutional review board. Each session was scheduled for 1 hour and included an introductory phase in which participants read and signed a consent form, the completion of a pregame survey, game play on a computer, and a postgame survey.

Measures

Participants completed pre- and postgame surveys to determine their level of health insurance understanding before and after playing the health insurance game. In both surveys, participants were asked to indicate their understanding of "what health insurance is" and "how to use health insurance," as well as rate

their understanding of 9 health insurance terms using a 5-point scale (very good to very bad) [29]. Additionally, to measure objective understanding of a given health insurance term, participants were asked to write a definition for each of the 9 health insurance terms. These items were adapted from previous research [29]. Similar to Wong and colleagues, a team of 4 investigators determined whether each health insurance term was defined correctly or incorrectly based on the content provided in the game and the definitions provided by health insurance companies and Healthcare.gov. Participants also completed demographic items, including sex, race/ethnicity, age, whether they were a first-generation college student (the first in their family to attend college), self-reported rating of their general health, year in school, whether they currently have health insurance, and whether they grew up in a household that primarily spoke a language other than English. In cases where multiple numerical responses were selected (eg, both 3 and 4 to indicate understanding of a health insurance term), the average of the 2 numbers (eg, 3.5) was used.

Analyses

Paired sample *t* tests were used to determine whether participants' self-reported understanding of what health insurance is, how to use health insurance, and the 9 health insurance terms were different between pre- and postgame play. A paired sample *t* test was also used to determine whether the total number of correctly defined health insurance terms differed from pre- to postgame play. A Cochran's Q test was used to examine differences in correctly defined health insurance terminology (paired nominal data) between pre- and postgame play.

Results

The purpose of this study was to determine whether a health insurance game is a viable tool to communicate important

information about health insurance terminology and how health insurance is used. The first hypothesis predicted that, following game play, participants would exhibit a greater self-reported, general understanding of what health insurance is and how it is used. Indeed, participants indicated a greater self-reported understanding of how to use health insurance from pregame play (mean=3.38, SD=0.98) to postgame play (mean=3.76, SD=0.76); $t_{71}=-3.56$, $P=.001$. There was no significant difference between pre- and postgame play for participants' self-reported understanding of what health insurance is. Given this, hypothesis one was partially supported.

Hypothesis 2 surmised that participants will exhibit increased self-reported understanding of critical health insurance terminology. For all health insurance terms, participants felt they had a better understanding of the term following the game; see Table 2 for complete results.

Finally, in addition to examining whether participants felt that their understanding of a given health insurance term increased after playing a health insurance game, we wanted to determine whether participants objectively define more health insurance terms correctly following game play. The proportion of participants who correctly defined a given health insurance term was significantly different for the following terms: "monthly premium," "referral," "in-network provider," "deductible," and "HMO/PPO"; see Table 3 for complete results.

Among participants who provided a definition for every health insurance term for both pre- and postgame play ($N=32$), participants correctly defined more health insurance terms following game play (mean=3.91, SD=2.15) than they did before game play (mean=2.59, SD=1.68); $t_{31}=-3.61$, $P=.001$. However, the number of correct definitions provided following game play did not correlate with participants' overall self-reported understanding of all terms following game play (self-reported scores for all terms were summed together), $r=.18$, $N=42$, $P>.05$.

Table 2. Self-reported understanding of health insurance terms, pre- and postgame play.

Health insurance term	Pregame self-reported understanding, mean (SD)	Postgame self-reported understanding, mean (SD)	Paired <i>t</i> statistic (degrees of freedom) ^a	<i>P</i> value
Affordable Care Act	2.75 (1.12)	3.73 (0.81)	-6.92 (70)	<.001
Premium	2.70 (1.20)	3.87 (0.81)	-8.89 (70)	<.001
Referral	3.11 (1.37)	4.13 (0.81)	-6.25 (70)	<.001
In-network provider	2.35 (1.37)	3.71 (0.97)	-8.58 (71)	<.001
Co-pay	3.24 (1.32)	3.72 (1.03)	-3.10 (68)	.003
Deductible	2.97 (1.17)	3.77 (0.80)	-5.06 (70)	<.001
Out-of-pocket maximum	2.23 (1.18)	3.39 (1.09)	-7.62 (69)	<.001
Coinsurance	1.91 (1.00)	2.39 (1.03)	-3.88 (68)	<.001
Health maintenance organization and preferred provider organization	1.97 (1.04)	3.26 (1.09)	-9.10 (68)	<.001

^aDegrees of freedom differ across terms given that participants had missing data on either pre- or postgame items at different rates for each term.

Table 3. Objective understanding of health insurance terms, pre- and postgame play.

Health insurance term	Correct pregame, n (%)	Correct postgame, n (%)	Cochran's Q test statistic (degrees of freedom)	Asymptotic P value
Affordable Care Act	15 (25)	17 (29)	0.33 (1)	.56
Monthly premium	27 (46)	39 (66)	5.54 (1)	.02
Referral	19 (31)	43 (70)	18.00 (1)	<.001
In-network provider	19 (40)	34 (71)	13.24 (1)	<.001
Co-payment	25 (41)	23 (38)	0.15 (1)	.70
Deductible	7 (12)	23 (40)	12.80 (1)	<.001
Out-of-pocket maximum	13 (25)	11 (22)	0.25 (1)	.62
Co-insurance	0 (0)	3 (7)	3.00 (1)	.08
Health maintenance organization and preferred provider organization	2 (4)	18 (39)	14.22 (1)	<.001

Discussion

Principal Findings

Findings from this study suggest that the implementation of a newsgame can facilitate health insurance knowledge among young adults, a population vulnerable to the negative impact of not having or understanding health insurance [27-29]. In this study, a Web-based newsgame about health insurance was developed by exploring health insurance challenges experienced by everyday consumers and re-creating these scenarios in the context of an interactive game.

Young adults, even those who are well-educated, struggle with understanding health insurance and health insurance terminology [29]. On the basis of the findings from this study, a game appears to be a viable option for presenting this audience with information about this challenging topic. This aligns with the existing research on the beneficial impact of narrative on health, decisions, and skills [31-33]. Following game play, participants self-reported a significantly greater understanding for all terms. It is encouraging that participants felt that they understood more of this difficult content, as previous research notes that evading health insurance information is common [25]. It may be that the medium, a gaming platform, combined with a narrative newsgame approach creates a context in which emerging adults feel comfortable, in contrast to pamphlets or static websites. Upon examining objective knowledge assessment through correctly/incorrectly defined health insurance terms, however, it is important to note that participants made significant improvements for some, but not all, health insurance terms.

In this study, significantly more participants provided correct definitions for the terms “monthly premium,” “referral,” “in-network provider,” “deductible,” and “HMO/PPO” following game play. The largest increase was seen for the term “referral,” where the frequency of correct definitions increased by 39%. It is possible that this is a term for which many students were already familiar with but needed to be reminded of the correct definition. Indeed, many of the top reasons why college students visit a health care provider are for health concerns that require a referral or prescription including respiratory infections, sexually transmitted diseases, birth control, and annual exams

(mainly women’s health such as pap smears) [38], which could explain why referral garnered the largest increase from pre- to postgame play.

In contrast, HMO and PPO are likely terms with which college students are not familiar with [29], yet a significant improvement was observed in this study. Indeed, before game play, only 2 participants in this study correctly defined this concept. A total of 18 participants (39%, 18/46) demonstrated an objective understanding of “HMO” and “PPO” after playing the game. In addition to this being the last term presented (and thus closest to the administration of the post-game survey), this effect could be due, in part, to the relatability of the client profile to the student participants. The client featured in the game regarding the “HMO/PPO” term admitted to being “new to having health insurance,” was relatively young (33 years old) and worked as a communications professional at a start-up company. Although the focus of this study was not on the relationship or relatability of the client/profile with the participant, perceptions of homophily would be a fruitful focus for future research when it comes to increasing engagement with health insurance information.

Although significant growth was not observed in the number of participants correctly defining the term “coinsurance” between pre and postgame play, it is worth noting that no participant provided a correct definition before playing the game. Following the game, 3 participants provided a correct definition. On the basis of the findings of this study, of the terms provided in the Healthcare America game, “coinsurance” requires the greatest exploration in future initiatives. This aligns with previous research, which suggests that patients often focus on the concept of paying premium every month but neglect other cost-sharing terms, including “coinsurance” [25]. “Coinsurance” may be commonly complicated with “co-payment” and perhaps “cost-sharing” and thus should be teased apart further in future initiatives. In this study, all terms were given equal attention (ie, presented an equal number of times, one opportunity to make a decision related to the term rather than repeated practice), yet findings suggest that future initiatives attribute greater explanation and additional examples for some terms.

Akin to Wong and colleagues, the correlation between the number of correctly defined health insurance terms and participants' self-reported understanding of all terms was nonsignificant [29]. One explanation for this discrepancy is that, although participants may feel that they understand health insurance content (self-report knowledge), *providing a definition* (objective knowledge) is notably more challenging. Although writing a correct definition served as a valuable method for assessing participant knowledge for the purpose of a research study and has been used in previous research [29], this is not how health insurance knowledge would be captured in everyday activities. Rather, individuals must make decisions using the given information, including completing calculations. It could be that participants would have been more successful in demonstrating their knowledge through applied scenarios and questions, comparable with what they did within the game. This is just one of many avenues for future research initiatives.

Additionally, in this study, participants indicated an increased self-reported understanding of how to use health insurance but not what health insurance is. In designing the game for this study, it became clear that there are a number of avenues to be tackled through games when it comes to health insurance. Future research should explore the needs of those who do not yet have health insurance and how gaming, immersion, and decision making can contribute to enrollment assistance. In conjunction with this initiative, those who currently have health insurance, yet struggle with using the health care system and insurance companies, would benefit from a game similar Healthcare America. Future gaming efforts could incorporate both suggestions into one game, having participants reach or unlock new levels as they successfully move from getting enrolled in health insurance initially, to making challenging decisions in a health care setting.

It should be noted that Healthcare America is just one example of how games can be used successfully to promote health knowledge and outcomes. There are a growing number of examples in which games and game projects are designed to engage audiences in health and wellness issues. Indeed, UnitedHealthcare offers a Health Insurance Matchmaking Game in which the player determines which type of health insurance is "right" for them based on a series of actions performed in the game [39]. Future iterations of this study could compare the effectiveness of Healthcare America with other games and strategies for increased interaction with and understanding of health insurance. In contrast, at the specific intersection of health games and health journalism, in which stories and scenarios from the real world are directly incorporated into the design of the game, there are only limited projects despite the possibilities for increased awareness, engagement, and education. *Seven Ways to Defy Death* from the Washington Post [40] does provide one example, as well as Propublica's experimental game, *Heartsaver* [41]. Journalists cite time, design and technical resources, and budget as pain points for developing games to engage audiences in game-infused storytelling. Free engines such as the Story Builder used for this project offer journalists the ability to create mobile games quickly and experiment with audience engagement in this space.

The use of a Web-based platform, such as that used in this study, has far-reaching implications. This is especially clear in context of growing mobile "smartphones," which are capable of accessing the Internet. Nearly all (92%) of Americans aged 18 to 29 own a smartphone [42]. As such, dissemination of our health insurance newsgame could be simple and extensive. The game could be texted to a phone number or the link sent through email, and shared via social platforms such as Facebook, Twitter, Instagram, or Snapchat, without the need for in-person game administration assistance. One avenue for future research would be the implementation of this game in college campus health and wellness center waiting rooms, where students may actively desire something to fill their time while waiting. Using a Web-based, mobile-ready game also provides the potential for reaching populations underserved in health insurance understanding; younger adult audiences may not get their news and information from traditional outlets, but this is a large population of the people who are online, on mobile technologies, and are playing games. There are also possibilities for game-infused programs for health insurance literacy that begin with the Healthcare America mobile game as part of a suite of health insurance literacy games that deploy automatically to participants at particular times during their university experience and incorporate participant follow-up surveys along the way possibly between 3 and 6 months, at 1 year, and at university exit/graduation. This strategy addresses the issue of building real literacy in this complex system, realizing it is not a problem that can be solved with one game, one time.

In addition to these explicit advantages with a young, tech-savvy population, the majority of adults with potentially low health literacy indeed have smartphones including those who did not graduate from high school (54% have smartphones), make less than US \$30,000 (64%), or are of minority race (72% of black adults and 75% of Hispanic adults). Future research initiatives should explore ways in which a newsgame would be a feasible method for connecting patients with low health literacy, general literacy, or experience difficulty with technology. One adjustment that could be made to Healthcare America is to offer audio cues and narration to facilitate engagement among these audiences. Additionally, game content could be further tailored to specific populations and include culturally relevant details, as well as specific health insurance scenarios encountered by patients who struggle with these skill sets.

Limitations

This study presents important findings that can contribute to future intervention initiatives regarding health insurance, health, and newsgames, yet it is not without limitations. First, the study was limited by sample size. The purpose of this study was to explore an initial iteration of a newsgame in this area, and our study indeed exceeds the sample size included in other, comparable studies [18,29]. In Healthcare America, players are provided with information about and definitions of health insurance terms. Information is not sufficient to change behavior [43,44]. However, in conjunction with an interactive game in which young adults were asked to note, evaluate, and assist clients with health insurance issues, it is the hope that players experience and learn about health insurance through modeling and applying information they acquire. An additional limitation

was the confines of the lab setting as well as participant self-selection (and convenience sampling) in choosing to play the game and participate in the study. It may be that participants felt they needed to respond to questions or act a specific way when playing the game. Participants could have felt pressured to take on the role of an “intern” for a health care position. With this in mind, within the game, the player is provided with the “pages from the intern manual” (the health insurance terminology explanations and examples) and thus must act and provide suggestions based on the information they have—a learning and growing process akin to working at an internship. In this study, we implemented previously used survey items [29]; however, other types of measures, including multiple-choice questions or selecting a “correct” answer from a list could have produced different results. Moreover, the findings rely on a single group pre- and postgame play design and did not measure subsequent behavior change or retained knowledge long term. In an effort to minimize these limitations in future studies, we are currently collaborating with the on-campus health and wellness center to make the Web-based game available on its website and thus extend access and data collection.

Conclusions

In this study, young adult participants indicated an increased level of self-reported and objective knowledge after playing an interactive, narrative-based newsgame about health insurance.

This population is particularly susceptible to being at risk for not having or understanding health insurance [27,29]; yet, based on the findings of this study, a game such as Healthcare America is an appropriate initial step to decreasing these health-related challenges.

Results from this study suggest that repeated play or multiple exposures to some concepts such as “coinsurance” may be needed to increase understanding of this more difficult term. In this study where only one example was implemented, few young adults increased in their understanding and confidence with this term. In contrast, terms that young adults encounter more often (and potentially have an increased immediate need for) such as “referral” need fewer examples or iterations to achieve understanding. Moreover, Healthcare America implemented client narratives based on real-world news stories, user experiences, and real-time information about health insurance to facilitate understanding. The strategy of asking young adults to help or assist others in need or with questions can be a fulfilling experience for the player and a beneficial game strategy.

Although the games for health field have grown considerably in recent years, this health insurance newsgame is the first of its kind. The design and pilot test phase shows promising results for game design strategy, health insurance content, and platform iterations, moving forward.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Full game design and possible game flow paths.

[[PNG File, 450KB - games_v5i4e22_app1.png](#)]

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Abbreviations

HMO: health maintenance organization

PPO: preferred provider organization

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Review

The Role of Transfer in Designing Games and Simulations for Health: Systematic Review

Derek A Kuipers^{1,2}, MSc; Gijs Terlouw¹, MSc; Bard O Wartena^{1,3}, MSc; Job TB van 't Veer¹, Ph.D.; Jelle T Prins⁴, PhD; Jean Pierre EN Pierie^{5,6}, MD, PhD

¹NHL Stenden University of Applied Sciences, Leeuwarden, Netherlands

²Medical Faculty LEARN, University Medical Center Groningen, University of Groningen, Groningen, Netherlands

³Industrial Design Engineering, Delft University of Technology, Delft, Netherlands

⁴MCL Academy, Medical Center Leeuwarden, Leeuwarden, Netherlands

⁵Surgery Department, Medical Center Leeuwarden, Leeuwarden, Netherlands

⁶Post Graduate School of Medicine, University Medical Center Groningen, University of Groningen, Groningen, Netherlands

Corresponding Author:

Derek A Kuipers, MSc

NHL Stenden University of Applied Sciences

Rengerslaan 10

Leeuwarden, 8917 DD

Netherlands

Phone: 31 0646064240

Email: kuipersd@nhl.nl

Abstract

Background: The usefulness and importance of serious games and simulations in learning and behavior change for health and health-related issues are widely recognized. Studies have addressed games and simulations as interventions, mostly in comparison with their analog counterparts. Numerous complex design choices have to be made with serious games and simulations for health, including choices that directly contribute to the effects of the intervention. One of these decisions is the way an intervention is expected to lead to desirable transfer effects. Most designs adopt a first-class transfer rationale, whereas the second class of transfer types seems a rarity in serious games and simulations for health.

Objective: This study sought to review the literature specifically on the second class of transfer types in the design of serious games and simulations. Focusing on game-like interventions for health and health care, this study aimed to (1) determine whether the second class of transfer is recognized as a road for transfer in game-like interventions, (2) review the application of the second class of transfer type in designing game-like interventions, and (3) assess studies that include second-class transfer types reporting transfer outcomes.

Methods: A total of 6 Web-based databases were systematically searched by titles, abstracts, and keywords using the search strategy (video games OR game OR games OR gaming OR computer simulation*) AND (software design OR design) AND (fidelity OR fidelities OR transfer* OR behaviour OR behavior). The databases searched were identified as relevant to health, education, and social science.

Results: A total of 15 relevant studies were included, covering a range of game-like interventions, all more or less mentioning design parameters aimed at transfer. We found 9 studies where first-class transfer was part of the design of the intervention. In total, 8 studies dealt with transfer concepts and fidelity types in game-like intervention design in general; 3 studies dealt with the concept of second-class transfer types and reported effects, and 2 of those recognized transfer as a design parameter.

Conclusions: In studies on game-like interventions for health and health care, transfer is regarded as a desirable effect but not as a basic principle for design. None of the studies determined the second class of transfer or instances thereof, although in 3 cases a nonliteral transfer type was present. We also found that studies on game-like interventions for health do not elucidate design choices made and rarely provide design principles for future work. Games and simulations for health abundantly build upon the principles of first-class transfer, but the adoption of second-class transfer types proves scarce. It is likely to be worthwhile to explore the possibilities of second-class transfer types, as they may considerably influence educational objectives in terms of future serious game design for health.

KEYWORDS

transfer; computer simulation; video games; serious games; games for health; fidelity; abstract learning; immersion; metaphor

Introduction

Games and simulations hold the promise of being learning machines [1] because of the ability to build in learning principles. They can harvest unique features to motivate, trigger, and facilitate learning processes, opening up new possibilities for designing learning for health care professionals and patients. With the positive effects on learner motivation and learning outcomes in mind [2-4], educators must think of new ways to make serious subject matter suitable for game play. A transformation of current forms and beliefs on learning may be needed to make a more natural connection between the *serious* and the *game*.

Transfer

A possible way to make such a connection can be found in thinking in terms of transfer. Although there are a wide variety of viewpoints and theoretical frameworks regarding transfer in the literature, transfer is seldom a starting point in developing serious games. Studies on serious games [5,6] have identified design principles for flow and immersion as major contributors to the gaming experience and presumably beneficial for learning. However, the way games facilitate learning is often regarded as a black box.

From an educational and technological perspective, transfer is a key concept in learning theory and education [7]. The purpose of (medical) education is transfer: the application of skills, knowledge, or attitudes that were or learned in one situation to another context. The concept of transfer is widely recognized, but ample evidence shows that transfer from learning experiences often does not occur. The prospects and conditions of transfer are crucial educational issues.

If we regard games and simulations as learning contexts that can be designed and specifically tailored for (at least a type of) transfer, it seems legitimate to focus attention on how transfer has been taken into account in designing game-like health interventions.

Two Classes of Transfer

Transfer theory determines two classes of transfer, both encompassing a variety of transfer types [8]. The first class takes the position that the more the learning context resembles the target context, the more likely transfer is to occur. The conditions for transfer are met when the learning experience shares common stimulus properties with the target context. This means that when game or simulation environments try to represent the real world as literal as possible, they aim for first-class transfer. The first class of transfer encompasses instances of literal, specific, nonspecific, vertical, lateral and low-road transfer.

The second class of transfer theories may be harder to grasp. According to Royer [7], figural transfer (belonging to the second transfer class) involves situations where a known complex of

ideas, concepts, and knowledge is juxtaposed against some new problem or situation. Figural transfer uses existing world knowledge to think or learn about a particular issue. Clear examples of the usage of figural transfer can be found in figural language such as metaphor or simile. Transfer occurs because of a successful memory search triggered by a figural learning context, assisting in understanding the transfer context. In some situations, the second class of transfer requires a debrief to explicate experiences and connections made. This class encompasses high-road transfer [8].

Optimizing Transfer Conditions

Games and simulations for health abundantly build on the principles of first-class literal transfer, but the adoption of second-class transfer types has proven to be scarce. In contrast to commercial off-the-shelf games, in serious game design, the usage of mindful abstractions and metaphorical representations is not common practice, despite the fact that it forms a natural fit with the second class of transfer theories. Earlier research has shown [9] that transfer is hard to establish and that the design of education should be key to optimize the conditions under which transfer can occur. Although *transfer of learning* is a well-established concept in the educational domain, the extent to which transfer may guide the development of game-like interventions in health has rarely been explored. This may be especially true for second-class transfer types: optimizing a game-like intervention design to accommodate the principles of figural transfer.

Fidelity Types

The most visible examples of the designers' uptake of transfer in game-like interventions are apparent in the application of fidelity types: the way fidelity is used in a game-like intervention or simulation demonstrates the expected road to transfer. A dominant perspective on fidelity in serious game design is that high fidelity is conditional for learning and transfer, corresponding with the first class of transfer.

According to Alexander [10], fidelity has dimensions beyond the visual design—physical, functional, and psychological fidelity [10]. A game or simulation therefore can be low in physical and functional fidelity but can be high in psychological fidelity. It is also possible that a simulation by design is high in functional and physical fidelity but lacks psychological fidelity. In the literature, the degree of fidelity often refers to physical fidelity alone. Therefore, in this study, cases of cognizant design decisions toward lower fidelity types may prove interesting, as they might include second class of transfer types.

Aim

Focusing on the design of game-like interventions for health and health care, this study aimed to (1) find out whether the second class of transfer is recognized or present as a road for transfer in game-like interventions, (2) review the application

of the second class of transfer type in designing game-like interventions, and (3) assess studies that include second-class transfer types reporting transfer outcomes.

Methods

Databases and Search Strategy

In total, 6 databases were searched for potentially relevant abstracts: PubMed, Scopus, ERIC, PsycINFO, Information Science & Technology Abstracts, and EMBASE. These databases covered a wide range of published research from the field of health and social care. A combination of search terms were used to identify relevant papers under the following categories: (video games OR game OR games OR gaming OR computer simulation*) AND (software design OR design) AND (fidelity OR fidelities OR transfer* OR behaviour OR behavior), where * represents a wildcard to allow for alternative suffixes. Search strategies were customized for each database. Searches included papers published between database inception and October 2016. The search was conducted between October 3, 2016 and October 21, 2016.

Study Selection and Inclusion and Exclusion Criteria

We included studies that discussed either digital simulations or games designed for health providers or on health topics. We included only original reports or papers that (1) addressed the design of a serious game or digital simulation; (2) involved an empirical study, either piloting a game-like intervention or validating the aspired effects; or (3) otherwise focused on a newly developed game or simulation, created specifically for the study in question. Papers were included when title and abstract were considered to be at least indicative of the presence of second class of transfer. Papers meeting any of the above criteria were selected for full-text screening.

The following exclusion criteria were used for full-text screening: (1) non-peer-reviewed papers such as abstracts, conference posters, or trade journals; (2) full text not available; (3) language other than English and Dutch; (4) papers that referred to transfer as transfer of data or disease; (5) not sufficient information; (6) repurposed commercial off-the-shelf games; (7) low fidelity as a means to reduce production costs; (8) nondigital games and simulations; and (9) papers using high fidelity solely as a description of the artifact rather than as a founded design decision. Also, in our screening, we considered the transfer class in relation to the fidelity type: high fidelity as a means for achieving literal transfer led to exclusion.

Screening Process

After removing the duplicates, the papers were screened based on title and abstract using Rayyan [11]. In total, 2 reviewers

(DK and GT) independently reviewed the title and abstract for relevance against the formulated inclusion/exclusion criteria. Papers were only included on the agreement of both DK and GT; a third reviewer (BW) resolved any disagreements. The degree of agreement was calculated by a kappa statistic. Full-text papers were retrieved after this step. Both reviewers (DK and GT) reviewed each included full-text article. Disagreements in this stage about inclusion were discussed until an agreement was reached. Finally, to check whether any eligible paper had been overlooked during the review process, our check included studies' references for additional papers.

Results

Search Results

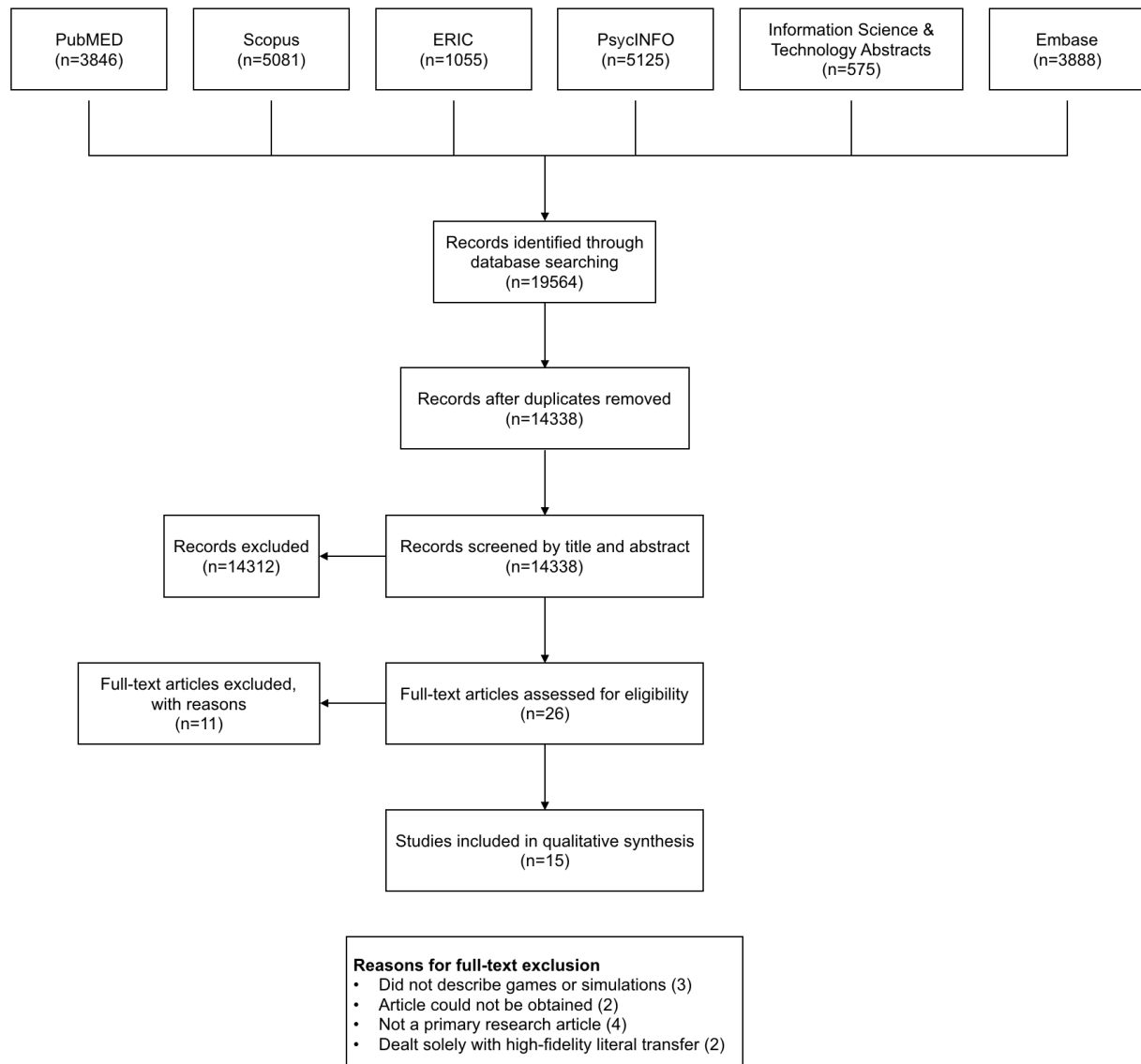
Our initial search yielded 19,564 records. After removing all duplicates (5226), 14,338 records remained for title and abstract screening, leaving 26 potential suitable papers for full-text assessment. We used Cohen kappa to assess the interrater reliability of paper inclusion. We found good agreement between the 2 reviewers ($\kappa = .78$, 95% CI 0.655-0.883). A total of 11 papers were excluded at full-text screening for various reasons. The total number of included papers is therefore 15. See Figure 1 for a flowchart of the results of the initial searches, screening, and selection processes. Table 1 shows an overview of included studies.

Second-Class Transfer in Game-like Interventions for Health and Health Care

We studied the full-text papers on how transfer was regarded and described in serious games or simulations. All 15 studies mentioned transfer in the initial concept of the design and described forthcoming consequences, mostly expressed in terms of fidelity. Although we assumed that the second class of transfer would be identified in varying ways, we found several other reasons to use abstract concepts and low fidelity. In the following section, we have categorized the papers, based on similarities in conjoining characteristics.

Reducing Cognitive Load

Out of the selected studies, 3 [12,17,24] questioned the necessity of high fidelity to achieve transfer. The basic theory is that high-immersive gaming environments decrease learning outcomes. The studies argue that reducing complexity prevents extraneous cognitive load. In these situations, low fidelity and deliberate abstractions are aiming—by design—for managing the trainees' working memory capacity. This is grounded in the cognitive load theory [27].

Figure 1. Flowchart of the results of the initial searches, screening, and selection processes.

Motor and Spatial Skills Training in Metaphorical Contexts

In our initial selection process, papers that presented literal transfer axiomatically were excluded. Out of the included studies, 3 [13-15] were regarded more closely because they use metaphorical game environments, possibly indicating the presence of second-class transfer types. These game-like interventions were designed for skills training (ie, laparoscopic surgery, spatial cognition skills, lifting and transfer techniques). In these scenarios, emphasis is placed on a high degree of validated functional fidelity, aimed at faithfully mimicking the desired skills. These games facilitate first-class low-road transfer by automating motor and spatial skills, hosted by low physical fidelity metaphors.

For example, the game *Underground* carefully mimics basic laparoscopic skills, including custom-made laparoscopic tool shells. The movements in the game are carefully calibrated to faithfully represent actual laparoscopic skills. These skills are acquired in a literal way. It is noteworthy that the tools and movements share high functional fidelity properties, whereas

the physical fidelity is low or even nonexistent. The same goes for *iLift*, where the lifting and transfer techniques maintain a mimetic correspondence to real-world tasks, although the game metaphor encompasses physical and psychological fidelity: catching sheep or helping little robots escape from a mine shows no medical content. These games use metaphorical contexts to host meaningful play for training skills.

Situational Games

Pervasive game design provides a different approach toward transfer. Of the papers, 2 [19,25] advocate pervasive games, where fusing the virtual world with the real-world positions them in between the first and second class of transfer. One could argue that situational games seek to provide what we like to call *blended transfer* by emphasizing context awareness in a true-to-life experience on the one hand and on the other hand adding virtual game elements. Both studies conclude by accentuating the promise of pervasive game play for transfer of knowledge [25] and transfer of behavior [19] but provide no implications for the design of virtual elements for future pervasive games.

Table 1. Details of included papers.

Author	Title	Transfer class ^a	Fidelity and transfer rationale	Year
Dankbaar, Alsma, Jansen, Van Merriënboer, Van Saase, and Schuit [12]	An experimental study on the effects of a simulation game on students' clinical cognitive skills and motivation	First	Low fidelity, reducing cognitive load	2016
Kuipers, Wartena, Dijkstra, Terlouw, van T Veer, Van Dijk, Prins, and Pierie [13]	iLift: A health behavior change support system for lifting and transfer techniques to prevent lower-back injuries in healthcare	First	Low-road transfer, skill automatization, metaphorical	2016
Jalink, Gores, Heineman, Pierie, and Ten Cate Hoedemaker [14]	Face validity of a Wii U video game for training basic laparoscopic skills	First	Low-road transfer, skill automatization, metaphorical	2015
Connors, Chrástil, Sanchez, and Merabet [15]	Action video game play and transfer of navigation and spatial cognition skills in adolescents who are blind	First	Low-road transfer, spatial recognition	2014
Rosenberg, Baughman, and Bailenson [16]	Virtual superheroes: using superpowers in virtual reality to encourage prosocial behavior	Second	Figural, metaphorical	2013
Schrader and Bastiaens [17]	The influence of virtual presence: effects on experienced cognitive load and learning outcomes in educational computer games	First	Low fidelity, reducing cognitive load	2012
De Freitas and Dunwell [18]	Understanding the representational dimension of learning: the implications of interactivity, immersion and fidelity on the development of serious games	Second	Figural, metaphorical	2012
Knoll and Moar [19]	The space of digital health games	Blended	Locative, situational	2012
Rooney [20]	A theoretical framework for serious game design: exploring pedagogy, play, and fidelity and their implications for the design process	Blended, both	Abstraction, situational	2012
Toups, Kerne, and Hamilton [21]	The team coordination game: zero-fidelity simulation abstracted from fire emergency response practice	Second	Nonmimetic, abstraction	2011
Hochmütz and Yuviler-Gavish [22]	Physical fidelity versus cognitive fidelity training in procedural skills acquisition	First	Cognitive fidelity, skill acquisition	2011
Stone [23]	The (human) science of medical virtual learning environments	First	Cost reduction	2011
Wood, Beckmann, and Birney [24]	Simulations, learning, and real world capabilities	First	Low fidelity, execution skills, reducing cognitive load	2009
Markovic, Petrovic, Kittl, and Edegger [25]	Pervasive learning games: a comparative study	First	Situational	2007
Alessi [26]	Fidelity in the design of instructional simulations	Both	Varying fidelity under conditions	1988

^aRefers to the aspired transfer type described or sought after with the game-like intervention.

The Application of the Second Class of Transfer

Of the studies, 3 describe game designs applying the second class of transfer, and one study [16] describes a video game to stimulate prosocial behavior. It examines how playing an avatar with superhero abilities increases prosocial behavior in the real world. The study indicates that the in-game superhero metaphor leads to greater helping behavior outside the game. The game therefore builds on the second class of transfer, although the study does not explicate design considerations regarding transfer.

De Freitas et al [18] describe *Re-Mission*, a video game designed for young people with cancer to encourage them to take their medication. The game metaphor, where the player has to combat cancer cells, seeks to reinforce behavioral change toward medication use. *Re-Mission* fits the figural transfer class as the in-game representation of the illness and the power to conquer

this illness are metaphorical rather than literal [18]. The game play shows little physical or functional fidelity to real-world processes, and measured effects can only be explained in terms of changed mental conceptions, referring to an instance of second-class (figural) transfer. However, the design considerations were not elucidated either in this study.

The third study [21] describes the *Team Coordination Game*, a simulation to practice team coordination during fire emergency response situations. The *Team Coordination Game* is a simulation that offers a game environment that requires the use of effective team communication skills, without concrete elements of the mimicked environment. This nonmimetic game offers a two-dimensional environment that shows low-fidelity to real-life fire emergency environments. In the game, 3 avatars in the role of *seeker* are searching for specific goals, while avoiding threats. A player in the role of coordinator directs the

seekers based on observing the environment from a different angle. Limited game time creates a certain amount of stress and pushes the players to work effectively. The study suggests that players were able to restore learned behaviors in communication and stress management in an alternative environment, remixing and repurposing them, suggesting a transfer effect.

Although the game offers a so-called zero-fidelity physical environment, it uses communication instruments that have the same characteristics as real-world radios. This implies at least a modicum of functional fidelity. Furthermore, the game is based on communication strategies and stress levels from real-world fire emergency situations, which suggests some level of psychological fidelity. The *Team Coordination Game* simulation study offers clear design implications, labeling and elaborating on abstraction from reality as a guiding principle, which differs from the other studies included.

Psychological Fidelity

In total, 7 studies [12,18,20-23,26] mention *psychological fidelity* as, if not *the* most, an important design parameter in serious games and simulations. In addition, these studies claim that representing the real world as literal as possible is less important for learning. The definition of psychological fidelity in these studies varies slightly [22], but all studies mention the abstraction of certain real-world concepts and a process of recontextualization. Of the studies considered, one [21] added *suspension of disbelief* as an important characteristic of psychological fidelity: one's temporary allowance to believe something that is not true. Despite the fact that the second class of transfer is not explicitly stated in those studies, they implicitly confirm the second class of transfer as a promising concept in serious game design for learning.

Effects of Design for Figural Transfer

The virtual superhero study [16] only reported a transfer effect just after playing the game. The study did not cover long-term effects but showed in an experimental 2×2 design that participants (n=60) in the flying superhero condition displayed significantly increased prosocial behavior compared with participants who were in the helicopter condition. The study mentions several possibilities for the differences found between the testing conditions: different experiences of immersiveness, involvement versus observation discrepancy, and primed concepts and stereotypes related to superheroes in general.

The study reporting on *Re-Mission* [18] did not elaborate on the efficacy of the intervention. Another study [28] focused in greater detail on the transfer effects of *Re-Mission* and found that playing the game increased young cancer patients' feelings of self-efficacy or beliefs in their own ability to control and cope with the disease. A randomized trial with 197 intervention group participants showed a significant increase in cancer-related knowledge and self-efficacy scores and offers empirical support for the efficacy of a game-like intervention in improving behavioral outcomes in adolescents and young adults with cancer.

Using a mixed-method approach, the *Team Coordination Game* [21] also reported some transfer effect, in addition to an in-game effect (n=64). The study suggested that players were not only

able to restore learned behaviors in communication and stress management in an alternative environment but also capable of remixing and repurposing them. The article—in several substudies—describes a variety of positive effects on communication and organizational skills, carried over from the game environment to live training.

Discussion

To our knowledge, this is the first review to explore the aspired transfer in designing game-like interventions in health. We tried to find and describe examples of the application of second-class transfer types by answering 3 research questions, discussed below.

Design for Transfer in Health

We tried to determine whether the second class of transfer types is recognized or present as a road for transfer in game-like interventions for health. In our initial search, we expected to find studies in which thinking about a desired transfer outcome would form a guiding principle in the design of game-like interventions. Moreover, clearer distinctions in suitable transfer types and established examples of figural transfer (or forms thereof) were anticipated. Both assumptions were proven wrong, and we had to broaden our inclusion criteria to capture studies regarding design considerations, including transfer.

Our results show that transfer is mainly mentioned as a desired outcome, not as a guide in the design process. The appearance of most included game-like artifacts can be explained by the designer's fidelity approach. As obvious as this seems, this fidelity approach also expresses assumptions about the way the transfer is expected to take place. As described before, we found several reasons for choosing low fidelity over high fidelity and vice versa. As none of the studies were designed for achieving transfer via a specific type or class of transfer, the question arises why the *design for transfer* perspective has received no attention.

By nature, design-centered research focuses more on the design itself and puts less emphasis on the eventual aspired outcome. Although it is too strong to state that the design itself of game-like interventions in health is not taken into account in thinking about desirable transfer outcomes, our search results show that describing the game-like interventions in terms of transfer variables is uncommon. One might argue that the design of a drug is essential to its workings and that the same principle applies for game-like interventions. The design of the artifacts as exercised in the virtual superhero game [16], *Re-Mission* [18], and the *Team Coordination Game* simulation [21] is intentional and differs strongly from game-like interventions as *Underground* [14] or *Digital Economy* [25]. These differences arise from a broad and ill-defined range of variables but inevitably reveal the designer's intent with regard to how the intervention should carry over the effect. Herein lies the rationale for design for transfer.

The Presence of the Second Class of Transfer

As described, we searched for particular examples of aspired transfer in the second class of transfer types, and found none. In 3 studies, the reported effects can only be explained via the

road of a second-class transfer type but are described in other terminology. Most studies report about psychological fidelity [12,18,20-23,26], virtual presence [17], and immersion [16,18] as important conditions for desired outcome.

An interesting observation is that the included papers show that functional and physical fidelity can be high or low for varying, well-founded reasons and that psychological fidelity is regarded as a variable that preferably should be high. The *Team Coordination Game* simulation [21] adopts a different position in stating that the gaming artifact has zero psychological fidelity. However, the way deliberate abstractions are described and how these resulted in the design of the game itself strongly suggests second-class transfer.

The 3 studies we identified exemplifying an instance of figural transfer introduced a metaphorical approach with recontextualized fidelity types. These game metaphors seem to address and replace both high functional and physical needs as well as promote immersion. At this point, we hypothesize that figural transfer builds upon immersion or virtual presence and subsequent suspension of disbelief [21]. In more abstract game-like interventions, metaphors provide a storyline, a context, and a reason for engaging in play. In this way, psychological fidelity is reappointed by the concept of suspension of disbelief, instigated by the metaphor itself.

Second-Class Transfer Outcomes

As the literature on transfer has consistently confirmed, long-term transfer effects are hard to measure. This might be particularly the case for the second class of transfer. All 3 examples report transfer effects, albeit short term and only vaguely proven. As second-class transfer is the result of the effects interventions trigger in one's head, the transfer outcomes are individual, often nonlinear, and even unpredictable if the second class is not implemented with due care. Precisely because

of this, we anticipated more conscious and elucidated design examples.

Limitations

Although this review is based on an extensive search of a large number of health and computer science databases, we hardly found any studies of second-class transfer types in game-like interventions for health. Studies tend to focus on the effectiveness of game-like interventions and the research methods used, not on design factors that lead or contribute to measured effects. Due to the very few direct hits, we focused on the subconscious application of the second class of transfer types by thoroughly screening titles and abstracts. The papers that were included were subject to interpretation, discussion, and consensus of the reviewers (DK, GT, and BW). To counteract subjectivity, papers were independently reviewed by 2 reviewers (DK and GT) and were only included on consensus from both reviewers. Remaining conflicts between the reviewers were resolved by the third reviewer (BW).

Conclusions

Studies about serious games and game-like interventions for health do not provide a conscious rationale for designing the artifacts for optimizing transfer conditions. We did not find any example of a game-like intervention that was the result of a cognizant design process focusing on transfer outcomes. In general, we found that definitions of low and high fidelity form the strongest influencers on the design of artifacts, mostly exemplified in visual quality or a true-to-life approach. High fidelity was aspired to for its first class, literal transfer aspects without exception. None of the studies explained second class of transfer or instances thereof, although in 3 instances, implicit design choices suggested otherwise. It is notable that studies on game-like interventions for health do not elucidate the design choices made, as they bridge the designer's intent and the aspired transfer outcome.

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Conflicts of Interest

None declared.

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Original Paper

Examining Motivations to Play Pokémon GO and Their Influence on Perceived Outcomes and Physical Activity

Oriol Marquet¹, PhD; Claudia Alberico¹, MSc; Deepti Adlakha², PhD; J Aaron Hipp¹, PhD

¹Department of Parks, Recreation and Tourism Management, Center for Geospatial Analytics, North Carolina State University, Raleigh, NC, United States

²School of Natural and Built Environment, Queen's University Belfast, Belfast, United Kingdom

Corresponding Author:

Oriol Marquet, PhD

Department of Parks, Recreation and Tourism Management

Center for Geospatial Analytics

North Carolina State University

2820 Faucett Drive

Raleigh, NC, 27606

United States

Phone: 1 919 798 1460

Email: omarque@ncsu.edu

Abstract

Background: Pokémon GO is the most played augmented reality game in history. With more than 44 million players at the peak of its popularity, the game has sparked interest on its effects on the young population's health.

Objective: This pilot study examined motivations to start playing Pokémon GO among a sample of US college students, and how motivations were associated with perceived outcomes of the playing experience and physical activity derived while playing.

Methods: In November 2016, we asked a sample of 47 US college students (all Pokémon GO players) to complete online surveys and install an ecological momentary assessment (EMA) tool and step counter on their smartphones. The EMA tool prompted a set of questions on playing behavior and physical activity, 3 times per day (12:00 PM, 7:00 PM, and 10:00 PM), for 7 days. We used a factorial analysis to identify 3 distinctive groups of players based on their motivations to start playing Pokémon GO. We tested differences across motivation groups related to 5 unique outcomes using 1-way analysis of variance.

Results: We extracted 3 interpretable factors from the clustering of motivations to start playing Pokémon GO: *Pokémon and video game fans* (n=26, 55% of the sample), *physical activity seekers* (n=8, 17%), and *curious & social* (n=13, 28%). The clusters differed significantly on the enjoyment of different aspects of the game, particularly battling, discovering new places, and meeting new people, as well as differences in agreement that playing improved mood and made them more social. Days when playing Pokémon GO were associated with higher number of steps reported at the end of the day, especially among *physical activity seekers*, but also for *Pokémon and video game fans*. All groups perceived traffic as a major threat to playing.

Conclusions: Days during which Pokémon GO was played were positively associated with a set of beneficial health behaviors, including higher physical activity levels, more socialization, and better mood. Results, however, depended on personal motivations and expectations when joining the game. These results highlight the importance of taking motivation into account when attempting to extract conclusions from the Pokémon GO phenomenon to enhance future exergames' designs or health interventions.

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KEYWORDS

Pokémon GO; physical activity; exercise; exergames; gaming outcomes; games, recreational; motivation

Introduction

Worldwide, governments, health advocates, and public health researchers have been exploring programs and interventions to promote regular physical activity [1]. Despite this, physical

activity levels have been declining worldwide. Adults and children in many countries around the world are not reaching recommended amounts of physical activity [2]. Early research suggests that playing Pokémon GO appears to increase daily physical activity levels, particularly among groups that have low levels of activity: teens, preteens, and younger adults [3].

Pokémon GO is a free-to-play, location-based augmented reality mobile game based on the popular video game series. The game was launched by Niantic, Inc in collaboration with Nintendo Co, Ltd in July 2016 in both Apple Inc's iOS App Store and Google Inc's Play Store. It involves capturing virtual characters, or Pokémon, that have been placed in prominent, real public locations, such as streets, parks, and other notable public buildings and spaces. The game allows players to create their virtual avatar and uses a mobile device's global positioning system capability to display the player's current geographic location on a map.

Pokémon GO is one among several recent augmented reality games that offer new ways to interact with the physical surroundings using a smartphone [4]. The physical activity component of the game, which requires players to walk and explore their surroundings using a detailed map of their neighborhood, led to several research opportunities on the potential benefits of Pokémon GO for youth and millennials. Among potential benefits, physical activity has been the most cited [4-8], as the active lifestyle promoted by Pokémon GO is seen as a potential intervention to tackle the obesity and inactivity epidemic [9,10]. What makes Pokémon GO particularly powerful and different from other kinds of exergames [11] is its attraction to people through game mechanics, making physical activity a secondary, or unintentional, behavior. The motivation and engagement of Pokémon GO players thus come not from turning physical activity into a game, but from a game with its own purpose that incorporates being active as part of the gaming experience.

Together with physical activity and motor skills, the game encourages players to explore their local communities and in the process may introduce them to new spaces [8]. This has led some to believe that Pokémon GO increases location awareness and public space use, and thus increases opportunities for social interaction within these spaces [12]. This capacity to increase social capital and establish new social networks through playing while being outside is also promising for mental health benefits [13,14], as social engagement linked to online gaming has been found to decrease perceived loneliness and depression [15]. In the particular case of Pokémon GO, the lack of an in-game chat app—a feature that other exergames include—makes players engage with one another via face-to-face communication and eliminates any possible alternatives via text messaging, which may be altering the socialization patterns usually seen in other online exergames. Finally, other potential outcomes may include better intergenerational relationships, as parents and their children engage together in outdoor activities [13], and increased knowledge of local patrimonial locations.

The rapid popularization of the game, which makes it the first augmented reality game with real global acceptance [16], has also raised some awareness of the risks players are creating or encountering [17,18]. These are mainly focused on the addictive nature of the game [19] and injury risk to players [20]. However, these are not risks associated only with Pokémon GO, as the risk of addiction has long been associated with some types of online video games [17], and injury risk is often a product of having distracted players in flawed public spaces that have long neglected pedestrians [12].

Overall, the game has many potential benefits that need proper research for validation and future interventions. To our knowledge, only a handful of studies have investigated the effects of playing Pokémon GO, establishing some links between playing and physical activity [4,5,21], and playing and risky behavior [12]. However, other aspects relevant to Pokémon GO's popularity and public health remain completely unexplored. Among the most relevant are establishing what motivates people to begin and continue playing (or interacting with) the game, what their expectations and intentions are while playing, and whether the playing experience meets these expectations and intentions. These questions are particularly important if we want to use gaming to improve future health interventions. In that regard, and before Pokémon GO appeared, Tong et al [22] demonstrated how individuals respond differently to various gamification strategies. More recently, Chia-Chen and Liu [23] demonstrated that Pokémon GO players are far from being a unified group when it comes to playing motivations. Part of the huge popularity of the game relies on its attraction for people seeking different kinds of experiences. While first adopters might overwhelmingly be original Pokémon fans drawn to the game by their love of the franchise characters, once the popularity of the game reached a critical mass, many other people joined seeking either the social aspect or the exploration experience, or even out of curiosity for the game or the phenomenon itself. Distinguishing the drivers that lead different people to the game, and their staying power, is thus crucial to understand player behavior and preferences. Together with this, research in media psychology demonstrates how attitudes and experiences that motivate people to take part in a game can also modify the outcomes of such games [16].

This study aimed to fill the gap in knowing why players feel attracted to Pokémon GO, together with understanding the particular aspects of the game that best fulfill their motivations. We aimed to examine whether motivations correlated with perceived outcomes of playing and perceived risks encountered when playing Pokémon GO. Finally, we intended to use step counts derived from smartphone data to examine whether physical activity levels attained while playing Pokémon GO would fluctuate dependent on the motivations that led each specific player to the game. Findings on players' behavior will inform future interventions through active games and exergames, enabling developers to design and tailor future games to target specific needs.

Methods

Recruitment

We recruited participants using the university recreation listserv of North Carolina State University, Raleigh, North Carolina, USA, with more than 8000 undergraduate student email addresses. The initial message stated the aim of the project and invited undergraduate students to participate in a study involving use of Pokémon GO and physical activity. We invited both players and nonplayers to participate. We offered entrance in a raffle of 8 gift cards worth US \$50 as an incentive for those completing all required steps in the study, which included 2 surveys and the completion of 7 days of ecological momentary

assessment (EMA). Recruitment occurred in early November 2016. After 1 week, we posted the same email message in an email from the student body president as part of a digest email including other topics. No additional recruitment efforts were included. All research protocols have been approved by North Carolina State University (Institutional Review Board no. 9242). We obtained written consent from all participants and stored the collected data on restricted computers in password-protected files.

Study Design

Participants were asked to answer an initial online survey to collect demographics, weekly physical activity, and activity habits regarding smartphone, video game, and social networks use, together with their Pokémon GO playing habits. We assessed physical activity using the International Physical Activity Questionnaire (IPAQ) Short Form [24]. We then converted the metabolic equivalent tasks (METs) reported through the IPAQ questionnaire into kilocalories of energy expenditure through the formula $1 \text{ MET} = 1 \text{ kcal/kg/h}$ [25]. We determined Pokémon GO playing habits through questions regarding playing frequency (number of days per week), time (played minutes per day), and time management (how they managed their playing time). Participants were also asked to download a step-counting app (PACER; Pacer Health Inc) to their smartphones together with an EMA app (PACO; Pacer Developers). PACER [26] is one of many step counters that use smartphone-enabled accelerometers to estimate daily steps. We chose PACER due to its simplicity and low battery consumption. PACO [27] was developed as a basic EMA tool for research and has been previously used in studies [28]. Over a 7-day period, the PACO app would prompt a brief questionnaire 3 times per day (12:00 PM, 7:00 PM, and 10:00 PM). Questions asked about playing behavior during the preceding time period, including whether they had played, where they had played, with whom they had played, how they travelled to the playing site, and in which environment they had played. The final question on the PACO questionnaire involved reporting the actual number of steps recorded by the step counter.

At the end of the 7-day period, we asked participants who self-identified as Pokémon GO players to answer a final online survey with information regarding their motivations and perceived outcomes from playing Pokémon GO. Participants who completed a minimum of 80% of the potential EMA responses were entered in a raffle for 1 of 4 gift cards worth US \$50.

Statistical Analysis

To capture the multiple factors encouraging people to play Pokémon GO, we used a factor analysis to sort the underlying motivations to start playing Pokémon GO. Factor analysis reduces the number of input variables to a manageable number. Using a multiple response question list of 9 factors from which participants could choose to answer as many as they liked, we extracted 3 interpretable factors that exhibited the clustering of motivation for different types of players. We chose to retain the 3 factors with eigenvalue >1 . Principal axis factoring and varimax rotation were used in deriving the results. We used means and standard deviations, together with 1-way analysis

of variance (ANOVA), to analyze the differences between group scores in several different outcomes. Outcomes included in the analysis were enjoyment with different aspects of Pokémon GO (measured on a Likert scale ranging from 1 to 4); spatial awareness while playing (1-4 Likert scale); and threats encountered while playing (multiple responses from a list). Finally, we also considered media effects by asking how playing Pokémon GO had made players more physically active, improved their mood, and increased social interactions (1-4 Likert scale). We used 1-way ANOVA and chi-square tests to test differences in means and distributions. We used post hoc Tukey tests on those variables with statistically significant difference in group means to confirm where the differences occurred between groups. Finally, between- and within-participants 1-way ANOVA were used to analyze differences between groups on the total amount of physical activity recorded at the end of the playing or nonplaying days (time=10:00 PM).

Results

Study Population

A total of 123 students replied to our emails expressing interest to participate. Because we did not know the actual number of email recipients actually reading the recruitment text, we were unable to calculate an accurate response rate. The overall study recruited both players and nonplayers. Among the final sample of 123 respondents, 49 had to be discarded because either they didn't answer the first online survey or they provided insufficient EMA data. From the 74 remaining participants, 27 identified as nonplayers during the initial online survey and 47 identified as players.

The study population ($n=47$) included 24 males with an average age of 19.8 years, and 23 females with an average age of 19.1 years. The most frequent ethnicity was white ($n=33$) followed by Asian ($n=10$). Most participants were between their freshman ($n=21$) and sophomore year ($n=14$). All of the participants had experience playing Pokémon GO prior to the start of the study. They had been playing Pokémon GO for a median of 122 days (SD 18.1) before the start of the study.

Factor Analysis

Together, the list of factors obtained through the factor analysis accounted for 60.5% of the variance among the 9 motivation variables listed (Table 1). The first factor scored highly on "I'm a Pokémon fan" and "I like video games," which we collectively grouped into *Pokémon and video game fans*. They likely represent the first wave of players, attracted by the contents of the game itself. The second factor scored highly on "to walk more" and "for exercise." We grouped these as *physical activity seekers* and hypothesized they were attracted to the game by the numerous reports that claimed playing was beneficial for physical activity. Finally, the third factor scored highly on a variety of answers, unrelated to the physical activity or the contents of the game. In particular, the scores were higher for "To learn about my city" and "To meet new people," with curiosity about the technology and the phenomenon itself also scoring highly. We referred to these as the *curious & social*.

Table 1. Analysis loadings and summary for factors encouraging people to play Pokémon GO^a.

Why did you start playing Pokémon GO?	Factor		
	1. Pokémon and video game fans (n=26)	2. Physical activity seekers (n=8)	3. Curious & social (n=13)
For exercise		.716	
To walk more		.872	
I was curious about the technology			.575
I was curious about people playing			.589
To learn about my city			.755
I'm a Pokémon fan	.822		
I like video games	.599		
To meet new people			.754
I was encouraged by others			.680
Summary statistics			
Eigenvalue	8.6%	15.5%	35.3%
Initial eigenvalue	1.12	1.82	3.54
Percentage of variance ^b	12.4%	20.3%	39.2%

^aOnly loadings >0.40 are shown. Keiser-Meyer-Olkin=.682; Bartlett <0.001.

^bCumulative percentage of variance captured by factors = 60.5%.

There were no significant differences in the demographic composition of each cluster, as [Table 2](#) shows. *Pokémon and video game fans* tended to be male, with the highest proportion of Asian American students. Although differences were not significant, *Pokémon and video game fans* tended to be less active (having the lowest energy expenditure in kcal/week reported among the 3 groups, at 2850 kcal). This group reported playing between 4 and 5 days per week, accumulating 120 minutes of play per week. The *physical activity seekers* showed an equal balance between sexes, were predominantly white, and were the youngest of the 3 groups, being either freshman or sophomore in class standing (generally 18-20 years of age). They were also the most active group overall, but reported playing only 3 days per week for a total of 59 minutes per week. Finally, the *curious & social* group were predominantly white females and 20 years of age on average. They reported almost 6 days of play per week and logged a total 120 minutes of play per week.

Of all analyzed variables, only the accumulated experience playing Pokémon GO at the start of the study was significantly different between groups. A post hoc test (Tukey) showed that the *physical activity seekers* differed significantly ($P<.001$) from the 2 other groups in the accumulated gaming experience before joining the study. While *Pokémon and video game fans* and *curious & social* players started playing Pokémon GO shortly after the launch of the game (accumulating a median of 122 and 123 days of experience, respectively, before starting

the study), *physical activity seekers* were drawn to the game much later and had only 100 days of experience at the start of the study.

Gaming Experience and Perceptions

The different underlying motivations to play Pokémon GO are reflected in both the gaming experience and the perceived behavioral outcomes of the game. [Table 3](#) displays players' perceptions regarding the factors in terms of what aspects they enjoyed and their perceived threats experienced while playing. Players could select as many enjoyment factors as they wanted and, on average, catching Pokémon and playing along with friends were the highest-rated aspects of the game. These scores, however, varied across motivation clusters. The clusters differed significantly on the rating of battling ($\chi^2_{(2,n=47)}=15.4, P<.001$), discovering new places ($\chi^2_{(2,n=47)}=11.5, P=.003$), and meeting new people ($\chi^2_{(2,n=47)}=20.9, P<.001$). In all 3 cases, post hoc tests revealed that the *curious & social* group had a significantly higher rating. While *Pokémon and video game fans* and *physical activity seekers* rated these 3 particular aspects very low, these were highly valued items for the enjoyment of the *curious & social* group.

The 3 groups did not differ significantly on encountering threats. Nearly half of the players (49%) reported encountering some kind of threat while they were playing, with the presence of traffic (n=16, 34%) and poor walking conditions (n=14, 30%) being the most frequent.

Table 2. Demographic characteristics and play averages per group of factors.

Characteristics	All (n=47)	Factor			Chi-square test	
		1. Pokémon and video game fans (n=26)	2. Physical activity seekers (n=8)	3. Curious & social seekers (n=13)	<i>F</i>	<i>P</i> value
Sex, n (%)					1.243	.54
Female	23 (49%)	11 (42%)	4 (50%)	8 (62%)		
Male	24 (51%)	16 (57%)	4 (50%)	5 (39%)		
Ethnicity, n (%)					1.244	.54
White	33 (70%)	18 (69%)	5 (63%)	10 (77%)		
Asian	10 (21%)	8 (31%)	0 (0%)	2 (15%)		
Other	4 (9%)	0 (0%)	3 (38%)	1 (8%)		
Academic standing, n (%)					2.985	.56
Freshman	21 (45%)	13 (50%)	4 (50%)	5 (39%)		
Sophomore	14 (30%)	7 (27%)	4 (50%)	4 (31%)		
Junior or Senior	12 (26%)	6 (23%)	0 (0%)	4 (31%)		
Analysis of variance						
Age (years), mean (SD)	19.5 (2.1)	19.3 (1.6)	19.0 (1.1)	20.1 (3.3)	0.77	.47
Energy expenditure (kcal/week) ^a , mean (SD)	3283.5 (1968.9)	2850.3 (1753.2)	4120.1 (1947.1)	3830.5 (2291.8)	1.78	.18
Play/week (minutes), median (IQR) ^b	154 (250)	120 (520)	59 (396)	120 (530)	1.03	0.37
Play/week (days), median (IQR)	5 (3)	5 (4.5)	3 (2)	6 (4)	0.22	.80
Playing experience (days) ^c , median (IQR)	122 (11)	122 (44)	100 (59.3)	123 (11)	11.674	<.001

^aEnergy expenditure estimated by transforming metabolic equivalent tasks (METs) into kilocalories, where 1 MET=1 kcal/kg/h [25].

^bIQR: interquartile range.

^cSelf-reported number of days playing Pokémon GO at the start of the study.

Table 3. Enjoyment elements and threats encountered per group of factors.

Questions	All (n=47) n (%)	1. Pokémon and video game fans (n=26) n (%)	2. Physical activity seekers (n=8) n (%)	3. Curious & social seekers (n=13) n (%)	Chi-square test	
					χ^2	<i>P</i> value
What do you enjoy the most? ^a						
Catching Pokémon	42 (89%)	24 (92%)	7 (88%)	11 (85%)	0.9	.64
Battling	22 (47%)	9 (35%)	1 (13%)	12 (92%)	15	<.001
Playing with friends	33 (70%)	18 (69%)	4 (50%)	11 (85%)	2.5	.28
Being outdoors	26 (55%)	12 (46%)	4 (50%)	10 (77%)	0.0	.98
Discovering new places	25 (53%)	9 (35%)	4 (50%)	12 (92%)	11.5	.003
Meeting new people	9 (19%)	1 (4%)	0 (0%)	8 (62%)	20.9	<.001
Have you encountered any threats while playing? ^a						
Traffic	16 (34%)	8 (31%)	5 (63%)	3 (23%)	3.59	.17
Poor walking conditions	14 (30%)	7 (27%)	4 (50%)	3 (23%)	4.1	.11
None	24 (51%)	15 (58%)	1 (13%)	8 (62%)	3.7	.15

^aDichotomized results of multiple-choice answers.

Table 4 displays players' perceived outcomes and changes in players' spatial awareness. Respondents were asked to respond on 4-point Likert-type scales ranging from "not at all" to "to a great extent." Players reported a very mild adherence to the idea that playing Pokémon GO had made them more physically active (mean score 2.89, SD 0.78). Differences were found in the statement regarding whether playing had improved their mood. On average, players did agree that playing had "somewhat" improved their mood. However, differences across groups were significant ($F_{2,45}=3.623, P=.04$), with the *physical activity seekers* agreeing least with the statement (mean 2.5 out of 4, SD 0.84). Post hoc Tukey tests revealed the *curious & social* to score significantly higher ($P=.008$) than the *physical activity seekers* on improved mood. Finally, players on average

stated that the game had done "very little" (mean 2.23 out of 4, SD 0.91) to improve their social interactions, with the highest rating among the *curious & social*, who significantly differed from the other 2 groups ($F_{2,45}=6.285, P=.004$) and stated that the game had made them "somewhat" more social.

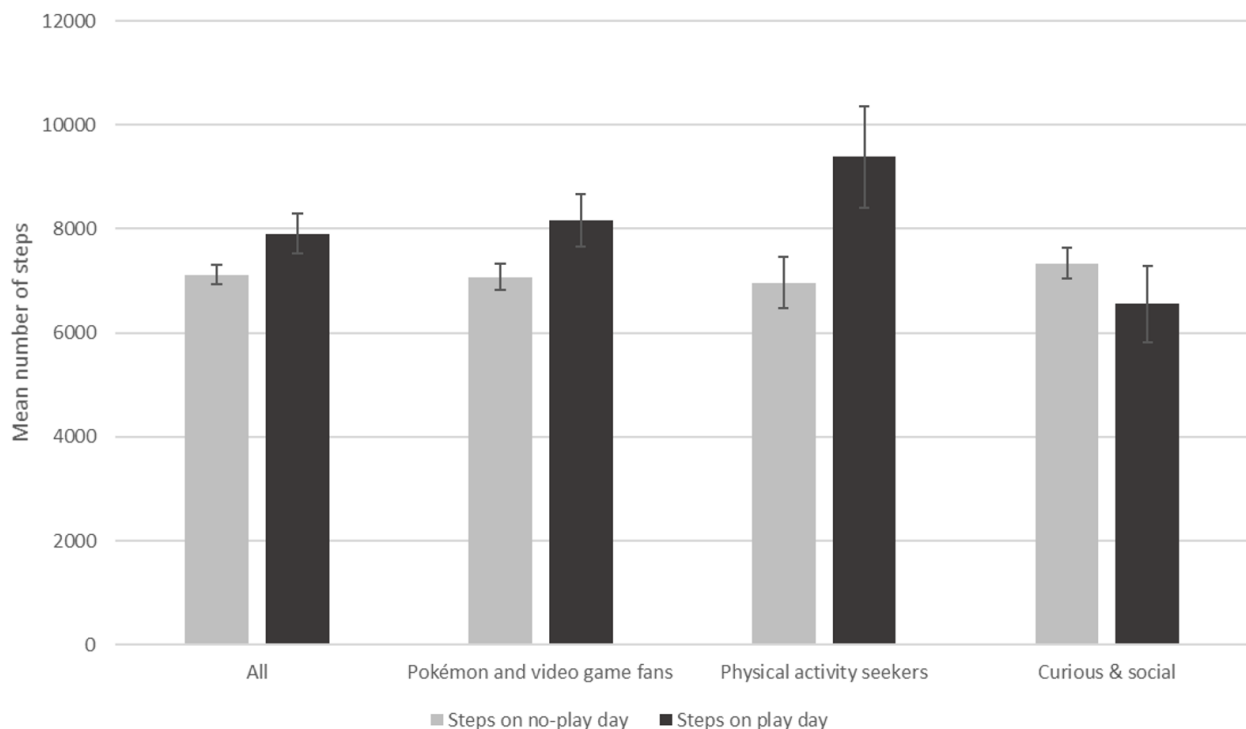
On average, players reported the game had made them a little more aware of their neighborhood, (mean 2.191, SD 1.08) and their surrounding facilities (mean 2.149, SD 1.02). Players also reported that playing had made them somewhat more aware of the public spaces around them (mean 2.776, SD 1.07). Significant differences were found in the reporting of neighborhood and facility awareness and, in all cases, *Pokémon and video game fans* had the least awareness, while the *curious & social* had the highest awareness.

Table 4. Outcome perceptions and spatial awareness per group of factors.

Questions	All (n=47)	1. Pokémon and video game fans (n=26)	2. Physical activity seekers (n=8)	3. Curious & social (n=13)	Analysis of variance	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F	P value
Has playing Pokémon GO...^a						
Helped you be more physically active	2.89 (0.67)	2.86 (0.76)	2.67 (0.52)	3.08 (0.49)	0.875	.42
Improved your mood	3.04 (0.589)	3.07 (0.54)	2.5 (.84)	3.23 (0.44)	3.623	.04
Improved your social interactions	2.23 (0.91)	1.96 (0.88)	2.0 (0.89)	2.92 (0.64)	6.285	.004
Has playing Pokémon GO made you aware of new...^a						
Neighborhood	2.19 (1.08)	1.89 (0.96)	2.33 (1.21)	2.77 (1.09)	3.304	.046
Public space	2.77 (1.07)	2.54 (1.2)	2.83 (1.17)	3.23 (0.44)	1.976	.15
Facilities	2.145 (1.02)	1.86 (1.11)	2.17 (0.75)	2.77 (0.60)	4.006	.03

^aAnswers were scored on a 4-point Likert scale: 1=not at all; 2=very little; 3=somewhat; 4=to a great extent.

Figure 1. Daily steps measured at 10:00 PM on playing and nonplaying weekdays. Error bars indicate SD.



Objectively Measured Physical Activity

Among the group of self-identified Pokémon GO players, a Pokémon GO playing day, versus a nonplaying day, was associated with higher number of steps reported ($F_{1,310}=8.903$, $P=.048$; Figure 1). Among the different motivation groups, the relationship is clearly stronger among *physical activity seekers* ($F_{1,39}=0.887$, $P=.02$), as they were reporting 34.76% more steps on playing days ($n=9382$) than on days when they had not played ($n=6962$). For *Pokémon and video game fans*, playing was also associated with a higher level of physical activity ($F_{1,195}=2.842$, $P=.04$). Finally, the *curious & social* group reported fewer steps on playing days than in nonplaying days, although that difference was not significant.

Discussion

Principal Findings

This study found that Pokémon GO players were motivated to play for a variety of reasons, and these motivations determined their perceived and objective behavioral outcomes of playing. Understanding the drivers of playing behavior, along with factors associated with the satisfaction of playing Pokémon GO, is a central part of using the whole phenomenon of the Pokémon GO craze of 2016 to inform better future health interventions through gaming. Together with understanding the outcomes of playing Pokémon GO, research on playing behavior might contribute to designing more effective interventions to tackle sedentary behaviors, increase physical activity, and increase outdoor socialization among younger adults.

Despite having a limited sample size and focusing on a specific population—that is, undergraduate college students—our analysis provides objectively measured physical activity as an outcome of playing, together with the use of an EMA tool to enhance the monitoring of motivations and perceptions of players. These results constitute a step forward toward empirically measuring the causes that have driven numerous players to Pokémon GO, together with objective measures of their playing experience.

Our results distinguished 3 unique groups from a sample of US college students drawn to Pokémon GO: explicitly seeking physical activity; being Pokémon fans; and being curious about the phenomenon and wanting to explore opportunities to socialize. Belonging to each group was associated with a different set of enjoyment factors and variations of perceived outcomes derived from playing. Due to Pokémon GO's novelty and trendiness, little research has been done on either the determinants or the outcomes of playing Pokémon GO. Until now, to our knowledge, only the study by Rasche et al [29] has assessed players' motivations. Consistent with their findings, this study also found that being a fan of Pokémon was the most frequent motivation to start playing. Undergraduate students are among the intended target of the game, being already familiar with the Pokémon world. According to Bonus et al [16], these players might have been attracted to the game by the power of a retro brand like the Pokémon franchise, stimulating their interest in the new product by triggering nostalgic and positive emotional attachments. Our data,

however, also found a specific group of players drawn to the game by the social aspect and another that mainly sought physical activity. Interestingly, this latter group was also the group that joined Pokémon GO later (with only 100 days of playing experience prior to joining the study). This might indicate that it took people reading or hearing about the physical activity benefits of the game reported in the press to become involved in Pokémon GO. This is also consistent with the idea that peer and social pressure in the form of encouragement from family and friends, together with praise from the press, might influence an individual's adoption of the game [16].

Our data clearly suggest that motivations and exposure effectively determined a player's response and outcomes. For instance, those who started playing because they were Pokémon fans enjoyed Pokémon-related characteristics of the game, but also playing with friends; those seeking physical activity enjoyed catching Pokémon; and those *curious & social* enjoyed the more social aspect of playing Pokémon GO (battling), together with playing with friends and making new discoveries. Playing alongside friends was, in fact, the highest-rated aspect, which also emphasizes the need for considering the social dimension in future games or interventions.

Significantly, *physical activity seekers* were the ones in least agreement with the idea that playing Pokémon GO could improve their physical activity levels. Members of the other groups, however, were more in agreement with Pokémon GO having increased their physical activity. This suggests that Pokémon GO may have a positive secondary outcome on increasing physical activity, but that people seeking exclusively physical activity may end up disappointed due to the limited increase in steps. The most agreed-upon assessment among all groups was that playing Pokémon GO improved their mood. This could have been a consequence of being physically active [30], being outdoors, or even staying focused on a single task while avoiding social media [31]. Also significant is that those who joined looking for increased social interactions (*curious & social*) were the ones most in agreement with the idea that Pokémon GO had improved their social interactions. This may validate the idea that playing Pokémon GO has some positive socialization effects, an idea that has been repeatedly posed by experts [7] but that has not yet, to our knowledge, been tested empirically. Our results also support the idea that Pokémon GO may increase spatial exploration and location awareness. While Pokémon GO fans paid little attention to their location, awareness of surroundings was highly appreciated by those who were playing because they were curious, or for social or physical activity, with the discovery of new public places being the most cited feature. Not paying attention to the surroundings could also be a risk factor, as players can become so focused on the playing experience that they put themselves in danger [12]. However, our study did not ask specifically about risky playing behaviors.

The study's group of players reported higher activity levels on days when they had actually played Pokémon GO. Playing also had different physical activity implications depending on the motivations of each player. Based on steps reported through smartphone accelerometers, our results suggest an 11.05% difference in the number of daily steps between active playing

days (n=7909) and nonplaying days (n=7122). This effect of Pokémon GO on physical activity, however, was not homogeneous across all groups. Pokémon fans registered a 15.37% increase in steps on playing days (from 7077 steps on nonplaying days to 8165 steps on playing days), while for the *physical activity seekers* this increased by 34.76% (from 6962 steps on nonplaying days to 9382 steps on playing days). The *curious & social*, by contrast, reported a 10.71% reduction of steps during playing days (from 7338 steps on nonplaying days to 6552 on playing days). The overall finding is consistent with the only other available study using objective counts of physical activity [21], which found a 22.4% step increase among Pokémon GO users considering only the first week after installing the game. Our motivation-specific results reinforce the idea that physical gains derived from Pokémon GO are not universal, as different player groups, with different motivations and expectations, may be getting different levels of physical activity during and because of their playing experience. Other analyses using self-reported measures of physical activity, with less accuracy but larger sample sizes, also reported slight increases in physical activity [3] and that Pokémon GO was particularly popular among people with sedentary behaviors [5].

Previous research [12] reported that increased socialization and a higher number of visits to green areas and public parks were among the most often reported benefits of the Pokémon GO phenomenon. Our results may contradict this and other exergame examples [32,33], as we did not find an association between those players who were more motivated by social connections and increased physical activity.

Limitations

Despite the use of EMA and objective physical activity through the smartphone accelerometer, this study has limitations. First and foremost, our small sample size limits the conclusions that can be drawn from this study. In the future, extending the study to a larger population, other age groups, and additional locations should validate and confirm the conclusions we reached. While the use of EMA tools provided higher accuracy on the collected data, it also made it necessary to keep surveys, which were administered 3 times a day, reasonably short in order to avoid low response rates. Not enough data were available from those who did not complete the EMA section of the study in order to compare their results with those who successfully completed it. With the short EMA surveys, we still removed 7 participants from the analyses because they did not complete 80% of the 21 surveys.

Conclusions

Bielik et al [34] described 10 design requirements that make exergames successful at promoting physical activity. Of those, Pokémon GO meets 6. (1) *Personal awareness of activity levels* and (2) *providing feedback on the accumulated activity* are met in that Pokémon GO players always know how many steps they have taken and how many times they have played. Pokémon GO also (3) *supports social influences*, both by allowing the sharing of in-game achievements with others and by promoting

spontaneous social interactions. It also (4) provides a *variety of motivational tools* that, as shown by our results, range from playing with the goal of catching Pokémon or playing with the goal of engaging in between-player battles, to playing for exercise or playing to socialize. This wide range of motivational tools creates (5) *short- and long-term incentives* for Pokémon GO players to leave home and engage in physical activity. Pokémon GO does this while (6) *understanding the practical constraints of each player's lifestyle* and allowing important freedom regarding schedules and playing bouts. Bielik and colleague's requirements that are not completely met by Pokémon GO are *giving the user proper credit for [physical] activity*; *ensuring fair play*; *providing the possibility of integrations with other existing solutions*; and, finally, meeting the issue of *data privacy* and how developers are protecting players' data.

Previous research had already demonstrated the positive effect that exergames can have on physical activity among young people [35,36], at the same time that others have demonstrated the impact of social online video games on the development of social capital in the form of new and stronger friendships [37]. The strong links in the literature between social interaction and exercise [38] make it plausible that the effects of Pokémon GO go beyond the mere increased physical activity and enhanced socialization toward a broader concept of mental health and well-being [16]. In particular, what makes Pokémon GO different and more effective than similar kinds of exergames are its social component and the special use of augmented reality that transforms the actual physical surrounding environment into a digital playing field.

Although the direct observed benefits of playing were small, the success of Pokémon GO can encourage future health interventions using active games and exergames. We have demonstrated the potential of this kind of game to increase physical activity levels among US college students. At the same time, we have also demonstrated how the effects were not homogeneous among all players, as motivations and personal attitudes toward the game can change the perceived and objective outcomes. The fact that Pokémon GO is gathering people seeking different experiences is a positive indicator and a note to future interventions that should plan for a broader range of players.

Understanding how to design games to bring together public health interventions will be important in a future with an ever greater presence of mobile games and virtual reality experiences. This study provides emerging evidence to validate some of the suggested positive outcomes of playing Pokémon GO and contributes to understanding the complexity behind gaming behavior and gaming experience. Further insights into how to engage players in even more active playing behaviors, along with new understandings on how to maintain long-term user engagement, will be necessary for the future. Finally, qualitative studies and mixed-methods approaches will be necessary in the future to deepen the conclusions advanced here.

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Conflicts of Interest

None declared.

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Abbreviations

- ANOVA:** analysis of variance
EMA: ecological momentary assessment
IPAQ: International Physical Activity Questionnaire
MET: metabolic equivalent task
PACO: Personal Analytics Companion

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Original Paper

Usability Test of Exercise Games Designed for Rehabilitation of Elderly Patients After Hip Replacement Surgery: Pilot Study

Yun Ling¹, PhD; Louis P Ter Meer², MSc; Zerrin Yumak¹, PhD; Remco C Veltkamp¹, PhD

¹Utrecht University, Utrecht, Netherlands

²Erasmus School of Health Policy and Management, Rotterdam, Netherlands

Corresponding Author:

Yun Ling, PhD

Utrecht University

Princetonplein 5

Utrecht, 3584 CC

Netherlands

Phone: 31 302534116

Fax: 31 302532804

Email: yunlingcn@gmail.com

Abstract

Background: Patients who receive rehabilitation after hip replacement surgery are shown to have increased muscle strength and better functional performance. However, traditional physiotherapy is often tedious and leads to poor adherence. Exercise games, provide ways for increasing the engagement of elderly patients and increase the uptake of rehabilitation exercises.

Objective: The objective of this study was to evaluate Fietsgame (Dutch for *cycling game*), which translates existing rehabilitation exercises into fun exercise games. The system connects exercise games with a patient's personal record and a therapist interface by an Internet of Things server. Thus, both the patient and physiotherapist can monitor the patient's medical status.

Methods: This paper describes a pilot study that evaluates the usability of the Fietsgame. The study was conducted in a rehabilitation center with 9 participants, including 2 physiotherapists and 7 patients. The patients were asked to play 6 exercise games, each lasting about 5 min, under the guidance of a physiotherapist. The mean age of the patients was 74.57 years (standard deviation [SD] 8.28); all the patients were in the recovery process after hip surgery. Surveys were developed to quantitatively measure the usability factors, including presence, enjoyment, pain, exertion, and technology acceptance. Comments on advantages and suggested improvements of our game system provided by the physiotherapists and patients were summarized and their implications were discussed.

Results: The results showed that after successfully playing the games, 75% to 100% of the patients experienced high levels of enjoyment in all the games except the squats game. Patients reported the highest level of exertion in squats when compared with other exercise games. Lunges resulted in the highest dropout rate (43%) due to interference with the Kinect v2 from support chairs. All the patients (100%) found the game system useful and easy to use, felt that it would be a useful tool in their further rehabilitation, and expressed that they would like to use the game in the future. The therapists indicated that the exercise games highly meet the criteria of motor rehabilitation, and they intend to continue using the game as part of their rehabilitation treatment of patients. Comments from the patients and physiotherapists suggest that real-time corrective feedback when patients perform the exercises wrongly and a more personalized user interface with options for increasing or decreasing cognitive load are needed.

Conclusions: The results suggest that Fietsgame can be used as an alternative tool to traditional motor rehabilitation for patients with hip surgery. Lunges and squats are found to be more beneficial for patients who have relatively better balance skills. A follow-up randomized controlled study will be conducted to test the effectiveness of the Fietsgame to investigate how motivating it is over a longer period of time.

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KEYWORDS

rehabilitation exercise; computer games; hip replacement; elderly; physical therapists

Introduction

Background

Elderly people consume a large part of the health care and social services, especially in developed countries [1]. Hip fracture is considered a major problem for elderly people because of its high incidence [2,3] and the related high mortality and morbidity [4,5], and as a consequence the decreased quality of life visible in reduced physical movement [6], and finally the increased costs of health care involved in the treatment of patients [1,2]. The most commonly used treatment method is surgery, which helps patients recover more quickly [7]. Besides, fracture hip replacement is a treatment for patients with abrasion of the hip joints to reduce pain and increase mobility. Establishing rehabilitation programs after hip surgery improves the quality of life of elderly patients [6]. Earlier studies with patients who received outpatient rehabilitation showed increased strength and better functional performance such as self-care ability and mobility after 3 months and 1 year, respectively, compared with those without rehabilitation [5,8]. However, conventional physiotherapy is often experienced as boring by the patient, leading to poor adherence [9].

Due to the engaging, entertaining, and thus motivating properties of exercise games, gaming has been proposed as a valuable instrument to encourage patients' participation in rehabilitation and improve patients' adherence to therapy programs [10]. For example, Pichierri et al [11] and Uzor and Baillie [12] showed better adherence in exercise gaming groups than in the controlled conventional groups. Furthermore, playing an exercise game can be used to distract patients' attention from pain resulting from their surgery or movement, and it thus contributes to the patients' motivation to use exercise games [13,14].

Exercise games have shown equal or superior effectiveness compared with conventional physiotherapy in rehabilitation in patients over 16 years of age [15,16]. A meta-analysis suggests that exercise games are equally effective to improve balance, when considering the aspects of balance and walking speed [15]. Warburton et al [16] showed that, because of improved engagement of the patient, cycling exercise games result in significant improvements in physical fitness, including muscular strength and flexibility, compared with conventional cycling exercise training.

Compared with traditional rehabilitation, exercise games allow for task-specific exercises to be delivered at different difficulty levels. This allows the patient to start at an appropriate level and then proceed, based on a set of goals, with a gradual progression of difficulty. However, according to Skjaeret et al [10], the majority of the studies used commercially available gaming technologies such as the Nintendo Wii game console, Sony PlayStation II, X-Box360, and Dance Dance Revolution. These commercial games are originally designed for entertainment, targeted at younger people, and not based on exercise principles. Commercial games are also too difficult and not engaging enough for elderly. Therefore, effective exercise games that are specific to the needs of the elderly are needed.

Achieving the goal of rehabilitation after hip surgery requires accurate and appropriate tracking and feedback. Therefore, we developed Fietsgame using Microsoft Kinect as an off-the-shelf three-dimensional (3D) depth camera. Kinect v2 offers marker-free full-body tracking on a conventional personal computer (PC). It has a wide field-of-view to provide full-body control of animated virtual characters. This allows the virtual character on the screen to mirror the movements of the user in real time. Earlier studies concluded that Kinect v2 has the potential to be used as a reliable and valid clinical measurement tool [17-19]. Hence, the physiotherapists can set the range of knee angle and hip angle as they usually do in the traditional rehabilitation training when they use the exercise games.

Objectives

To the best of our knowledge, only a few Kinect games offer exercises with full-body animated virtual characters and configurable level of difficulties, which are required for rehabilitation after hip surgery. Earlier studies using Kinect to design rehabilitation exercise games either focus on rehabilitation of the upper body [20-23] or use simple balance training exercises [24-27]. These games are lacking the variety of exercises with a very limited range of difficulty levels. We, therefore, have developed a series of immersive and motivating exercise games with real-time feedback and a configurable wide range of difficulty levels.

In general, applications supporting the management of illnesses or providing assistance in daily living activities for the elderly showed good usability and high acceptance [28,29]. For example, Arnhold et al [28] showed that applications for elderly diabetes patients have moderate to good usability. Hossain and Ahmed [29] found that elderly participants interacted with the virtual caregiver easily and were highly satisfied with its assistance during their daily activities. Exercise games are designed to elicit motivation for rehabilitation training. Studies testing the usability of exercise games among the elderly population showed that the games that were specifically designed for the elderly were positively evaluated by the elderly participants with respect to their usability, user acceptance, enjoyment, and its rehabilitation effect [30-32].

In this pilot study, we were interested in getting an insight into the point of view from the physiotherapists, in particular whether the exercise games satisfy the nature of a motor rehabilitation program for elderly patients after hip surgery (Research question 1) and whether they have the intention to use the exercise games to treat the patients in the future (Research question 2). Furthermore, we investigated whether the patients experienced a high level of presence and enjoyment and an expected level of exertion and pain (Research question 3), and whether they found the games easy to use and wanted to continue using the exercise games to do further rehabilitation (Research question 4).

Methods

Participants

In total, 2 physiotherapists (a male aged 31 years and a female aged 29 years) and 7 patients (5 females and 2 males) with age

range of 60 to 82 years (mean 74.57, SD 8.28) from Aafje Rehabilitation Center in Rotterdam, The Netherlands, participated in this study. The patients were recovering from hip joint replacement (hip arthroplasty) or (unipolar) short-stem hemiarthroplasty surgery. The inclusion criteria of the patients were that they should be capable of performing the exercises and understanding the instructions of the exercise game. Patients with acute illness in the past 3 weeks, with mental disorders, or with poor visual acuity (not capable of seeing the visual features on the TV screen) were excluded.

All participants provided written informed consent before their participation in the experiment. After completing the experiment and answering the questions, they received a compensation gift. The exercise games imposed the same risk as a regular therapy session, because the patients performed the same exercises as part of their normal treatment. Whenever the patient was playing the game, a physiotherapist was always present. The load of the exercise games was comparable with the normal treatment for both the patients and the therapists, according to the physiotherapists. This study has been approved by the board of directors of the rehabilitation center of Aafje and the ethical committee of Utrecht University.

The Fietsgame

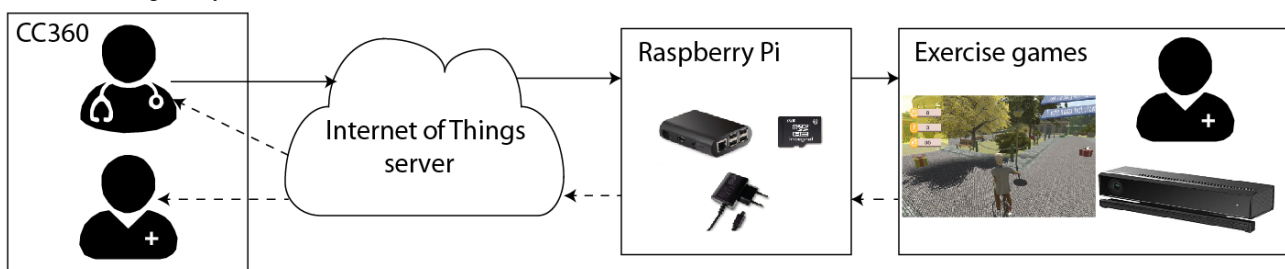
The Fietsgame has been designed by a consortium of physiotherapists, game designers, researchers, and an information technology company with the goal of improving the rehabilitation process. The specific aim was to increase the mobility of the joints and surrounding soft tissues and to increase

muscular strength as well as endurance. The system has the following two components: the exercise games and Community Care 360 (CC360) with a therapist control interface and the patient's medical record. The exercise games and CC360 are connected by the Internet of Things (IoT) server from Consultants to Government and Industries (CGI) [33]. The games were run on a PC with Windows 10 software and displayed on a 48-inch TV. A Raspberry Pi device was used to connect the PC to the IoT platform.

Figure 1 shows the architecture of the Fietsgame. The system works as follows: first, basic information such as the age, the date of intake, and a photo of the patient is fed into the patient's medical record in CC360 and sent to the IoT server. Then, the patient logs into the system through a face recognition technology embedded in the exercise game using Kinect v2. We used face recognition to identify the user because of the following two reasons: first, it allows natural interaction with the system, with high recognition accuracy [34-37], and second, in the future, we can extend the exercise game system with emotion recognition using the camera [38-40].

After the exercise game recognizes the identity of the patient, assigned workout is automatically retrieved from the server using the Raspberry Pi. When the patient completes the exercise game, his or her workout data such as the number of exercises, knee or hip angles, and game scores are sent to the IoT platform and stored for further analysis. Both the patient and the physiotherapist can read the patient's workout data through CC360.

Figure 1. The Fietsgame system.



The Exercise Games

The purpose of hip rehabilitation is to reduce symptoms such as pain and inflammation and improve hip joint function approached through a systematic progression, depending on the patient's present pathology and functional needs. The patients must understand the related precautions and the recommended progression for their individual situations. The physiotherapists advise a suitable exercise program by defining frequency, duration, and range of motion after considering the patient's level of discomfort and physical status of the hip joints [41]. In our case, we created the exercise games based on the physiotherapists' advice and requirements over a period of 4 years. The physiotherapists gave their suggestions and requirements to the design team regarding the exercises they need to have and what parameters the design team needs to configure in the rehabilitation program. Before the pilot test, we did 2 usability tests with 2 real patients and 2

physiotherapists to improve the usability issues of the earlier version of the exercise games. This paper presents the results of testing the beta version of the exercise games.

The games are implemented using the Unity 3D game engine. There are 6 exercise games with 6 different balance exercises: cycling in a life-like virtual village for stepping, dancing under the spotlight with fellow dancers for sidestepping, ringing the bell in a church for squats, picking up apples for lunges, playing football for back kicks, and fishing on a boat for single leg stance (Figures 2-7). The participant's avatar is presented from a third person perspective. The therapist can adapt the difficulty level of the exercise games according to the patient's physical condition and level of discomfort. Possible configuration parameters for each game are shown in Figures 2-7. In addition to the final scores, the games consist of motivational elements such as awards and sounds. The interface of the game is in Dutch. In the following paragraphs, we summarize the play of each game.

Figure 2. The cycling game—stepping; left: virtual environment, right: configurable variables.



1. Number of steps
2. Knee angle (mean, standard deviation)

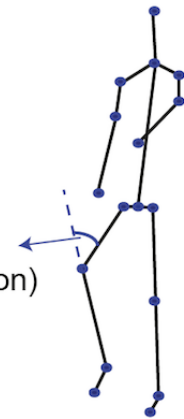
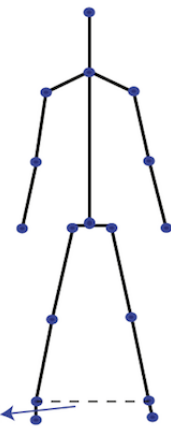


Figure 7. The dancing game—sidestepping; left: virtual environment, right: configurable variables.



1. Number of steps
2. Minimum step width



Cycling

In the cycling game (Figure 2), the player is instructed to finish stepping exercises with the minimum required knee angle. When the player performs the exercises correctly, the bike goes forward smoothly. If not, the bike stops going forward. There are gift boxes and pedestrians on the road. An arrow indicates when the player comes to the end of the road. The player needs to put out his/her left (or right) hand to turn left (or right). If the player follows the direction of the arrow, she/he can get to the destination faster. The player can pick up the gift box to earn money by running over it and can wave to the pedestrians to earn social points. When the player waves at the pedestrians, the bell of the bike rings. The configurable variables in this

game are the number of steps and required knee angle with mean and SD.

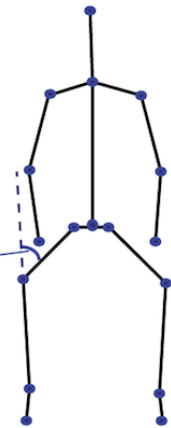
Dancing

The dancing game (Figure 3) works as follows: the player is expected to do the sidestepping exercises with the minimum required step width. The arrow in the interface indicates which side the player should take a step. When the exercise is performed successfully, the avatars in the virtual environment give feedback by dancing and clapping their hands. The avatars stay in the standing pose if the player does not perform the exercise correctly. The configurable variables are the number of steps and minimum step width.

Figure 3. The ringing the bell game—squats; left: virtual environment, right: configurable variables.



1. Number of squats
2. Squat duration
3. Knee angle range



Ringing the Bell

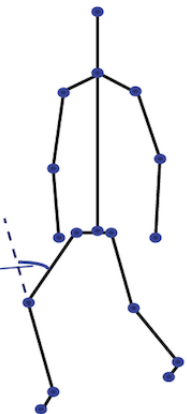
During the ringing the bell game (Figure 4), the player is expected to do squats with the required knee angle and duration as defined in the configuration file. When the squat pose is correct, the avatar mimics the player and a circle indicating the progress starts to fill with brighter colors to count for the duration of the squat. When the patient manages to stay in balance for the required duration of the squat, the circle is fully

bright and the bell rings, indicating the accomplishment of the exercise. When the patient fails in doing the squat correctly, the progress circle does not fully turn to a bright color. Furthermore, the brightened part of the circle disappears if the player fails to hold the correct squat pose for the required duration and needs to start again. The configurable variables are the number of squats, squat duration, and knee angle range (minimum and maximum).

Figure 4. The apple picking game—lunges; left: virtual environment, right: configurable variables.



1. Number of lunges
2. Lunge duration
3. Minimum foremost knee angle
4. Frequency of exercises for the left or right leg



Apple Picking

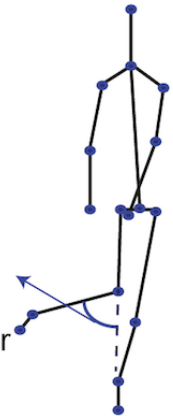
The apple picking game (Figure 5) asks the player to perform lunges with a required minimum front knee angle. An apple falls from the left/right side of the avatar, and the player should step the mirrored left/right leg forward to perform lunges. The function of the yellow circle works similar to the one in the ringing the bell game. The avatar mimics the player’s movement, and the circle starts to fill with brighter colors to count for the duration of the lunge when the lunge pose is correct. When the patient manages to stay in balance for the required duration, the

circle is fully bright and the apple is picked up and thrown into the basket. When the patient fails in doing the exercise correctly, the yellow circle does not start to fill with brighter colors to count the duration of holding the lunge. The brightened part of the circle disappears if the player fails to hold the correct pose for the required duration. The basket shown in the front of the avatar in the game is to show the award by playing lunges successfully. It has no other function in the game. The configurable variables are the number of lunges, lunge duration, minimum foremost knee angle, and the frequency of exercises for the left or right leg.

Figure 5. The football playing game—back kicks; left: virtual environment, right: configurable variables.



1. Number of back kicks
2. Back kick duration
3. Knee angle (mean and standard deviation)
4. Frequency of exercises for the left or right leg



Football Playing

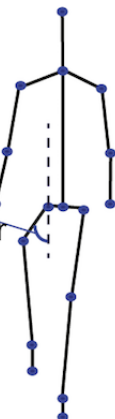
The goal of the football game (Figure 6) is to kick the ball to one of the 5 holes. At each turn, the number assigned to the holes is changed, and when the user aims at the hole with a higher number, he/she scores higher. The player raises one of the legs to prepare for a back kick and holds the leg in that position for the duration defined in the settings. The user turns his/her upper body to left/right to aim for the hole while keeping the leg raised. An arrow indicates which leg should be used to

do the back kicks. The real-time feedback function of the yellow circle is the same as the ones in the ringing the bell and the apple picking games. Once this duration of back kick is completed, feedback is provided by showing the avatar kicking the football out. No kicking actions of the avatar will be shown when the player does not perform the exercise correctly. The configurable variables are number of back kicks, back kick duration, knee angle (mean and SD), and the frequency of exercises for the left or right leg.

Figure 6. The fishing game—one leg stance; left: virtual environment, right: configurable variables.



1. Number of one leg stance
2. Stance duration
3. Minimum hip angle
4. Frequency of exercises for the left or right hip



Fishing

The objective of the fishing game (Figure 7) is to perform single leg stance. The player is required to perform one-leg stance exercise with a configured minimum hip angle and holding time. A fish is caught and put into the boat when the player performs the exercise correctly in each turn. An arrow indicates which leg should do the one leg stance. The real-time feedback function of the yellow circle is the same as the ones in the ringing the bell, the apple picking, and the football playing games. No fish will be caught if the player fails in doing one leg stance. The configurable variables are the number of one leg stances, stance duration, minimum hip angle, and the frequency of exercises for the left or right hip.

Community Care 360

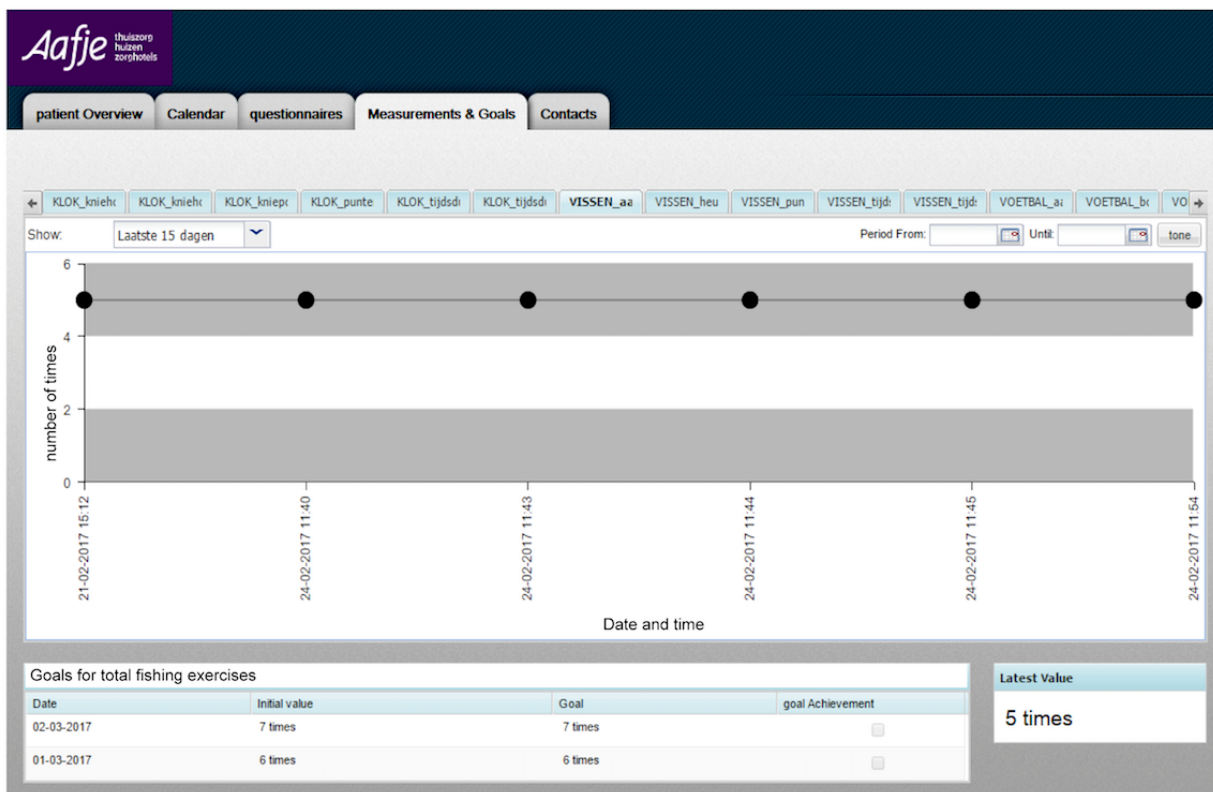
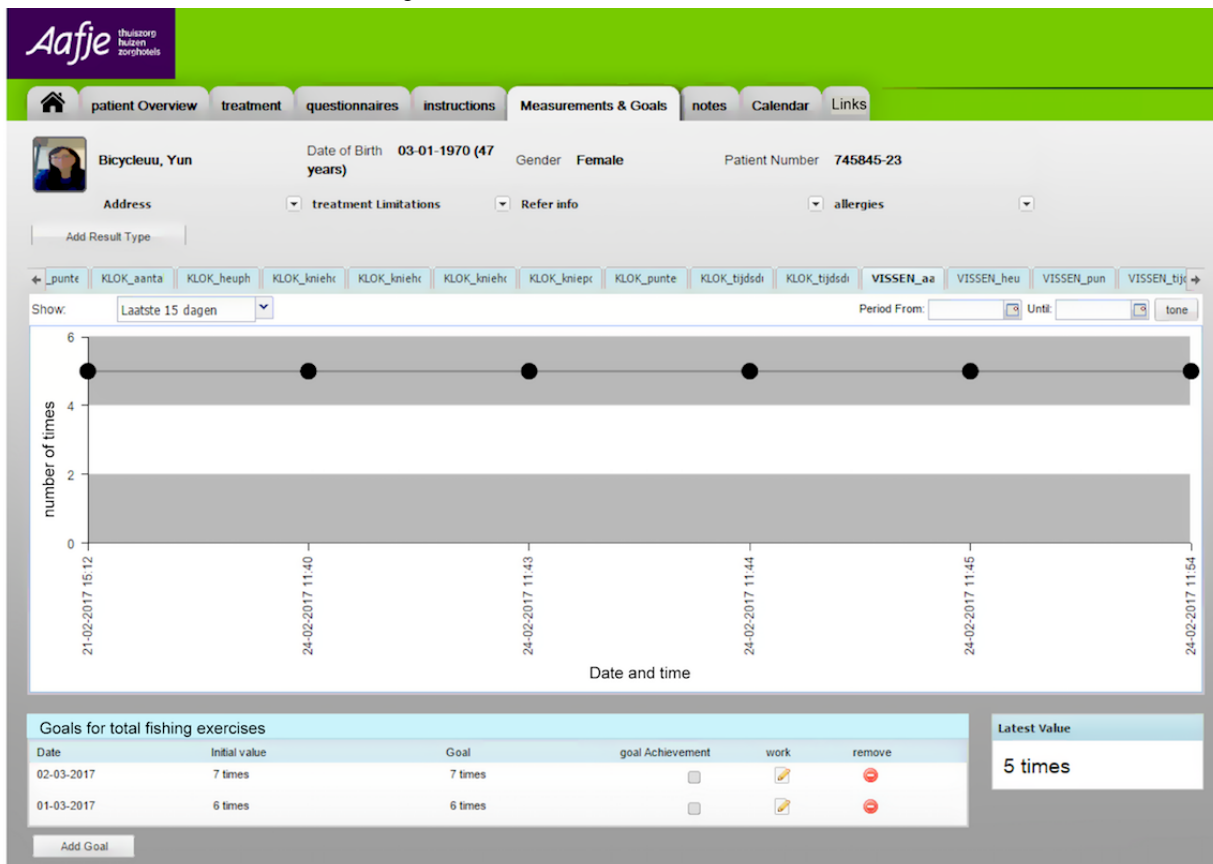
CC360 is a patient-centric health platform that allows the patients, health care professionals, and other stakeholders to monitor and manage the patients' health. CC360 provides

applications for both the therapists and the patients. The configuration interface (Figure 8 top, originally in Dutch; see also Multimedia Appendix 1) allows the physiotherapists to set the goals of the game according to the patients' conditions and the rehabilitation goals. The therapist can specify the treatment for each patient such as the required range of the knee and hip angles during the game, depending on the patient's physical capabilities. Thus, the therapist application allows the physiotherapists to work more effectively, following whether a patient is following the treatment plan and being prepared for consultations. In the patient application (Figure 8 bottom, originally in Dutch; see also Multimedia Appendix 2), the patient can see the exercises assigned to him/her by his/her physiotherapist and play the exercise games by performing the required therapeutic movements. The game software assesses the performance of the patient by analyzing the data captured by Kinect v2. The final results, such as the number of successfully accomplished movements, knee angle, hip angle, and start and end time of the exercises, will be recorded and

sent to the IoT platform and can be accessed through the therapist and patient applications in CC360. The exercises can also be assigned through a local configuration file on a PC when

the patient receives no assignment from the physiotherapist through CC360.

Figure 8. Top: the physiotherapist control interface; bottom: the patient interface showing patient’s medical record in CC360. The configuration parameter `vissen_aantal` means the number of fishing exercises.



Measures

The measurements used in the experiment include psychometric tools, such as self-reported questionnaires, and objective behavioral measurements. Objective behavioral measures such as knee angle, step width, hip angle, and the number of successfully finished exercises were captured by Kinect v2 and sent to the IoT platform via the Raspberry Pi. The experiment was also video-recorded for further analysis of the comments of the therapists and the patients during the exercise game. Self-reported questionnaires were filled in by the therapists and were answered by the patients. The questionnaire for the patients was designed to measure the subjective feeling of presence, enjoyment, exertion, pain level, and technology acceptance, whereas the questionnaire for the physiotherapist was aimed to get an expert opinion on the usability of the game from the technology acceptance and rehabilitation point of view. More details about the questionnaires are given below, and the questionnaires for patients and physiotherapists are attached in [Multimedia Appendices 3](#) and [4](#), respectively.

Self-Reported Questionnaires for the Patients

At the beginning of the experiment, patients were asked to fill in a questionnaire containing the following personal data: date of intake, the current number of daily exercise sessions, age, gender, mother tongue, gameplay experience, and social status. Visual acuity was measured using the Freiburg Visual Acuity Test at a distance of 3 m [42]. The experience of playing the exercise game was measured through standard questionnaires, including feelings of presence, enjoyment, exertion, pain level, and technology acceptance.

The concept of presence in virtual reality covers three aspects: spatial presence, social presence, and copresence [43]. In this study, we are interested in testing whether patients' attention can be distracted by the real world. Therefore, spatial presence where patients' feeling of being present in the virtual environment instead of being aware of the real world is important. Schubert et al [44] created an Igroup presence questionnaire (IPQ), which consists of 14 items rated on a 7-point Likert scale to measure spatial presence. The scores on the 14 IPQ items are mapped onto 3 subscales: spatial presence (the relation between the virtual reality and the physical real world), involvement (the awareness devoted to the virtual reality), and experienced realism (the sense of reality attributed to the virtual reality). It also includes one general item that assesses the general feeling of being in the virtual reality. To lower the burden of answering questions for the elderly, we measured presence using only the general item.

Enjoyment was tested by using a 1-item question on a 7-point Likert scale, "Do you find the exercise game interesting?" [45]. The Perceived Exertion Scale [46] was used as a measure of perceived exertion. It is a 15-point scale ranging from 6 (very light exertion) to 20 (very hard exertion). The Perceived Exertion Scale is widely used and has adequate reliability and validity. The perceived pain level was measured using the Visual Analogue Scale (VAS) [47]. The VAS contains 11 brief pain severity descriptions. Scores on the VAS ranged from 0 (no pain) to 10 (very severe pain).

The adapted Technology Acceptance Model (TAM) from Hu et al [48] was used in this study for measuring patients' and physiotherapists' intention to use the game system. It was suggested that TAM was able to provide a reasonable depiction of physicians' intention to use telemedicine technology [48]. TAM consists of 21 items with the following 4 subscales: perceived ease of use, perceived usefulness of the technology, attitude toward using the technology, and intention to use the technology. The participants' responses were rated on a 7-point Likert scale from -3 (strongly disagree) to 3 (strongly agree).

Self-Reported Questionnaires for the Physiotherapists

At the beginning of the experiment, the physiotherapists were asked to fill in a questionnaire, which recorded their age, gender, mother tongue, education, and gameplay experience. The experience of using the exercise game was investigated through questionnaires, including criteria for rehabilitation of the exercise game [49] and the adapted TAM from Hu et al [48]. The questions in the TAM questionnaires were virtually the same for both the patients and the physiotherapists, but the terms used were rehabilitation and patient care for patients and physiotherapists, respectively.

Regarding the usability of the game for motor rehabilitation, we used a revised version of the design criteria for stroke rehabilitation programs for elderly users from Flores et al [49]. It includes the following five criteria:

1. Adaptability to the motor skill level of the patient. As motor impairments vary among patients and patients' motor skills improve over time, the changeable level of difficulty in the exercise game is necessary.
2. Meaningful tasks. Tasks should be incorporated so that exercises in the game can be correlated with daily life activities.
3. Appropriate feedback for both the patient and the physiotherapist. The exercise game should provide real-time feedback on how well the patient is doing and how much she/he has been improving and provide encouraging feedback to stimulate the patient to adhere to the exercise game. Providing exercise record such as charting the history of patients' exercise accomplishments can help the physiotherapist to better plan future therapy sessions.
4. Therapy appropriate range of motion. This refers to the extent the game demands the therapeutic motions needed for the rehabilitation program of patients after hip surgery.
5. Focus diverted from exercise. The game should be fun enough to divert patients' attention from the exercises to the objectives of the gameplay.

Participants' responses were rated on a 7-point Likert scale from -3 (strongly disagree) to 3 (strongly agree).

Qualitative Feedback

After playing each exercise game, all the participants were asked to give general feedback and comments on each game. At the end of the experiment, participants were asked to discuss their favorite and least favorite part of playing the exercise game in open questions.

Procedure

To ensure high quality of recognition, we tested the exercise games in a controlled environment. To be more specific, the camera was set to track the closest person as long as possible, and only the player is within a distance of 2 to 3 m in front of the camera where the tracking accuracy is the best [50]. No objects or other persons are between the player and the Kinect v2 camera. There were 3 experimenters, 1 for the technical support of CC360 and making notes of the comments given by the patients and the physiotherapists, 1 for the technical support of the exercise game and also for making notes of the comments from the participants, and 1 for administrating the consent, questionnaires, and debriefing of the experiment.

After obtaining consent and basic information from the patients and the physiotherapists, participants were introduced to the exercise games, including the Kinect v2 sensor and CC360. One of the experimenters took a picture of the patient and uploaded it to the IoT platform for facial recognition to start the exercise games. The therapist then assigned the exercises according to the patient's recovery status through the configuration file on a PC. The patients were asked to play 6 different exercise games, each lasting about 5 min. The physiotherapist was always in the same room as a guide for the patient and answered all the questions the patient asked during the game. Each participant was assessed individually during the session, which in total lasted about 60 min. Patient's behavior and the voice of the experimenters and the physiotherapist were recorded by a laptop camera for later transcription.

Before each exercise game, the physiotherapist showed how to play the exercise game correctly and explained the instructions on the screen. Participants, if applicable, wore their prescription glasses during the experiment. All the patients used chairs to prevent falling. The chairs were placed on the left or right and behind the player. After each exercise game, the patients were asked to report their experienced level of presence, enjoyment, perceived exertion, and pain level by one of the experimenters and their reported scores were noted in the printed hard copy of questionnaire; the physiotherapists were asked to fill in a short questionnaire, which measures whether the exercise game meets the criteria for rehabilitation. Both the patient and the physiotherapist were asked to give a general feedback and comments on the game that the patient just played. Objective behavioral measures, including knee angle, step width, and hip angle, and the number of successfully finished exercises, were captured by Kinect v2 during the gameplay.

At the end of the experiment, both the patients and the therapists were asked to fill in the questionnaire for the TAM and to give their general comments about the exercise games. The patients were also asked whether they felt any discomfort before they

left the room. They were requested to rest until they feel better when they experienced any discomfort. After completing the experiment, participants were debriefed and given a gift of 10 euros for their contribution. As CC360 is a widely used commercial product [33], we did not ask the patients or physiotherapists to use and evaluate CC360 itself.

Data Analyses

All the behavioral data and self-reported scores of the questionnaires were analyzed with SPSS statistics package version 24. To answer our research questions, the measured data, including behavioral and self-reported data, were analyzed using descriptive statistics for all the 6 exercise games, and 2 trained researchers coded the qualitative feedback from patients and physiotherapists separately. Under the broad question, themes emerged from the coded data. The researchers discussed and refined the codes, that is, codes with similar meanings were grouped together, and the more frequently a code appeared, the more the theme was strengthened. We then analyzed the codes addressing gaming experience, game design, system operation, usefulness, and intention to use the exercise games.

Results

Patient Descriptions

A summary of demographic data and personal information of the patients is provided in [Table 1](#). All the patients had their intake after hip surgery at Aafje Rehabilitation Centre between January and November in 2016. The pilot test was conducted in December 2016. Patients' visual acuities were sufficient for playing the exercise games, which were rendered on a 48-inch TV placed at a distance of 3 m in front of them.

Median and interquartile ranges of workout assignments in the configuration from the guiding physiotherapist are provided in [Table 2](#). Some of the configured variables such as the required knee angle in the cycling game were the same for all the patients. To keep the configuration of the knee angle more consistent between different exercise games, we need to change the mean and SD of the knee angle into minimum and maximum knee angles for the cycling game and the football playing game in the next version of the games.

All the patients used chairs to keep balance during the exercises. [Figure 9](#) shows the number of participants who successfully accomplished assignments from the physiotherapist, who dropped out because of personal reasons, and who could not finish the exercise because of recognition errors. Of the patients, 2 dropped out of cycling and fishing because of personal schedules, and 3 participants had to give up playing apple picking to do lunges because the exercise game could not recognize their movement even though they exercised correctly according to the guiding physiotherapist.

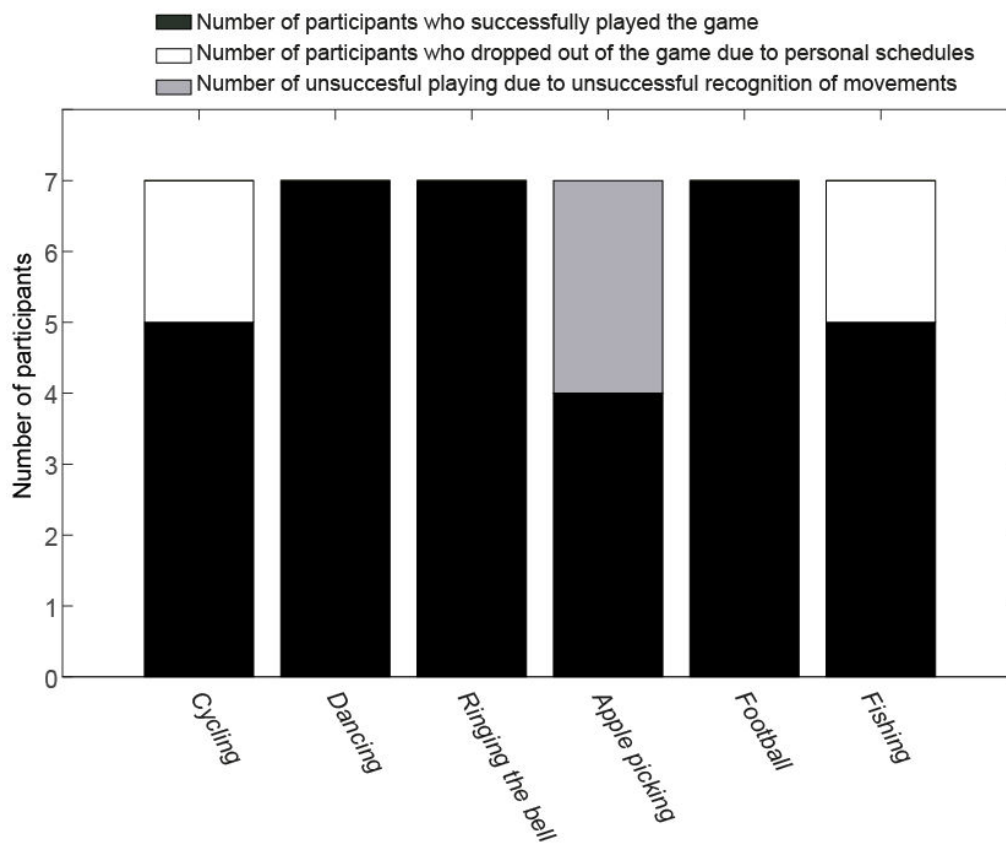
Table 1. Demographic and personal data of the patients.

Patient	Planned exercises per day	Age	Gender	Native language	Visual acuity	Sport	Frequency of playing computer games	Living status
1	2	70	Female	Dutch	0.69	Physio-training	Occasionally	Alone
2	3	82	Female	Dutch	0.48	Fitness and physio-training	Everyday	With partner
3	6	82	Male	Dutch	0.66	Physio-training	Never	With partner
4	3	60	Female	Dutch	0.73	Swimming, walking, and physio-training	Never	Alone
5	4	81	Female	Danish	0.64	Nordic walking and physio-training	Never	Alone
6	2	77	Female	Hungarian	0.53	Physio-training	Never	Alone
7	4	70	Male	Dutch	0.53	Coordinating football in the field and physio-training	Never	Alone

Table 2. Patients' workout assignments in the exercise games (medians and interquartile ranges).

Games	Behavioral measurements	Median	Interquartile range
Cycling	Repeated number of steps	40	56
	Mean knee angle (degree)	45	N/A
	Knee angle standard deviation (degree)	10	N/A
Dancing	Repeated number of steps	10	N/A
	Minimum step width (cm)	30	10
Ringing the bell	Repeated number of squats	5	N/A
	Squats timer (second)	2	1
	Knee angle minimum (degree)	40	N/A
	Knee angle maximum (degree)	100	N/A
Apple picking	Repeated number of lunges	5	N/A
	Time to hold the lunges (second)	2	0
	Foremost minimum knee angle (degree)	30	0
Football playing	Repeated number of back kicks	10	N/A
	Standing timer (second)	3	0
	Mean knee angle (degree)	30	N/A
	Knee angle standard deviation (degree)	10	N/A
Fishing	Repeated number of one leg stance	10	N/A
	Standing timer (second)	3	1
	Minimum hip angle (degree)	80	20

Figure 9. Number of participants who successfully played the game, who dropped out of the game, and who could not finish the assignments because of the unsuccessful recognition of their movements.

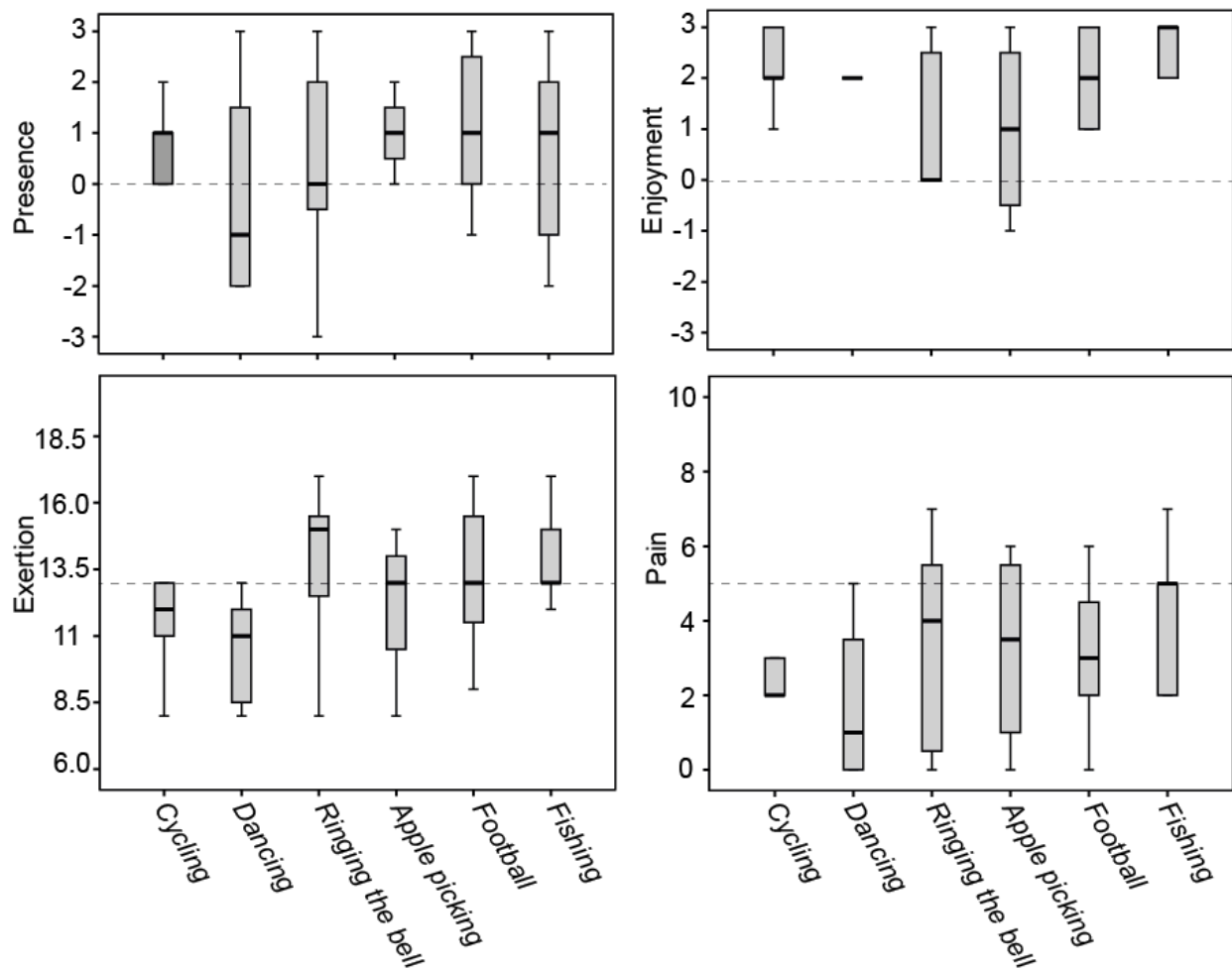


Patients' Gaming Experience

Medians and interquartile ranges of patients' perceived feelings of presence, enjoyment, exertion, and pain during each exercise game are shown in Figure 10. The score of each game was only from those participants who successfully accomplished the assignment as assigned by the physiotherapist in the exercise game. The majority of the participants reported high levels of presence (with presence score >0) in cycling (60%), apple picking (75%), football (71%), and fishing (60%) but a low level of presence in dancing (57% of the participants scored enjoyment below 0). Presence score for ringing the bell was evenly distributed over the score range. All the participants (100%) found cycling, dancing, and football enjoyable (with

enjoyment score >0). Most of the participants found apple picking (75%) and fishing (80%) enjoyable to use, but only 43% of the participants rated ringing the bell enjoyable. All the participants (100%) experienced low to moderate exertion (exertion ≤ 13) in cycling and dancing. The majority of the participants also indicated low to moderate levels of exertion in apple picking (75%), football (57%), and fishing (60%), and a high level of exertion (exertion >13) in ringing the bell (57%). Most of the participants had low to moderate pain (score ≤ 5) while playing the exercise games such as cycling (80%), dancing (100%), ringing the bell (71%), apple picking (75%), football (86%), and fishing (80%). Very few participants reported a pain score above 5 during their exercises.

Figure 10. Medians and interquartile ranges of patients' perceived feeling of presence, enjoyment, exertion, and pain for all the 6 exercise games. Scoring of presence and enjoyment ranged from -3 to 3, scoring of exertion ranged from 6 to 20, and scoring of pain ranged from 0 to 10. The horizontal line represents the median and the distance between the top, and the bottom of the bar represents the interquartile range.



Physiotherapists' Evaluation of Game Design

The scores on the 5 items about whether the exercise games satisfy the nature of a motor rehabilitation program from 2 physiotherapists are shown in Table 3. Both physiotherapists expressed positive attitudes toward the exercise games on all the 5 items: (1) adaptability of the game to the motor skill level of patients, (2) providing meaningful tasks to promote quality of life, (3) giving appropriate feedback for both the patient and the physiotherapist to encourage adherence to the game and keep track of the patient's recovery status, (4) staying within

therapy-appropriate range of motion, and (5) diverting the patient's consciousness from exercise toward game playing.

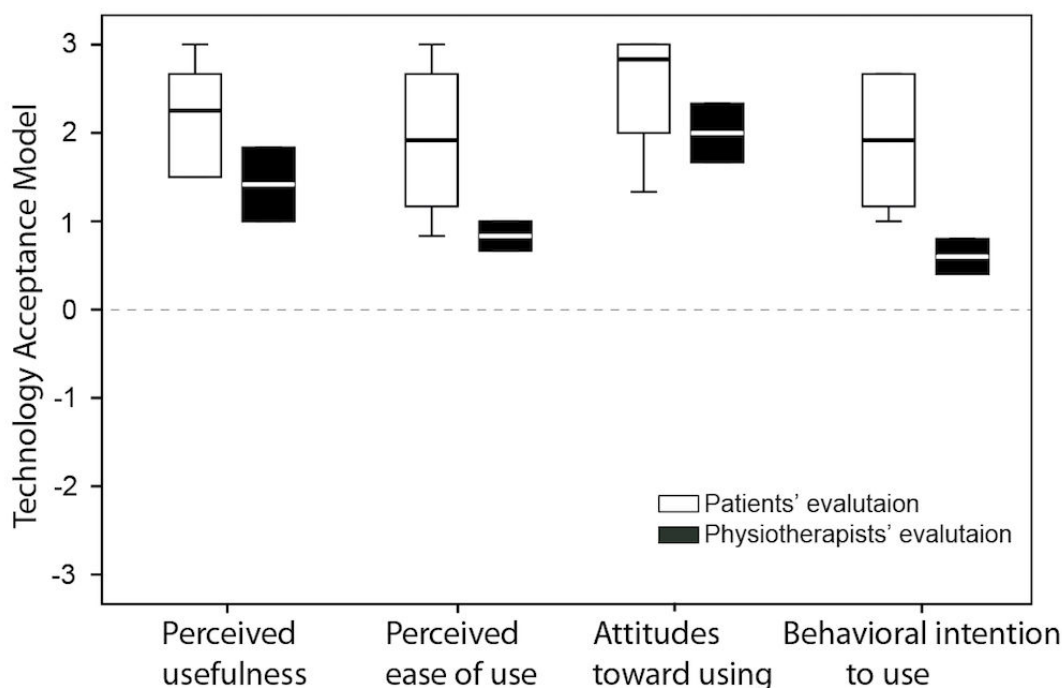
Technology Acceptance Model

Figure 11 presents the medians and interquartile ranges of TAM items that were evaluated by both the patients and the physiotherapists. The exercise games were considered to be useful and easy to use. The participants expressed positive attitudes toward using the exercise games, as well as an intention to continue using the exercise games in their future rehabilitation or patient care.

Table 3. Evaluation of game design (scoring ranged from -3 to 3).

Game design evaluation	Cycling	Dancing	Ringing the bell	Apple picking	Football playing	Fishing
Physiotherapist 1						
Adaptability	2	2	0	1	0	2
Meaningful tasks	1	2	2	2	1	2
Appropriate feedback	1	2	2	2	2	2
Range of motion	2	2	2	2	2	2
Diverted focus	2	2	2	2	2	2
Physiotherapist 2						
Adaptability	2	2	1	2	2	2
Meaningful tasks	2	2	1	3	2	3
Appropriate feedback	2	2	1	2	2	3
Range of motion	2	2	1	2	2	2
Diverted focus	3	3	1	3	1	3

Figure 11. Medians and interquartile ranges of evaluation of Technology Acceptance Model (TAM) from both the patients and the physiotherapists. Scoring ranged from -3 to 3. The horizontal line represents the median, and the distance between the top and the bottom of the bar represents the interquartile range.



Qualitative Feedback and Implications for Design Guidelines

Comments provided by the physiotherapists and the patients and their implications are presented in Table 4. In general, we received very positive feedback. The patients liked and enjoyed the games a lot, and sometimes they were genuinely excited. The game design, for example, the beautiful virtual environment, background music, and rewarding sound, brought in enjoyment to the patients. The patients can quickly exercise on their own in the exercise games. The players found the gameplay experience comparable with real physiotherapy and expressed intention to play again. Despite the overall positive comments

on the *gaming experience, usefulness, and intention for future use*, we also encountered some issues relating to *game design and movement recognition by Kinect v2*. We discuss the main issues revealed from the negative comments and the corresponding implications for future work below. The requirements and implications hold for all the Kinect exercise games targeting the elderly population.

Game Design

Cognitive Load

For some players, the exercise games were too complicated because of the requirement of engaging in multiple activities

simultaneously. For example, in the cycling game, the patients sometimes need to do the stepping exercise, collect gift boxes and wave to the virtual pedestrians, and indicate directions occasionally at the same moment. Some patients found it difficult to follow the instruction arrow indicating which leg they should practice in the football playing game. However, most of the patients thought the game interface was rather easy to understand. Minimizing the amount of information presented on the screen might allow older patients with poor cognitive skills to perceive information. Hence, older patients can follow the instruction and commands more easily [28]. To tailor our exercise games to individual needs of cognitive challenges, picking gift boxes and waving to the other virtual humans should be optional in the cycling game. We believe that as the patients become more experienced with the games and their performances improve, the cognitive load of the games can be made more challenging by introducing levels. In this way, patients can be mentally challenged over a longer period, thus maintaining long-term exercise habits.

Lack of Real-Time Feedback on Wrong Movements

Some patients were unsure of what action should take place at a particular time. Providing helpful information and feedback at the appropriate time throughout the game will be beneficial [51]. For example, a real-time instruction such as how far away the patients' knee angle is from the required knee angle should be given when the patient is performing the cycling game. How far the patients are away from achieving the minimum step width should be shown on the screen while playing the dancing game. Similarly, instructions such as how far away the patient's knee/hip angles are from the required knee/hip angles and how much time is left for the required duration should be given when the patient is performing the rest of the games.

Mismatched Movements

Some patients got confused when the movement of the representing avatar did not match their movements when playing the dancing and football games. The patients were asked to do

sidestepping without clapping hands when playing the dancing game, and they do not need to shoot the ball when doing back kick in the football game. Instructions showing that movements such as clapping hands and shooting the ball are not compulsory should be given at the beginning of the games to help the patients understand how the games actually worked.

Balance Skills

Patients at the beginning phase of their physiotherapy found some of the games more difficult. For example, it was difficult for them to do sidestepping in the dancing game. During the cycling game, waving to the avatars and indicating directions raising one of the hands were difficult for some of them because of impaired balance. Therefore, we suggest that the stepping exercise should not require the patient to go to the same side for more than once. Waving to the avatars can be optional in the game. Other ways for indicating directions such as turning the upper body or automatically changing directions should be configurable for patients with poor balance skills.

Indistinguishable Objects

Patients complained that all the fishes looked similar and they prefer varieties in the game content.

Kinect Tracking

The Kinect did not properly recognize squats and lunges played by a few of the female patients with a wide blouse or obesity. Chairs, mirrors, and other objects in the environment sometimes interfered with the Kinect tracking. Of the participants, 3 had to quit playing the apple picking game as their lunges were not recognized. We observed that Kinect v2 could recognize lunges for patients with relatively normal mass level even with support chairs; however, for patients with obesity, it did not recognize their lunges. Furthermore, we found that Kinect v2 could not recognize movements of patients with a wide blouse or trousers; it worked better when they changed their clothes to relatively tight ones. Hence, we suggest that players wear relatively tight clothes when playing Kinect exercise games.

Table 4. Comments made by the physiotherapists, the patients, and the implications. Note that feedbacks from the physiotherapists are in *italic*.

Exercise games	Positive comments	Negative comments	Implications
Cycling	"I like this game a lot!"	<i>"It is difficult for the patients who are at the beginning phase of their physiotherapy to wave to other virtual humans or to put out a hand to indicate direction."</i>	Picking gift boxes and waving to the other virtual humans should be optional in the game.
	"I like the beautiful village in the virtual environment."	"The bike runs too fast and it made me dizzy." "I tried not to run over the gift boxes on the street."	The speed of the bike should be configurable. Other ways for indicating directions such as turn the upper body should be configurable.
Dancing	"The game is nice. It is much better than the boring exercises we normally do."	<i>"As the patients were using chairs to support balance, it was difficult to go to the same side for 2 or more side steps."</i>	For patients who need support for balance, stepping exercise should not require the patient to go to the same side for more than once.
	"The music is good."	"My movements did not match with the movements of the dancing avatars on the screen."	Patients should be told that they could clap their hands if they want, but it is not required in the exercise.
	"I really looked forward to dancing and it was even better than I expected." "The game looks easier than it really is."		
Ringing the bell	"It is a nice game."	<i>"It is a difficult game; hence, patients' pleasure is lost."</i>	It is a difficult game for the patients, and it is more suitable for patients who have better balance skills.
	"The rewarding music brings in enjoyment in the player."	<i>"It is a difficult exercise and patients intended to do a wrong performance."</i> "I was disappointed that the game did not recognize my squats while I was wearing my wide blouse."	Patients should wear relatively tight clothes to ensure more accurate movement recognition by Kinect v2.
Picking apples	"It is a nice game."	<i>"The supporting chairs interfere with Kinect's recognition of the movements."</i> "The game does not respond to my correct movements."	The chairs interfere with tracking for lunges. It is more suitable for patients who are at a later stage of their rehabilitation, that is, patients who can do lunges without balance support.
Football playing	"It is a very useful game for balance training, and it reacts very well to the movements of the player."	<i>"Patients intended to shoot the ball."</i>	To reduce cognitive load, let the patient play the game by doing back kicks using their left and right legs alternatively.
	"It is a great game. It made me feel like that I was playing a real football game."	"It is difficult for me to pay attention to the arrows indicating which leg I should use."	Instructions should tell the patients that they do not have to shoot the ball.
Fishing	"It is a nice game. I had a feeling that I had a real therapy."	"I focused on the timer, and the virtual environment was not noticeable for me."	Different types/sizes of fish need to be created in the game.
	"This game would help a lot in my rehabilitation."	"All the fishes looked similar. It would be nice if I could catch a different fish."	
	"The virtual environment is beautiful and I like it a lot!"		

Exercise games	Positive comments	Negative comments	Implications
General comments	<i>"Playing games distracted patients' attention from exercise and pain."</i>	<i>"Some patients were unsure of what action was supposed to take place at a particular time. When the patients fail in doing the exercise successfully, they do not get feedback on how to do it correctly."</i>	<i>Real-time feedbacks on how far the patients are away from the required range of motion should be provided on the screen when the patients are performing the exercises.</i>
	<i>"You can use the game for fun besides the physiotherapy."</i>	<i>"You have to be clever enough to play the games as it requires paying attention to multiple things at the same time."</i>	To satisfy personal preferences, interfaces and virtual environments should be configurable to meet the needs of different cognitive challenges.
	<i>"Patients have enjoyment and they can exercise by their own quickly by using the exercise games."</i>	<i>"I am very smart, so the game could be made slightly more difficult for me."</i>	
	<i>"These are very nice and useful games and I would like to play them again."</i>		
	<i>"You could play the game at home, but you would still need the physiotherapists' feedback on how well you are doing with your rehabilitation by using the games."</i>		
	<i>"It is good to receive feedback on the exercises from the games. It prevents you from doing the exercises in the wrong way."</i>		
	<i>"After you get used to playing the exercise games, you have a lot of fun."</i>		

Discussion

Principal Findings

This study assessed the usability of the exercise games in terms of the experienced level of presence, enjoyment, exertion, pain, and technology acceptance among patients, and game design and technology acceptance among physiotherapists. The results showed that, in general, the patients experienced a high level of enjoyment, a moderate to high level of presence, and a low to moderate level of exertion and pain. The physiotherapists rated the exercise games as highly satisfying the nature of a motor rehabilitation program for elderly patients after hip surgery. Finally, both the patients and the therapists found the exercise games useful and easy to use and intended to use the exercise game system in the future.

The results of the evaluation of the game design are encouraging. The physiotherapists found all the exercise games meet the requirements for rehabilitation exercises [49]. The exercise games had a high level of adaptability to the patients' motor skills, which is in line with the evenly distributed exertion levels experienced by the patients. The games were beneficial to the patients' daily life activities such as walking, sitting, and standing. The games provided appropriate feedback on whether the patients exercise correctly and provided encouragement to the patients to continue with the therapy. The required range of motion such as step width, knee angle, and hip angle can be configured properly in the games. Furthermore, patients had high levels of enjoyment while exercising in the game. Therefore, the results suggest that the physiotherapists can devise novel rehabilitation programs by using our exercise games.

Patients experienced moderate to high levels of presence during the experiment with the lowest level of presence while playing the dancing game. During the dancing game, because of impaired balance skills, the patients used chairs to prevent fall. Hence, their attention was divided between the virtual and the real environment [52], which might explain the low level of presence in dancing. However, patients had quite a lot of enjoyment and little pain. Presence has been found to be associated with enjoyment. Earlier studies have found that participants experiencing high levels of enjoyment also show high levels of presence [53,54]. Being engaged in playing the game can also cause a decreased perception of pain [55]. Therefore, we expect that patients who can play the games without the support chair will experience a higher level of presence and enjoyment and less pain. In our experiment, all the patients used chairs as support.

According to the qualitative feedback, both the patients and the physiotherapists found squats the most difficult. Patients also reported the lowest enjoyment but highest exertion while doing squats in ringing the bell game. In an exercise game named Astrojumper, Finkelstein et al [56] found that participants' ratings of perceived exertion positively correlated with their level of motivation. However, Rhodes et al [57] suggested that activities based on relatively moderate to low exertion and maximum enjoyment should be provided to increase adherence for elderly adults. Therefore, we suggest that to motivate the patients to use the game, squats should be used for patients who have relatively better balance skills.

Patients scored high on the technology acceptance scale, which was comparable with the scores in Wuest et al [32]. Patients found the exercise games understandable and easy to use. They found the exercises meaningful and useful for balance training.

All the patients showed positive attitudes toward using the game in the rehabilitation center or at homes. Patients also expressed that they would like to continue to use the exercise games in their rehabilitation routinely. Our patients showed high acceptance of exercise games that were designed according to their cognitive and physical limitations. This finding is in line with the high acceptance rating of games that were specifically designed for patients, such as exercise games for home-based stroke rehabilitation [30,32].

In general, people are more inclined to use a system if they perceive it as useful, easy to use, and enjoyable [30]. Furthermore, earlier studies found that elderly participants strongly preferred virtual exercise gaming to traditional physical exercises [58,59]. Similarly, our system is designed to elicit increased motivation for rehabilitation, and the participants showed positive attitudes with regard to their gaming experience and the usability of the game system. Hence, we expect that the adherence rate of using our exercise games is higher than the traditional exercises, and participants will continue using our games when this system is implemented in the rehabilitation center or at homes.

Limitations and Future Work

Apart from the contributions, there are still a number of limitations to this study. First, this study recruited a small sample of patients and physiotherapists because of limited availability of participants. Usability test with a larger group of elderly patients would be beneficial and allow exploration of usability within different subgroups, for example, patients who are at different recovery phases. It has been shown that with a pilot study of 4 or 5 participants, it is already possible to find 80% of the usability problems [60,61]. There were also 2 physiotherapists who got involved in the design of the exercise games, and 2 other physiotherapists evaluated the exercise games, which gives us confidence about the usability about our system at the level of therapists.

Second, most of the exercises had to be performed while holding onto a chair, which sometimes influenced the tracking accuracy for exercises such as squats and lunges. Similarly, Ofli et al [62] reported that the highest tracking errors were found in hip and ankle joints while using Kinect. Hence, we suggest that patients who are at the beginning phase of physiotherapy after hip surgery should use the exercise games such as cycling, dancing, football, and fishing, which are not affected by supporting objects. Furthermore, we did meet problems with Kinect v2 recognizing obese patients for playing apple picking lunges. Patients with obesity may not be recognized as correctly as patients with an average body mass [63]. Future research should look into the difference in tracking accuracy and reliability comparing people with different levels of body mass.

Third, some user aspects of the game design such as high cognitive load and lack of real-time feedback on wrong movements and mismatched movements would pose barriers to future use. To address these issues, we plan to include the customization of the user interface and virtual environment according to personal preferences for cognitive challenges by providing real-time feedback on how far the patients are away from the required range of motion when they are performing

the exercises and by giving informative instructions at the beginning of each exercise game. Furthermore, there are still some minor problems with the games that need to be fixed; for example, the setting of going to the same direction for more than once in dancing should be configurable in the therapist interface.

Finally, in this pilot test, we focused on the usability of the exercise games. However, it would be interesting to assess the usability of the CC360 and find ways to improve it according to elderly people's abilities and preferences when the system is ready in the rehabilitation center or at homes.

The social aspect is known to affect exercise adherence [62]. In general, social support can increase self-efficacy and then enhance adherence [64]. In this study, as a first step, the exercise games will be used in the rehabilitation center, where different patients exercise in a common area. Thus, the patients can share their scores with others, forming a healthy competitive exercise environment among the elderly patients. Future work such as creating leader boards and score-based achievements will also help foster competition with the possibility of cooperation among patients and enabling social engagement during the exercise. Furthermore, CC360 provides accomplished exercise record of patients. In this way, the patients can be monitored by physiotherapists and other caregivers and encouraged to adhere to the exercises by playing the game.

As a next step, the effectiveness of the exercise games will be tested in a randomized controlled trial with 15 patients in each group, that is, an experimental group combining traditional exercises with playing exercise games versus control group with traditional exercises. The study will be conducted in the rehabilitation center and can shed some light on how motivating the game system is over a period of time.

Conclusions

We created Fietsgame, an engaging and motivating exercise game system, which translates traditional rehabilitation exercises into playful exercises. The performance of the users was automatically tracked using a 3D depth camera and stored for further analysis by the physiotherapists. The results indicate that the game can be used by patients as a new rehabilitation tool after hip surgery, and both the patients and the physiotherapists expressed positive attitudes toward using the game in the future. Although this study had a limited number of participants, it provides sufficient insights on the usability of the system and suggests improvements in the future. The qualitative feedback revealed that exercise games designed for elderly patients should be challenging enough to keep their interest and attention, but also should take into account their impaired motor, sensory, and cognition functions. We will improve the game by including real-time corrective feedback when patients are performing the exercises, by providing a customizable user interface allowing adjustments to cognitive load and by creating more varieties of game content. A randomized controlled clinical trial will be conducted covering a longer time period, testing the effectiveness of the game. The final goal is to provide elderly patients with a game that can be used in nursery houses or at homes to achieve improved physical functions and maintain independent living.

Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1

The original physiotherapist control interface of CC360.

[[PNG File, 124KB - games_v5i4e19_app1.png](#)]

Multimedia Appendix 2

The original patient interface showing the patient’s medical record in CC360.

[[PNG File, 124KB - games_v5i4e19_app2.png](#)]

Multimedia Appendix 3

Questionnaires answered by the patients.

[[PDF File \(Adobe PDF File\), 78KB - games_v5i4e19_app3.pdf](#)]

Multimedia Appendix 4

Questionnaires answered by the physiotherapists.

[[PDF File \(Adobe PDF File\), 60KB - games_v5i4e19_app4.pdf](#)]

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Abbreviations

- CC360:** Community Care 360
- CGI:** Consultants to Government and Industries
- IoT:** Internet of Things
- IPQ:** Igroup presence questionnaire
- PC:** personal computer
- SD:** standard deviation
- TAM:** Technology Acceptance Model
- VAS:** Visual Analogue Score

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